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# Importance of 'pre-adaptation', consumer opportunism and limited interference competition in facilitating urban living by exotic Common Mynas

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Introduced Common Mynas *Sturnus tristis*, are abundant in many eastern Australian cities, towns and adjacent rural (exurban) areas. They are widely considered to be pests, because they nest in house roofs, form noisy roosting aggregations, may spread human pathogens and allegedly negatively impact upon native birds through competition for food and nest sites. To test the latter allegation adequately, we need further investigation of the species' ecology, particularly in cities. To that end, this study documents aspects of Common Mynas' ecology in Melbourne, Australia and its exurban hinterland in the non-breeding season. Common Mynas' diet and foraging ecology were similar in Melbourne and the adjacent exurban environment. Collectively, in both environments, one or more other bird(s) foraged less than, or within, five metres of a focal foraging myna more than 90 percent of the time, but in the entire study only five aggressive encounters involving foraging Common Mynas occurred during direct observation (0.74 encounters/observation hr). All these encounters occurred in the city, but only two of them were with heterospecifics. The abundance of Common Mynas appeared to be similar in urban and exurban environments in the subset of habitats surveyed. Myna abundance was negatively correlated with the presence of native Noisy Miners *Manorina melanocephala* and *Eucalyptus* and *Corymbia* trees, but positively associated with the presence of exotic trees. We propose that the Common Myna's successful exploitation of urban food resources in Australia stems from a combination of 'pre-adaptation', some opportunistic consumer innovation with respect to human food waste and a low level of interspecific interference competition for food. Planting more native trees in the urban environment might ultimately make Australian cities less hospitable for Common Mynas, but also probably more hospitable for Noisy Miners.

## INTRODUCTION

Invasive, exotic animals can contribute to native animal decline and sometimes even extinction, and adversely affect human economies, health and wellbeing (Pimental *et al.* 2006; Pejchar and Mooney 2009; Primack 2014). Cities are particularly susceptible to settlement by exotic birds that can live commensally with humans and many of these 'urban exploiters' (McKinney 2002) are ecological generalists with bold temperaments (Case 1996; Bonier *et al.* 2007; Atwell *et al.* 2012). They often attain a greater abundance in the urban than the non-urban, rural (hereinafter exurban) environment. There are allegedly two reasons for this: (a) urban food resources are augmented deliberately or incidentally by people; many urban invader birds have a relatively large brain that facilitates opportunistic, innovative exploitation of this resource (Bonier *et al.* 2007; Carrette and Tella 2011), and (b) cities have lower predator densities than exurban areas (Anderies *et al.* 2007). Some 'urban exploiters' may also be able to aggressively 'outcompete' native, resident species for access to critical resources (Holway and Suarez 1999).

Common Mynas *Sturnus tristis* are omnivorous. They inhabit open woodland and cultivated land in their original geographic range in India and central and southern Asia. They nest in tree cavities and roost in large, arboreal aggregations (Feare and Craig 1999). They have been deliberately introduced

to all continents (except Antarctica), usually to control insects considered agricultural pests (Feare and Craig 1999). However, the Common Myna itself is considered a pest in many countries to which it has been introduced because of its alleged negative impact on native birds, consumption of domestic crops, role in spreading noxious weeds and the 'noise and mess' it makes when roosting and nesting in cities (Long 1981). It has been declared one of the 100 worst invasive species worldwide by the International Union for the Conservation of Nature (Lowe *et al.* 2004).

Common Mynas were introduced to Australia from 1863–1872 to control pest insects (Long 1981) and are now common in Melbourne, rural eastern and central Victoria, the Australian Capital Territory (ACT), the Sydney–Wollongong region, other coastal towns in New South Wales, and from Cairns to Townsville and Toowoomba to Brisbane in Queensland (Barrett 2003). The species could potentially spread further north and west in Australia (Martin 1996). It is considered a pest by many Australians, was voted 'Australia's most significant pest/problem' in a nationwide survey (Thompson *et al.* 2005) and has been targeted by numerous local eradication campaigns (e.g. Canberra Indian Myna Action Group Inc. 2013). The main reasons for this negative perspective in Australia are similar to those overseas, including the myna's supposed negative impacts on native birds through competition for food and nest sites (Pell and Tidemann 1997a, b; Garrock *et al.* 2012).

However, the claim that Common Mynas aggressively compete for food with native birds is not supported by the evidence to date (Crisp and Lill 2006; Lowe *et al.* 2011; Old *et al.* 2014). There is some indication that urban Common Mynas 'outcompete' some native bird species for natural nest cavities or nest-boxes (Grarock *et al.* 2012, 2013b), but in total the evidence is not completely clear-cut (Lowe *et al.* 2011) and is fairly narrow in its scope. Ironically, there is also modelling indicating that the level of culling currently conducted in the ACT is inadequate to achieve a broad-scale reduction in myna abundance there (Grarock *et al.* 2014).

Consensus exists that more research is required before we can make definitive judgements about Common Mynas' role in native biodiversity loss and sound recommendations about possible management strategies (Fitzsimons 2006; Lowe *et al.* 2011; Grarock *et al.* 2012, 2013a). Knowledge of the species' ecology and possible competitive impact on native bird species in urban Australia is still fairly limited and mostly restricted to four cities. The Common Myna is suburban Melbourne's second most abundant bird (White *et al.* 2005). Crisp and Lill (2006) showed that: (a) its breeding season abundance in Melbourne was greatest in wooded parkland, (b) it foraged mainly by gleaning on grass and sealed surfaces, and (c) its involvement in interspecific aggression during foraging was negligible, resulting only in local spatial displacement. However, their investigation did not encompass the myna's non-breeding season in Melbourne or its ecology in exurban, rural Victoria at any time of year.

This study's aim was therefore to document Common Mynas' abundance, foraging ecology and interspecific interactions with other birds in Melbourne and exurban, rural, eastern Victoria during their non-breeding season. Comparison of the findings with Crisp and Lill's (2006) breeding season data will: (a) allow determination of whether these aspects of the species' ecology vary markedly seasonally in Melbourne, and (b) help in ascertaining whether these aspects differ between urban Melbourne and the neighbouring exurban environment. The latter comparison will provide an insight into the relative importance of 'pre-adaptation' (inherent suitability), phenotypic plasticity (ability to rapidly adjust) and opportunism (ability to exploit novel resources) in colonizing the urban environment by this species (Duncan *et al.* 2001; Lowry *et al.* 2013). A native honeyeater, the Noisy Miner *Manorina melanocephala*, (24–27 cm), is also abundant in Melbourne and much of rural Victoria and exerts a very strong influence on avian community structure (Maron *et al.* 2013). Therefore we also recorded its abundance in the sites at which we surveyed Common Mynas, to determine whether myna abundance was influenced by this highly aggressive, native species.

