ELSEVIER

PII: S0006-3207(96)00112-7

Biological Conservation **79** (1997) 145–153

0006-3207/97 $17.00+.00

THE IMPACT OF TWO EXOTIC HOLLOW-NESTING BIRDS ON TWO NATIVE PARROTS IN SAVANNAH AND WOODLAND IN EASTERN AUSTRALIA

A. S. Pell & C. R. Tidemann

Department of Forestry, School of Resource and Environmental Management, Australian National University, Canberra, ACT 0200, Australia

(Received 28 February 1996; accepted 29 May 1996)

Abstract

This paper examines factors which could influence the breeding success of native parrots in savannah and woodland areas in which substantial populations of the introduced hollow-nesting sturnids, myna Acridotheres tristis *and starling* Sturnus vulgaris, *are present. The two exotic sturnids were shown to be the dominant users of available nest resources (nest-boxes and natural hollows) in the study sites. The myna was successful in most aggressive encounters with starling and the two native parrots during the period of nest-site selection and occupancy. There was evidence of partitioning of nest resources between species in the different areas and habitats available. The exotic sturnids, particularly the myna, demonstrated the potential to reduce the breeding success of the native parrots studied. Copyright © 1996 Elsevier Science Limited*

Keywords: sturnids, parrots, hollow-nesting, breeding success, Australia.

INTRODUCTION

Most of Australia's native parrots use hollows in old and dead eucalypt trees for nesting. Since European settlement of Australia, the supply of such hollows has decreased substantially. Over a similar period, the introduction of exotic hollow-users has potentially placed further demands on the supply of this resource. Two exotic sturnids, the common myna *Acridotheres tristis* and the common starling *Sturnus vulgaris*, both use hollows which may be suitable for three native parrots in the Canberra region, viz: the crimson rosella *Platycercus elegans*, the eastern rosella *Platycercus eximius* and the red-rumped parrot *Psephotus haematonotus*. It is likely that there will be overlap in size of hollows used by these five species, which are not efficient primary excavators of trees and are therefore not capable of substantially altering existing hollows to suit requirements.

It is commonly believed that in eastern Australia the two exotic sturnids usurp hollows suitable for use by native parrots and may constitute a threat to breeding success of parrots in suburban and open woodland habitats (e.g. Taylor & Canberra Ornithologists Group, 1992). Evidence on the nature and scale of this threat is limited. A small number of observations indicates that the myna may displace native species from potential nest-hollows (Wright & Wright, 1991; Lindenmayer, 1993; Peters & Peters, 1993). The significance of these threats at the population level has not been quantified.

The starling is now well-established in grassland and open woodland areas in much of eastern Australia, although it avoids the denser woodland and forested areas. The myna is predominantly a bird of urban areas, living commensally with humans (Counsilman, 1974; Hone, 1978; Wood, 1995). A total of 110 mynas were released in the Canberra area between 1968 and 1971 (Gregory-Smith, 1985) and they have increased steadily in numbers and suburban distribution since that time (Davey, 1991). Mean population density estimate for myna in two suburbs bordering current study sites during 1994 was 118 ± 60 birds/km^2 (Pell & Tidemann, 1994). Information on the use of nature reserves by mynas is limited and little is known of the extent to which it utilises available nesting-hollows.

The current study aims to document the use of nesting resources in two nature reserves close to urban areas in which myna and starling population densities had been established, by preliminary survey, to be high. The preliminary survey indicated that native parrot populations were relatively high in one reserve (Red Hill Nature Park) and relatively low in the other (Oakey Hill Nature Park). Nest-boxes were provided to supplement natural hollows available in each reserve.

The outcome of interspecific aggressive interactions, particularly in the period of nest-site selection, may govern success rate in obtaining suitable nest-hollows. Interspecific destruction of eggs or chicks can obviously directly affect reproductive performance. Any differential use of nesting resources in the different vegetation types or habitats available may ameliorate the effects of any competition between species. The study sought information on these factors, each of which

could influence the breeding success of native parrots in areas with substantial populations of exotic sturnids.

STUDY AREAS

Two study areas were used: Red Hill Nature Park and Oakey Hill Nature Park.

Red Hill Nature Park

Red Hill Nature Park is an area of approximately 300 ha, bounded on all sides by suburban Canberra, ACT. An area of approximately 120 ha was identified for detailed survey, as shown in Fig. 1. Vegetation in this area was predominantly grassy, open savannah, with *Eucalyptus blakelyi, E. rossii, E. melliodora, E. polyanthemos* and *E. bridgesiana* as the most common eucalypt species present. Their distribution was generally sparse and heterogeneous, ranging from isolated trees to an area of regrowth woodland at the northern end of the site. The understorey of the site consisted of a dense cover of introduced pasture grasses and was actively grazed by cattle. Isolated shrubs (e.g. *Pyracantha* spp., *Rubus* spp. and *Rosa* spp.) were present, with isolated non-eucalypt trees (*Acacia baileyana, A. dealbata, Casuarina stricta* and *Exocarpus cupressiformis)* scattered across the site.