The broader underlying narrative here is to evaluate why Common Mynas are so successful in urban Australia, whether their competitive impact on native birds should be a high management priority and, if so, whether culling is the optimal management tool.

## METHODS

### Study area

The investigation was conducted from May–August, 2011 (temperate southern hemisphere autumn and winter) in eastern suburban Melbourne (37.8136°S, 144.9631° E) and

exurban (rural) eastern Victoria. Melbourne covers 9900 square kilometres, has 4.35 million human residents and a population density of 430 people/square kilometre. Fifty-eight study sites were spread over an urban area extending 35 kilometres east from the central business district (CBD) of Melbourne and 60 exurban sites were spread over an area extending out from Melbourne 219 kilometres northwards to Cobram (35.9667°S, 145.6500°E) and 233 kilometres eastwards to Bairnsdale (37.8333°S, 147.6167°E) (Fig. 1). Study sites were chosen 'haphazardly' from maps without prior knowledge as to whether Common Mynas and/or Noisy Miners were present, but with the provisions that: (a) districts throughout the study area were sampled fairly evenly, and (b) sites were greater than 1.5 kilometres apart to reduce pseudoreplication.

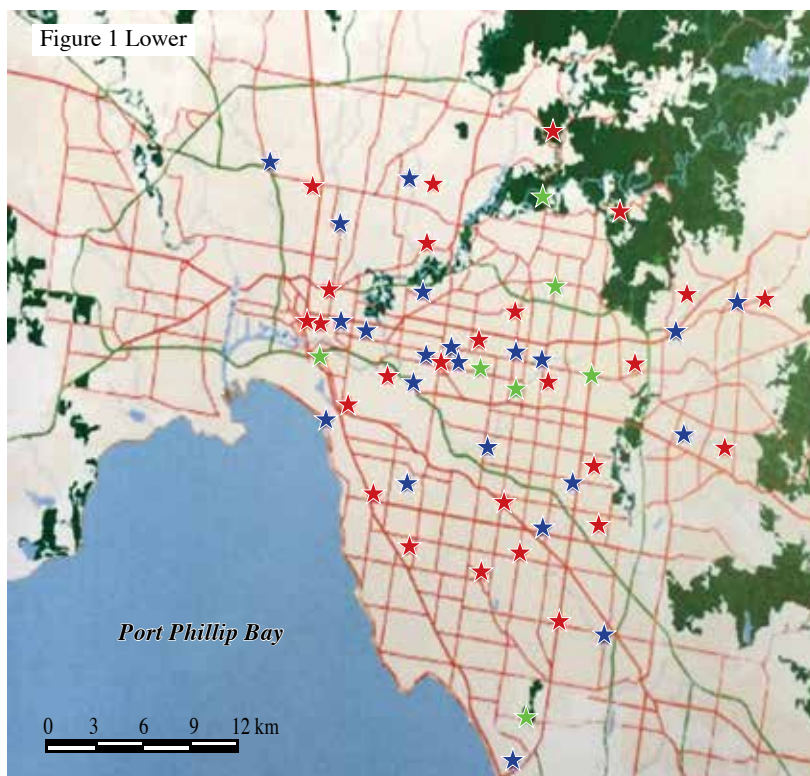
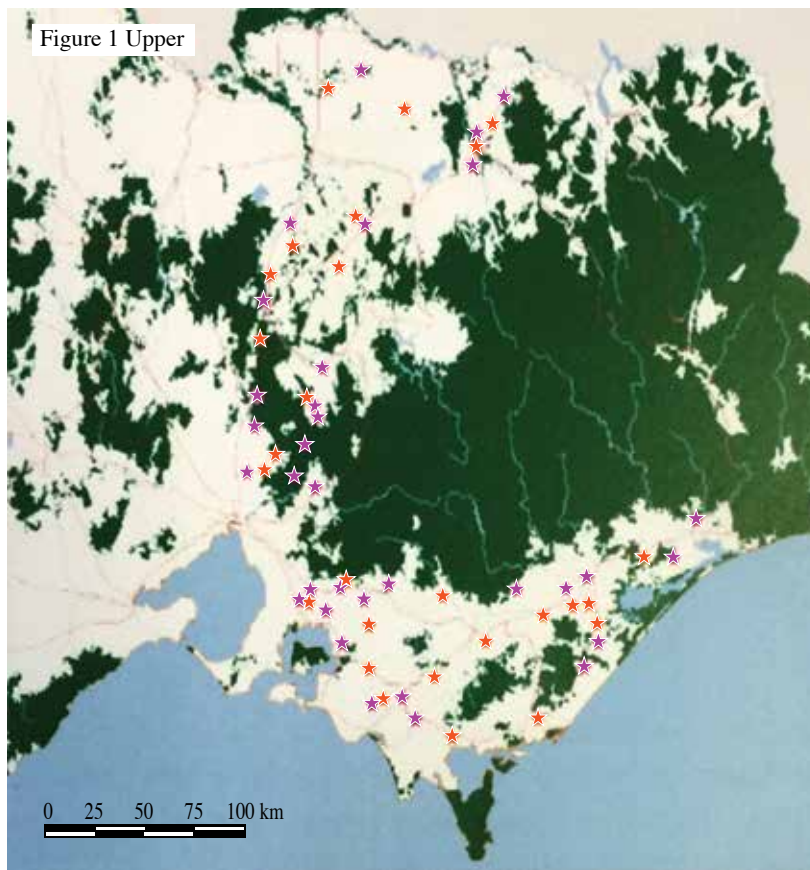
Urban sites were in the three validated habitat types found by Crisp and Lill (2006) to have the highest breeding season Common Myna abundances: (1) streetscape (26 sites) – residential streets dominated by houses and gardens, (2) open parkland (22 sites) – open grassland areas, occasionally surrounded by fringing trees and shrubs, and (3) wooded parkland (10 sites) – woodland, with vegetation dominated by native trees and shrubs, but vegetation less dense than in native bushland. Fewer sites were used in wooded parkland because it is less common and Crisp and Lill (2006) found lower myna densities in this habitat. Exurban sites were in the two habitat types in which most rural Common Mynas occurred: (1) roadside corridors (32 sites) – rural roads and the adjacent tree belt in the road reservation, and (2) paddocks (28 sites) – fenced, grassy farmland, sometimes fringed by trees and shrubs and occasionally containing farm buildings. We further distinguished between paddocks containing and not containing livestock at the time of observation.

### Abundance surveys

Surveys were conducted throughout the study period from 1.5 to 3.5 hours after sunrise and in a similar time 'window' before sunset. Each site was surveyed once, but surveys were systematically spread across environments (urban/ exurban) and among habitats to achieve temporal comparability in sampling. At each site, one 600 metres long × 30 metres wide belt transect (Bibby 1992) was walked at a pace of approximately 3.5 kilometres/hour and all Common Mynas and Noisy Miners within the transect (but not flying overhead) were counted. The numerically dominant tree type at each transect was also determined. This was done by characterising (as eucalypt, other native tree or exotic tree) up to six trees taller than five metres closest to the start, mid-point and end of the transect. In some cases, there were too few transect trees to achieve this, so a smaller sample size was used or a few trees immediately outside the belt were included.

### Foraging behaviour

Common Mynas' foraging behaviour and diet were observed opportunistically in association with each abundance survey, using a recording scheme adapted from Crisp and Lill (2006). Focal birds were chosen haphazardly for observation and up to three foraging records were obtained per focal bird during an observation period lasting maximally five minutes. When a focal bird changed its foraging substrate, behaviour or type of food items being procured within the five minutes observation



**Figure 1.** Location of study sites in exurban environment (upper image) and urban Melbourne (lower image). Roadside and paddock habitat sites in exurban environment shown as orange and mauve stars, respectively. Streetscape, open parkland and wooded parkland habitats in urban environment shown by red, blue and green stars, respectively.

period, a new foraging record was obtained. Variables recorded for each foraging event were:

- 1) substrate on which the myna stood or perched; classified as grass, bare ground, sealed surface, leaf litter, building, other artificial structure (e.g. garbage bin, fence), or tree.
- 2) substrate on which the food item was situated; classified as for the foraging myna's substrate. For example, a myna might be standing on bare ground (bird's substrate) and reach up to take a fruit attached to a tree (food substrate).
- 3) behaviour – classified as gleaning (picking item off substrate with beak), flaking (moving substrate with beak or foot and exposing food underneath), stretching up or out, and 'other' (after Remson and Robinson, 1990).
- 4) food items - categorized as seeds, invertebrates, human food waste (food scraps and fruit cores) and other plant material (e.g. fallen flowers). We also recorded whether food item identification was absolutely certain or just probable, because it was often difficult to identify items from a distance with complete assurance.

#### Foraging sociality and aggression

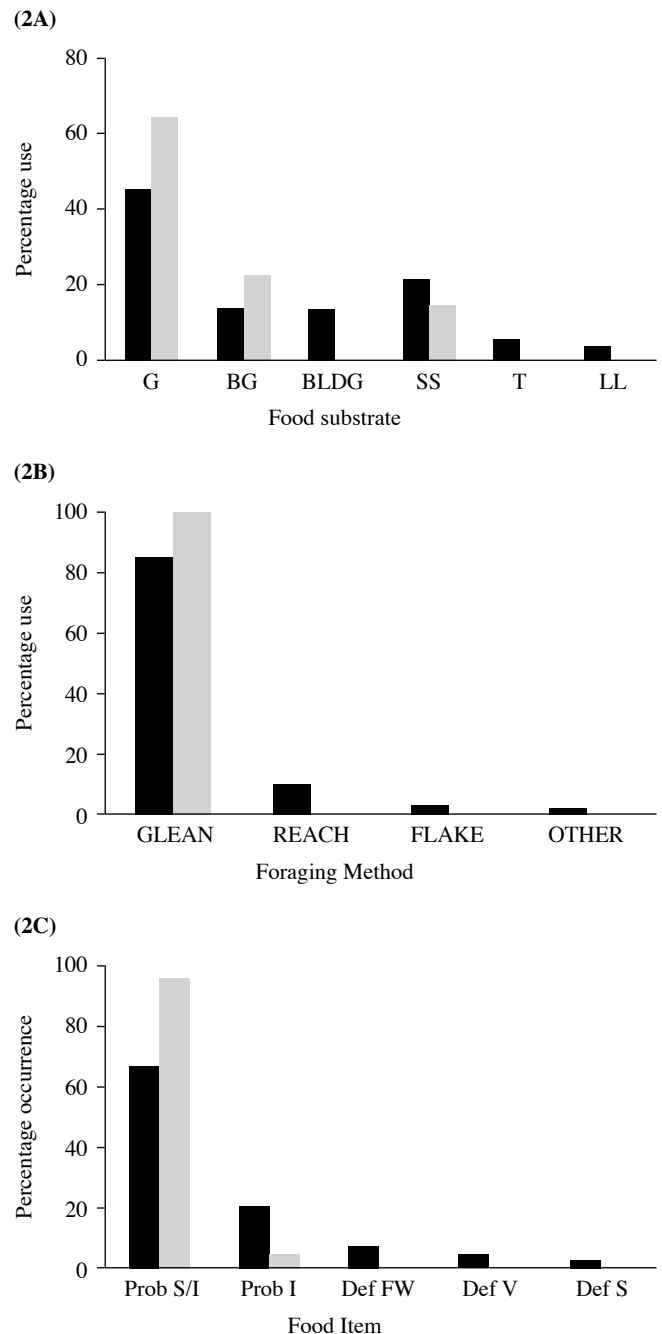
To determine whether aggressive interference competition for food (Case and Gilpin 1974) was significant in urban and exurban Common Mynas, we recorded: (a) how many con- and/or heterospecifics were within a visualized five metres of each focal foraging myna, and (b) any agonistic interactions involving Common Mynas noted during foraging observations. The aspects of agonistic interactions recorded were: the other species involved, the initiating species, the nature of the encounter (approach-supplant; chase; fight) and its outcome (no response; local displacement a visualized <10 m from site; displacement > 10 m from site).

#### Data analysis

Statistical analyses were conducted with R (R Development Core Team 2011).