Oakey Hill Nature Park

Oakey Hill Nature Park (Fig. 2) is an area of approximately 85 ha, surrounded by suburban Canberra, and is predominantly grassy, open savannah, with a heterogeneous, generally sparse, distribution of *Eucalyptus* spp. These include recent plantings (*E. cinerea, E. viminalis*) and remnant trees (mainly *E. blakelyi*) and dead stags, providing potential nest-hollows. The understorey is characterised by a dense, grassy cover (mainly introduced pasture species but with some native grasses (e.g. *Themeda australis*)). The site is no longer grazed. Isolated shrubs (e.g. *Pyracantha* spp., *Rosa* spp.) are present, with isolated non-eucalypt trees (e.g. *Acacia rubida, A. baileyana* and *Casuarina stricta*). The site includes an area of approximately 10 ha of woodland consisting of plantings of *Eucalyptus globulus* (spp. *bicostata*), too young to provide potential nest-hollows.

METHODS

Population density estimates

For survey purposes, the Red Hill Nature Park site was divided into four areas, viz: Eastern and Western Edges, Woodland and Interior (arbitrarily defined as being a minimum of 150 m from any suburban interface in the non-woodland areas of the site). Population density estimates were obtained by direct count on strip transects as shown in Fig. 1: Eastern Edge: one transect (1·4 km × 100 m) along the eastern edge of the reserve; Western Edge: one transect (1·3 km × 100 m) along the western edge of the reserve; Interior: two transects (0·7 and 0·6 × 150 m) running across the reserve and, in part, along the internal ridge of the reserve (counts from the two Interior transects were combined for further analysis); Woodland: one transect (300 m × 100 m) through woodland in the northern section of the site.

On the Oakey Hill Nature Park site, two strip transects (1·2 km and 2·2 km × 100 m), running essentially along eastern and western edges of the reserve respectively (Fig. 2), were used for population density estimation.

Transect counts were carried out in alternate months of 1994 (February – December), using six separate daily counts in each of the months surveyed. Counts were all carried out between 07.00 and 09.30 h, in the absence of strong wind or rain.

Population density estimates (birds per km^2) for introduced (myna and starling) and native (crimson rosella and eastern rosella) species were then compared by analysis of variance using the Genstat 5, Release 3.1, statistical program (Copyright 1994, Lawes Agricultural Trust, Rothamstead Experimental Station, UK), following transformation to square root format to stabilise variance of means.

Aggressive interspecific interactions

During the period of hollow-selection, nest-building and reproduction (September – December), outcomes of aggressive interactions between species were recorded while transect counts were being carried out. The large majority of these interactions were of the supplanting type, in which the aggressor flew directly at another bird, usually perched. If the latter conceded its position, it was recorded as losing the encounter. A few interactions reached the fighting stage. The species clearly retreating from the area was recorded as the loser. Success rates in aggressive interactions between species were compared using Chi^2 analyses.

Nest-boxes

Nest-boxes were constructed of water-proof seven-ply wood and were of internal dimensions 235 mm × 200 mm (base) × 400 mm (height), with a 65 mm diameter entrance hole. Internal volume was 0·019 m^3. Boxes had hinged, overlapping lids, internal wire-mesh ladders and wooden perches fitted 30 mm below the entrance hole, which faced south. Boxes were hooked onto a bolt in the tree, at a standard height of 4 m, by means of a wire loop at the top of the back of the box. The box was stabilised using a 3 cm-wide flexible steel strip, attached to either side of the lower part of the back of the box and to the tree.