Significance tests were not used to compare species' abundances in the two environments because of the non-comprehensive nature of the sampling design for abundance. Accordingly, we interpret variation in abundance with environment conservatively. To analyse associations of (a) environment and (b) habitat with the foraging substrates and behaviours used by the Common Mynas, two three-way contingency tables were created after some initial, necessary pooling of categories (e.g. of foraging substrates used very infrequently). The associations were then examined with a Cochran-Mantel-Haenszel test (Quinn and Keough 2002).

Least squares linear regression models were employed to examine the relationships between the (arcsine-transformed) percentages of types of tree on the survey transects and the (square root-transformed) associated Common Myna abundances. Unadjusted and Bonferroni-adjusted probabilities were calculated. Conditional inference tree analysis (CITA) (Nagy *et al.* 2010; Johnstone *et al.* 2014) employing a 95 percent confidence level was also used in exploring whether the abundance of each bird species was influenced by the abundance of the other bird species and/or by tree type on the transect.



**Figure 2.**

**A.** Percentage use of food substrates by Common Mynas in urban and exurban environments. G= grass, BG = bare ground, BLDG = building, SS = sealed surface, T = tree and LL = leaf litter. Percentage use of substrates on which foraging mynas stood/perched was very similar and is not illustrated here.

**B.** Percentage use of foraging methods by Common Mynas in the urban and exurban environment.

**C.** Percentage occurrence of food items in diet ingested by Common Mynas in urban and exurban environments. Prob S/I = probable seed or invertebrate; Prob I = probable invertebrate; Def FW = definite human food waste; Def V = definite vegetation component; Def S = definite seed.

For A, B and C, black columns = urban, and grey columns = exurban environment. n = 80 for urban and 48 for exurban environment throughout.

**Table 1**Mean  $\pm$  SE abundance of Common Mynas and Noisy Miners in six urban and exurban habitats.

Habitat	Mean $\pm$ SE individuals/ha		No. surveys
	Common Myna	Noisy Miner	
1. Exurban paddock with livestock	4.0 $\pm$ 1.4	0.5 $\pm$ 0.3	11
2. Exurban paddock without livestock	0.3 $\pm$ 0.2	0.1 $\pm$ 0.05	17
3. Exurban roadside	1.3 $\pm$ 0.3	0.5 $\pm$ 0.2	32
4. Urban streetscape	2.4 $\pm$ 0.4	0.9 $\pm$ 0.2	26
5. Urban open parkland	2.2 $\pm$ 0.8	1.9 $\pm$ 0.2	22
6. Urban wooded parkland	0	3.8 $\pm$ 0.1	10
7. All urban	1.9 $\pm$ 0.4	1.7 $\pm$ 0.2	56
8. All exurban	1.5 $\pm$ 0.3	0.4 $\pm$ 0.3	58

## RESULTS

### *Common Myna and Noisy Miner abundance*

Common Mynas occurred at mean abundances of 1.9 individuals/hectare in the urban and 1.5/hectare in the exurban environment, whereas Noisy Miners were numerically 4.3 times more abundant in the urban than the exurban environment (1.7/ha and 0.4/ha, respectively) (Table 1). However, it is important to note that some habitats that are occupied by one or both species, particularly habitats in the urban environment (Crisp and Lill 2006), were not surveyed in the present study (e.g. forest remnants). Common Mynas were entirely absent from urban wooded parkland, a habitat in which Noisy Miners' mean abundance was 3.8 individuals/hectare. The highest mean abundance of Common Mynas recorded (4.0 individuals/hectare) was in exurban paddocks carrying livestock, but their mean abundance in exurban paddocks lacking livestock was only 0.3 individuals/hectare (Table 1).

### *Common Myna foraging behaviour and diet*

Common Mynas' use of foraging substrates and behaviours was similar in the urban and exurban environments ( $\chi^2_{(2)} = 2.564$ ,  $P = 0.277$ ). The main substrates that foraging mynas stood/perched on and those from which they obtained their food were similar (Fig. 2A); grass predominated and bare ground and sealed surfaces (e.g. bitumen, concrete) were used moderately frequently. Gleaning comprised all exurban and greater than 80 percent of urban foraging behaviour records, with small frequencies of reaching and flaking also being recorded in the urban environment (Fig. 2B). At a coarse-grained level, the food items consumed were also similar in both environments, with small seeds and/or invertebrates comprising greater than 60 percent and greater than 90 percent of records in the urban and exurban environments, respectively (Fig. 2C).

### *Common Myna sociality and aggression during foraging*

In both urban and exurban environments, birds that foraged within a visualized five metres of focal, foraging Common Mynas were mostly frequently conspecifics. Thus focal mynas foraged close to other mynas in 88 percent and 56 percent of observations in the urban and exurban environments, respectively (Table 2). However, other species were also present near foraging mynas nearly half of the time; collectively, twelve other species foraged near foraging Common Mynas, nine in each

environment (Table 2). The exotic Common Starling *Sturnus vulgaris* was foraging mynas' most frequent heterospecific neighbour in the urban environment, being present 21 percent of the time, but the Magpie Lark *Grallina cyanoleuca* held this position in the exurban environment (being present 16% of the time). Starlings occurred close to focal foraging Common Mynas in greater numbers than any other heterospecifics in the exurban environment (6.3 starlings/observation), but Rock Doves *Columba livia* (5.6/observation) were the most numerous heterospecifics near foraging mynas in the city.

Although collectively in both environments there was at least one other bird within five metres of a focal foraging Common Myna more than 90 percent of the time, only five aggressive encounters involving foraging mynas occurred during direct observation in the entire study (0.74/hr), all in the city. Two of them were with heterospecifics, a Noisy Miner and a Rock Dove, and the Common Myna was displaced in both instances.