Groups of nest-boxes were established in May 1994, well in advance of the breeding season. On Red Hill Nature Park, the Eastern Edge and Interior areas were schematically divided into grids of 1 ha squares and 20 boxes were randomly allocated across each of these areas. The Woodland area was divided into a grid of 0·5

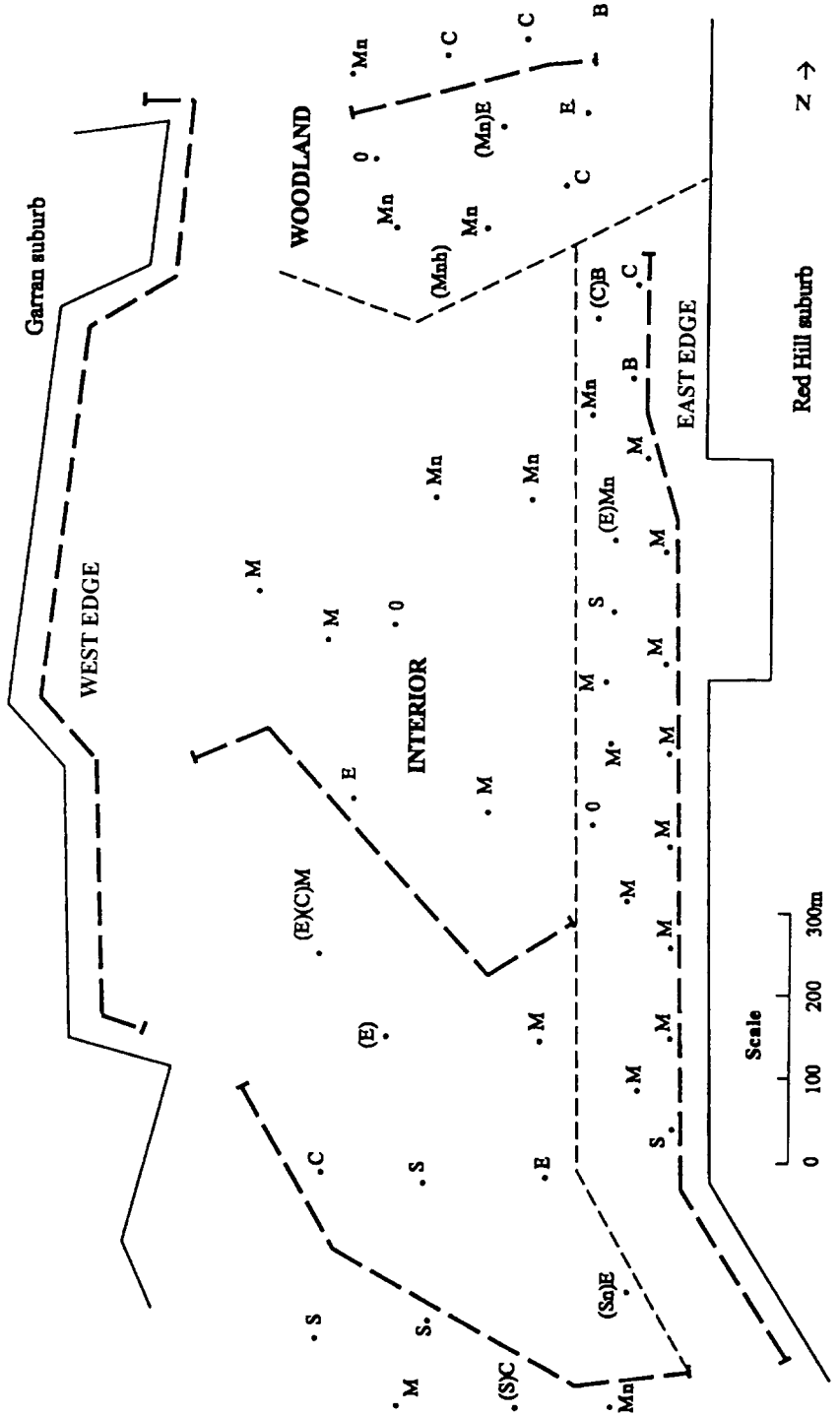

Fig. 1. Study sites, transect locations, nest-box locations and user species on Red Hill Nature Park. — — —, transects; - - - -, study area divisions; ●, nest-box locations with letters indicating eventual user species (S, M, C, E, B, O for starling, myna, crimson rosella, eastern rosella, bees and 'unused' respectively). Postscript 'n', the species concerned built a nest but did not proceed further. 'Mnh', use of a natural hollow by mynas at that location. A species letter in parentheses (e.g. (C)) indicates that that species initially occupied that box, laid eggs, but was superceded in the box by the next-named species. *x* indicates the location of a myna roost. Further details are given in the text.

ha squares and 10 boxes were randomly allocated across this area. On Oakey Hill Nature Park, 20 and 10 nest-boxes respectively were randomly allocated in 1 ha and 0·5 ha squares in Savannah and Woodland areas. Figures 1 and 2 show the positions and users of nest-boxes at each site, with the exception of two vandalised boxes (one in Oakey Hill Savannah; one in Red Hill Interior).

Inspection of nest-boxes

During the months of June to November 1994, any inspection activity by birds at nest-boxes along transect routes was recorded while transects counts were being carried out. Observation of inspection activity at the remaining nest-boxes not on transect routes was undertaken over similar time periods in alternate months when transect counts were not scheduled. Species involved and relevant box number were recorded.