### *Influence of Noisy Miners and tree types on Common Myna abundance*

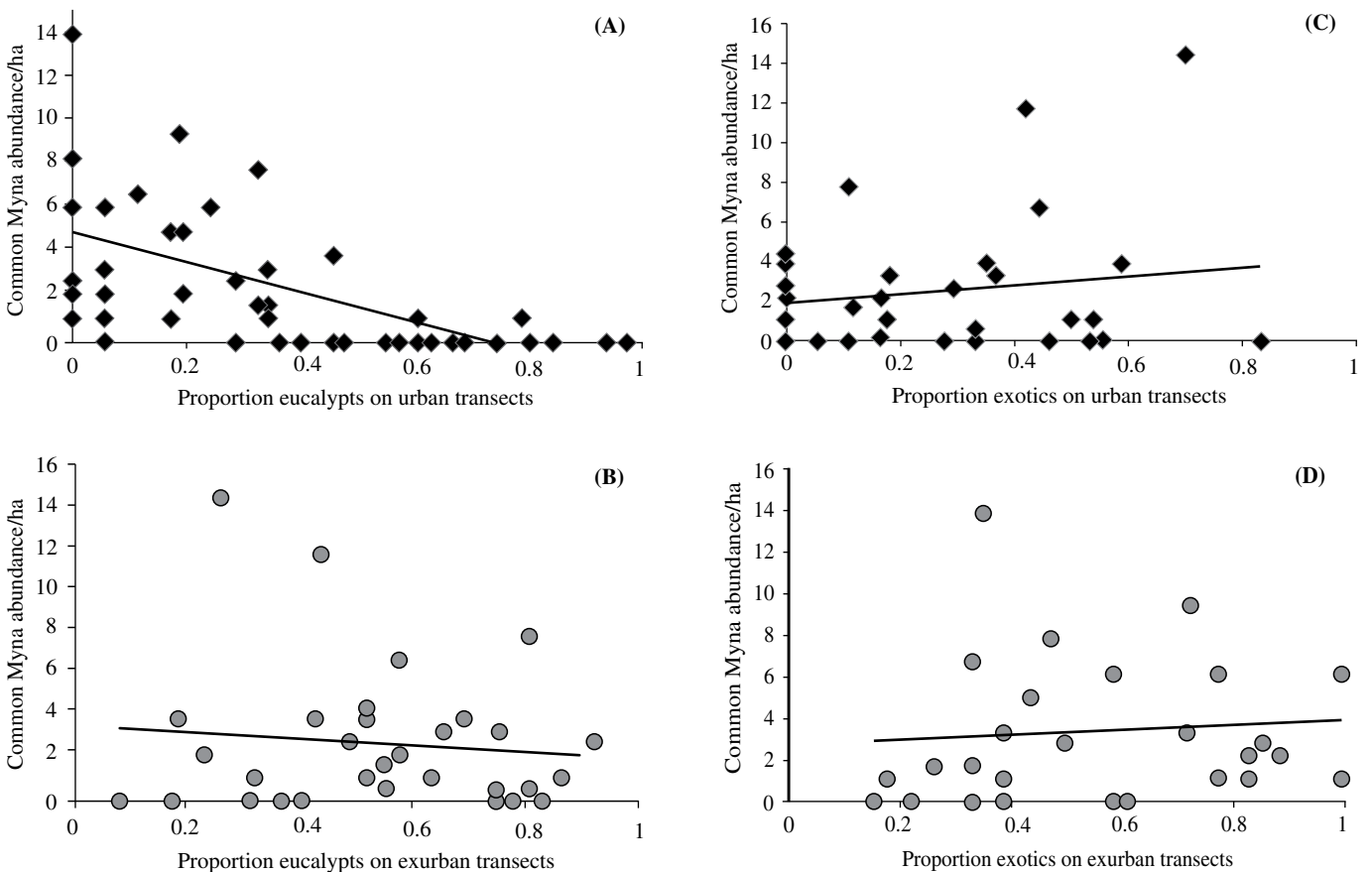
Least squares linear regression analysis indicated that in the urban environment Common Myna abundance decreased as a function of the increasing proportion of native eucalypts (including *Corymbia* spp.) on a survey transect ( $R^2 = 0.36$ ,  $F_{(1,56)} = 31.62$ , unadjusted  $P < 0.001$ ), but increased as a function of the increasing proportion of exotic trees present ( $R^2 = 0.24$ ,  $F_{(1,56)} = 17.36$ , unadjusted  $P < 0.001$ ) (Fig. 3 A and C). In the exurban environment, Common Myna abundance was not significantly influenced by the proportion of native eucalypts on a survey transect (unadjusted  $P = 0.061$ ), but increased as the proportion of exotic trees increased ( $R^2 = 0.13$ ,  $F_{(1,58)} = 8.82$ , unadjusted  $P = 0.004$ ) (Fig. 3 B and D). The significance/non-significance of these relationships was unaltered by the application of a Bonferroni probability adjustment for multiple comparisons with  $\alpha = 0.013$ .

Conditional Inference Tree analysis indicated that in the city Common Myna abundance was significantly greater (node 1,  $P < 0.001$ ) (median  $3.71 \pm 0.2$  birds/ha) at sites lacking, than at sites having, Noisy Miners (Fig 4 A). At sites with Noisy Miners, Common Myna abundance was significantly greater (node 3,  $p = 0.006$ ) (median =  $1.16 \pm 0.47$  birds/ha) at the subset of those sites where the proportion of native trees was less than or equal to 0.73, rather than greater than 0.73 (node

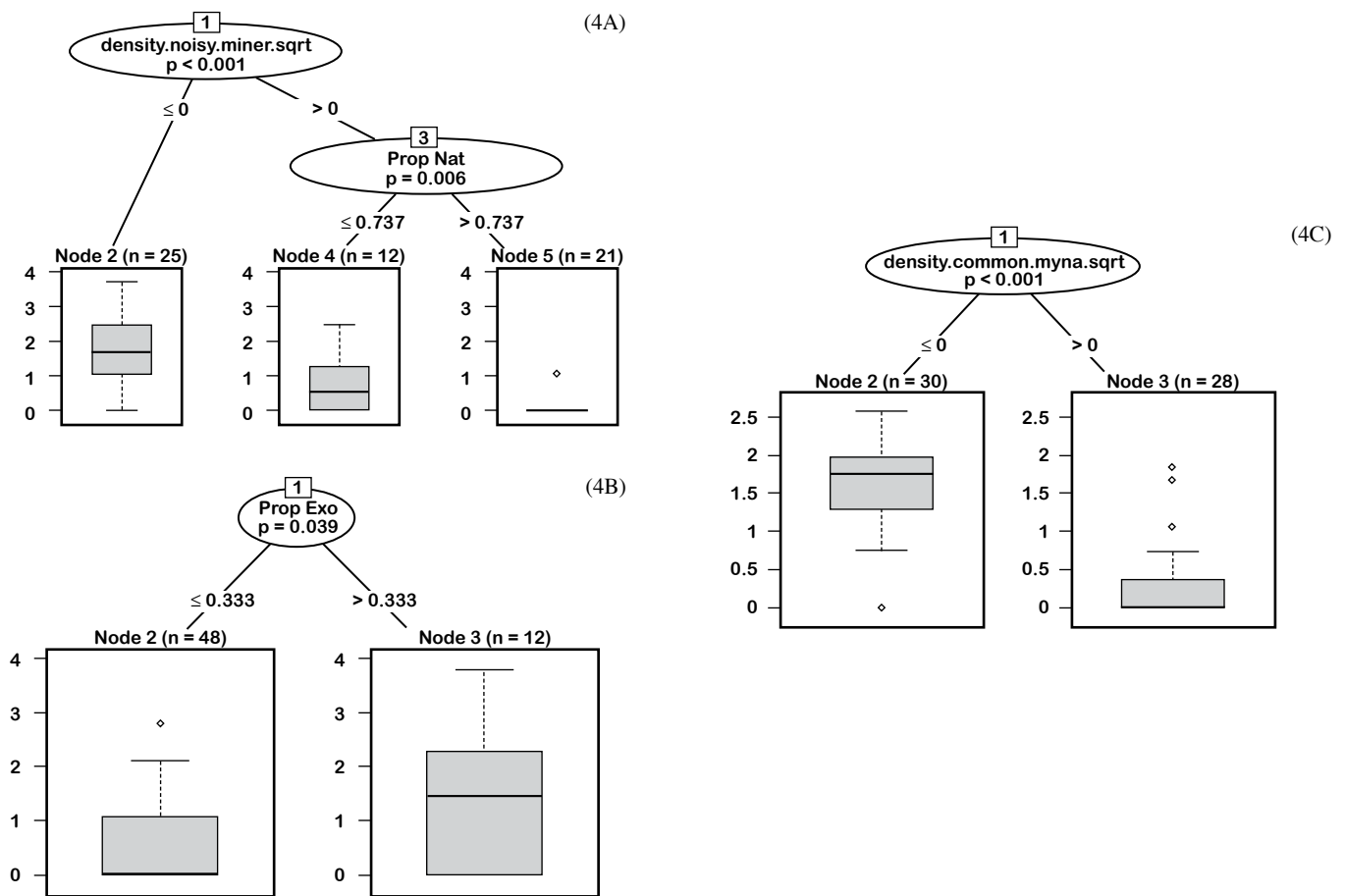
**Table 2**

Percentage of observations in which thirteen bird species were within a visualized five-metre radius of a focal foraging Common Myna in the urban ( $n = 80$ ) and exurban ( $n=48$ ) environments. <sup>E</sup> denotes exotic species.

Species	Percentage of observations near focal Common Myna	
	Urban	Exurban
Common Myna <i>Sturnus tristis</i> <sup>E</sup>	88	56
Common Starling <i>Sturnus vulgaris</i> <sup>E</sup>	21	6
Spotted Dove <i>Streptopelia chinensis</i> <sup>E</sup>	15	0
Magpie-lark <i>Grallina cyanoleuca</i>	9	15
European Blackbird <i>Turdus merula</i> <sup>E</sup>	9	3
Rock Dove <i>Columba livia</i> <sup>E</sup>	6	1
Noisy Miner <i>Manorina melanocephala</i>	3	0
House Sparrow <i>Passer domesticus</i> <sup>E</sup>	3	0
Crested Pigeon <i>Ochophaps psephotus</i>	1	0
Australian Magpie <i>Cracticus tibicen</i>	0	3
Raven <i>Corvus</i> sp.	0	3
Willie Wagtail <i>Rhipidura leucophrys</i>	0	4
Unidentified sp.	0	1



**Figure 3.**  
**A.** Abundance of Common Mynas (individuals/ha) as a function of the proportion of eucalypt trees on urban transects  
**B.** Abundance of Common Mynas as a function of the proportion of eucalypt trees on exurban transects.  
**C.** Abundance of Common Mynas as a function of the proportion of exotic trees on urban transects.  
**D.** Abundance of Common Mynas as a function of the proportion of exotic trees on exurban transects.  
 Trend lines on all graphs (A–D) show the linear relationship between Common Mynas’ abundance and the proportions of tree types.  $n=56$  for urban and 58 for exurban environment



**Figure 4.** Conditional inference trees for Common Myna abundance in (a) urban environment and, (b) exurban environment, and for (c) Noisy Miner abundance in the urban environment. Abundances of both species were square-root transformed (e.g.  $\text{density.noisy.miner.sqrt}$  = square-root transformed abundance of Noisy Miner). Prop.Nat and Prop.Exo = proportion of native and exotic trees, respectively. Values in box plots are median, 1<sup>st</sup> and 3<sup>rd</sup> quartiles, maxima and minima and outliers. Terminal nodes correspond to the subpopulation means of the transformed data; means ( $\pm$  SE) for (a) are  $3.71 \pm 0.2$  birds/ha (node 2),  $1.16 \pm 0.47$  birds/ha (node 4) and  $0.13 \pm 0.09$  birds/ha (node 5), for (b) are  $0.83 \pm 0.23$  birds/ha (node 2) and  $3.57 \pm 31$  birds/ha (node 3), and for (c) are  $2.96 \pm 0.36$  birds/ha (node 2) and  $0.4 \pm 0.16$  birds/ha (node 3).

Figure 4(a) can be interpreted as follows: Common Myna abundance at urban sites is significantly and most strongly influenced by Noisy Miner abundance. The proportion of native vegetation (mainly eucalypts) at an urban site is a significant and the next most influential factor affecting Common Myna abundance. Median Common myna abundance is greater at urban sites with native vegetation where the proportion of such vegetation is  $\leq 0.737$  rather than  $> 0.737$ . Median Common Myna abundance is greatest at urban sites that lack Noisy Miners ( $\leq 0$ ).

4). Thus Common Myna abundance was lowest (median  $0.13 \pm 0.09$  birds/ha) at those urban sites having Noisy Miners and a proportion of native trees greater than 0.737 (node 5). In the exurban environment, CITA showed that Common Myna median abundance was significantly greater (node 1,  $P = 0.039$ ) at sites with a proportion of exotic trees  $> 0.333$  (Fig. 4 B). Noisy Miner mean abundance was significantly ( $P < 0.001$ ) greater at sites lacking Common Mynas (Fig. 4 C).

## DISCUSSION

### Common Myna abundance

Bird species that occupy both urban and exurban areas tend to have higher population densities in the former than the latter areas (Møller 2009). The reasons for this are thought to include the greater food abundance resulting from human food waste and longer plant growing seasons, and the lower rate of predation on adult birds in cities than in exurban areas

(Anderies *et al.* 2007). However, Common Mynas appeared to be similarly abundant in Melbourne and exurban Victoria in our investigation. This could be due to sampling limitations, such as the total sample sizes, unequal survey effort among habitats, or the restricted suite of urban habitats surveyed. Nonetheless, the mean urban abundance in the non-breeding season resembled that recorded over a broader suite of urban habitats in Melbourne (2.5 birds/ha) in the species' principal breeding season (Crisp and Lill 2006). It was also similar to that recorded by White *et al.* (2005) in Melbourne streetscapes with mostly native trees (1.9/ha) and in recently developed streetscapes lacking mature trees (2.5/ha), but interestingly lower than that in streetscapes with mostly exotic trees (4.2/ha). Common Mynas were absent from wooded parkland in our study. This is intriguing, because whilst Fitzsimons *et al.* (2011) recorded a low abundance of 0.8 mynas/hectare in urban woodland remnants in Melbourne, Crisp and Lill (2006) reported an estimated mean abundance of  $5.1 \pm 1.6$  individuals/hectare in this habitat in the breeding season.



Collectively these data suggest that either myna abundance varies greatly among Melbourne's urban woodland remnants or Crisp and Lill's (2006) higher breeding season estimate may reflect the presence of tree-hollows for nesting in this habitat.

It seems likely that the apparent similarity in exurban and urban abundances of Common Mynas is 'real', but if so, the reason is unclear. Melbourne streetscapes provide considerable volumes of supplementary food (human food waste) which Common Mynas consume (Crisp and Lill 2006; this study), but the level of exploitation was modest in the present study. Predation could also influence population densities, but whether predation pressures in Melbourne are similar to those in rural Victoria is undocumented. In contrast, the Noisy Miner's abundance appeared to be substantially greater in the subset of urban habitats surveyed than in paddocks and road corridors in exurban Victoria. The apparently greater abundance of Common Mynas in rural paddocks-with-livestock than in unstocked rural paddocks probably relates to the species' habit of feeding on insects disturbed by grazing stock (Higgins *et al.* 2006).

#### 'Pre-adaptation' and innovation in urban foraging

Common Mynas' use of foraging substrates and behaviours was similar in urban Melbourne and exurban Victoria. In both environments, Common Mynas foraged predominantly on grass, bare ground and, to a lesser extent, sealed roads and pathways, although only urban mynas foraged on buildings. In both environments, gleaning was the main foraging method and small seeds or invertebrates were the principal food items. It thus seems that the Common Myna, whose native habitat is open woodland and cultivated land (Feare and Craig 1999), is 'pre-adapted' or inherently suited (Duncan *et al.* 2001; Van Heezik *et al.* 2008) to some extent for foraging in the urban environment. Consuming human food waste accounted for approximately 10 percent of feeding behaviour in the city, but was rare in exurban sites where such food resources were less abundant. Therefore innovative foraging resulting from either behavioural plasticity or natural (genetic) selection (Sol *et al.* 2011; Lowry *et al.* 2013) played a small role in food acquisition in the city, but was negligible in exurban areas. The diet of free-living Common Mynas in New South Wales contained a much larger proportion of human food waste than that recorded in the present study (Sol *et al.* 2012). Sol *et al.* (2011) showed that 'consumer innovation' (consuming novel foods using familiar methods) and 'technical innovation' (consuming novel foods in a novel manner) occurred in about half and one quarter, respectively, of wild-caught, captive Common Mynas, and mynas from more highly urbanized areas solved the technical task faster than those from less urbanized sites.

Urban foraging behaviour and the (probable) diet of Common Mynas were also very similar to those reported by Crisp and Lill (2006) for urban Melbourne in the main breeding season. This suggests that seasonal variation in the species' foraging is probably not substantial in the urban environment, although the two studies were conducted several years apart.

#### Opportunism versus interspecific competition for food

Exotic, invasive birds can acquire novel urban foods by either aggressively displacing native resident birds from the sources available (the competition hypothesis) or by exploiting

food that cannot be used much by native birds (the opportunism hypothesis) (Sol *et al.* 2012). Common Mynas had at least one heterospecific bird close to them nearly 50 percent of the time while foraging. The five species that were close to focal, foraging mynas in greater than or equal to five percent of our observations are ground-foragers and might all potentially be considered food competitors with the Common Myna to some extent. However, we only recorded two aggressive encounters between foraging Common Mynas and heterospecific birds foraging nearby during the study. Thus interspecific aggressive interference competition for food involving Common Mynas was negligible, which may be a significant factor facilitating urban-dwelling in this exotic species in Melbourne.

The observed level of interspecific aggression was less than that recorded by Crisp and Lill (2006) in Melbourne in the main breeding season. Lowe *et al.* (2011) recorded a comparably low level of initiating interspecific aggression by Common Mynas in urban Sydney (2 initiations/36 hr of surveying) and Haythorpe *et al.* (2014) a very low level of intra- and interspecific aggression (i.e. in 1.4% of sightings) by Common Mynas in, and close to, Newcastle, New South Wales. Haythorpe *et al.* (2012) also found that Common Mynas showed only an intermediate level of interspecific aggression relative to seven other bird species when visiting artificial feeding stations in the Newcastle area and were responsible for only 11 percent of aggressive displacements from the feeder. Sol *et al.* (2012) found that Common Mynas exploiting artificial food patches (comprising a pile of dog pellets and seed within a two-metre diameter circle) were more frequently attacked by Australian Magpies (*Cracticus tibicen*) than *vice versa*, but the mynas won only 4.6 percent of these encounters. Thus with respect to novel food resources, urban Common Mynas appear to be more opportunistic than aggressively competitive.

Similar low levels of interspecific aggression during natural foraging have also been reported for several native, 'urban adapter' bird species in Melbourne, the Red-rumped Parrot *Pesphorus haematonotus* (Lowry and Lill 2007), Rainbow Lorikeet *Trichoglossus haematodus* and Musk Lorikeet *Glossopsitta concinna* (Smith and Lill 2008; Stanford and Lill 2008), Crested Pigeon *Ocyphaps lophotes* (Mulhall and Lill 2011) and Little Raven *Corvus mellori* (Lill and Hales 2015). Although interspecific aggression is sometimes important in effecting invasion success (Holway and Suarez 1999), it may equally well be that a low level of aggressive interference competition for food with resident species often facilitates urban-dwelling by exotic and native birds. However, the possibility of involvement in exploitative interspecific competition (niche partitioning) for food, whilst less likely (Sol *et al.* 2012), needs to be examined more thoroughly for Common Mynas.

It is possible that Common Mynas compete with some native, cavity-nesting birds for urban nest sites. Pell and Tidemann (1997a, b) stressed the Common Myna's potential to reduce the breeding success of some native parrots, because it dominated use of nest-boxes and natural tree hollows in bushland reserves in the ACT, and won most interspecific aggressive encounters at nest sites. Grarock *et al.* (2012) also found a negative relationship between the Common Myna's presence and the abundance of three native, cavity-nesting birds in the ACT. Grarock *et al.* (2013b) also found that although

the observed incidence of actual interference in rosella nesting attempts by Common Mynas was not particularly high, Crimson Rosella (*Platycercus elegans*) and Eastern Rosella (*P. eximius*) abundances declined as a function of increasing nest-box occupancy by mynas in urban nature reserves in Canberra. In contrast, Lowe *et al.* (2011) found that Common Mynas in Sydney used significantly fewer tree hollows than did native bird species and argued that interspecific competition for nest sites by Common Mynas was relatively insignificant. This whole issue requires further research, ideally incorporating an experimental approach.

#### *Mynas, miners and trees*

In urban Melbourne, Common Myna abundance was negatively associated with the presence of: (a) Noisy Miners, and (b) a high proportion of eucalypt, rather than exotic, trees in the local area. The Noisy Miner is known to have a direct, negative influence through its aggressive behaviour on the presence and abundance of co-habiting small bird species (e.g. Grey *et al.* 1997, 1998; Maron *et al.* 2011, 2013; Haythorpe *et al.* 2014). Intriguingly though, we observed only one aggressive event between a focal foraging Common Myna and Noisy Miners during our investigation. However, conceivably exploitative competition favours some degree of spatial segregation between urban Common Mynas and Noisy Miners, because the former are predominantly ground-foragers (Crisp and Lill 2006) and urban Noisy Miners also feed on the ground to a significant extent (Ashley *et al.* 2009; Lill and Muscat in press).

Exotic trees are not very important to Common Mynas for feeding, but they use them extensively for communal roosting and to some extent for nesting (Wood 1995; Feare and Craig 1999; Old *et al.* 2014). White *et al.* (2005) also found that Common Mynas in Melbourne were more abundant in urban streets with mostly exotic rather than native trees. Although the Noisy Miner consumes parts of exotic vegetation to a limited extent, it is very strongly associated with eucalypts in both the urban and exurban environments, obtaining nectar, insects, manna and honeydew from them (Ashley *et al.* 2009; Maron 2009). Thus Maron (2007) showed that the probability of Noisy Miners being present in rural Buloke *Allocasuarina luehmannii* woodland increased markedly where approximately five eucalypts/hectare were present. In the present study, in the exurban environment Common Myna abundance was greater at sites where more than one third of the trees were exotic. Noisy Miners were more abundant where the proportion of exotic trees was low and Common Mynas were absent, possibly in part due to aggressive exclusion by Noisy Miners (Lill and Muscat in press). This interesting interaction between exotic Common Mynas and native Noisy Miners and the way in which it is affected by their differing tree use patterns requires more extensive exploration. Are urban Common Mynas drivers of reduction of native bird species richness or merely passengers of habitat change (Garrock *et al.* 2014)? It could be that both they and Noisy Miners are influenced more directly by tree characteristics than by each other. Common Mynas are more abundant at low than high tree densities (Garrock *et al.* 2013 b, 2014), so the typical densities, as well as the proportions, of exotic and native trees in the urban environment need to be considered in any further exploration of the relationship among mynas, miners and trees. Planting more eucalypts and/or reducing the proportion of exotic trees could

decrease Common Mynas' abundance in the urban environment. However, it could also increase the abundance of Noisy Miners, which would be likely to lead to reduced native bird diversity overall (Maron *et al.* 2013).

#### *Management perspective*

To obtain a comprehensive understanding of the Common Myna as a successful urban invader in Australia, we need information on its ecology in several cities and in the adjacent exurban environment. Despite the present study's limitations (e.g. lack of replication over several years), it expands our knowledge by documenting the species' foraging ecology and abundance in one non-breeding season in Melbourne and rural Victoria.

It now seems reasonably clear that the key to the Common Myna's success in exploiting food resources in Australian cities stems from a combination of 'pre-adaptation', some consumer innovation and a low level of interspecific interference competition. Common Mynas may indirectly contribute to the reduction of small native bird diversity in Australian urban environments (Garrock *et al.* 2014), but not apparently through aggressive dominance of food resources (Phillipps 1994; Lowe *et al.* 2011). Perhaps Common Mynas' very conspicuous aggression towards potential nest predators (Fitzsimons 2006; Conole 2007; Trost and Olsen in press) may have contributed in a minor way to the perception that they aggressively compete with many native birds for food resources. However, this widely-held perception may simply be a sort of 'ecoingoism' that has contributed to the emergence of well-intentioned and enthusiastic, but misguided and usually ineffective, culling by enthusiastic amateurs and professionals alike (Trigger *et al.* 2008; Garrock *et al.* 2013a).

The case for Common Mynas 'outcompeting' a limited set of native, cavity-nesting birds for urban nest sites is more persuasive (Garrock *et al.* 2013 a, b, 2014). However, it may not necessarily lead to reduction of native bird diversity in Australian cities. It is important to establish definitively whether such competition really does reduce the diversity of native urban birds, because currently a lot of money and effort are being directed at Common Myna eradication that might potentially be more profitably directed towards more clearly proven and greater threats to urban native biodiversity.

Exotic Common Mynas may potentially be a greater threat to native bird diversity on oceanic islands than on the continental mainland and much effort has been expended on their eradication in such sites (e.g. Dulloo *et al.* 2002; Feare *et al.* 2011). There are some persuasive examples of Common Mynas negatively affecting endemic birds in such vulnerable island ecosystems (Komdeur 1996; Blanvillain *et al.* 2003). However, even the literature on this issue contains many qualifications about the evidence and many statements about the need for more definitive research.

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