Inspection rates of nest-boxes across species were compared using Chi^2 analyses.

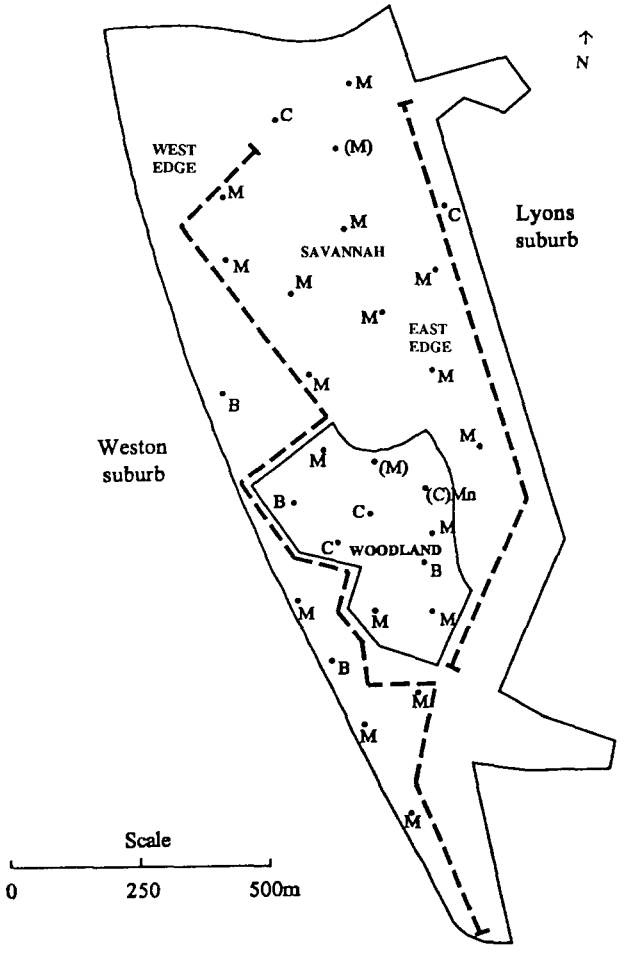

Fig. 2. Study sites, transect locations, nest-box locations and user species on Oakey Hill Nature Park. – – – –, transects; ●, nest-box locations with letters indicating eventual user species (M, C, B for myna, crimson rosella and bees respectively). For other abbreviations, see Fig. 1. Further details are given in the text.

Use for reproduction

Nest-boxes were opened for inspection at approximately 3-weekly intervals during the breeding season (October – January) to determine occupancy and for evidence of egg or chick loss. Usage rates of nest-boxes across species and areas were compared using Chi^2 row × column contingency analysis. Usage rate data from Woodland areas at both study sites were combined in order to increase 'expected' cell numbers in the Woodland row.

Use of natural nest-hollows

Areas measuring 2·5 ha of Red Hill Eastern Edge and of Red Hill Interior, and a 34 ha area of Oakey Hill Savannah, were intensively surveyed during the breeding season to determine rate of use of natural hollows. Hollows in each area were surveyed visually from the ground at 2-weekly intervals from mid-September to end-December 1994, a total of nine observations per plot. A hollow was considered to be in use if at least three distinct observations of a particular species entering the hollow were recorded on separate occasions during this period. Direct inspection of each hollow was not possible. Usage rates of natural hollows at both study sites were compared across species and areas using Chi^2 row × column contingency analysis.

RESULTS

Population density estimates

Population density estimates for introduced versus native species in the four surveyed areas of Red Hill Nature Park (Western Edge, Eastern Edge, Interior and Woodland), with associated least significant differences, are given in Fig. 3. Estimates for introduced species were significantly higher than those for native species in Red Hill Western Edge: $p < 0{\cdot}001$; Red Hill Eastern Edge: $p < 0{\cdot}001$; and Red Hill Interior: $p = 0{\cdot}003$, while in the Woodland area native species estimates were significantly greater than those for introduced species ($p < 0{\cdot}001$).

Population density estimates for introduced versus native species in the Western Edge and Eastern Edge transects at Oakey Hill Nature Park, with associated least significant differences, are given in Fig. 4. Estimates for introduced species were significantly higher than those for native species in Oakey Hill Western Edge: $p < 0{\cdot}001$; and Oakey Hill Eastern Edge: $p = 0{\cdot}026$.

In general, estimated population densities of introduced and native species both increased with the onset of the breeding season, at both study sites.

Aggressive interspecific interactions

Table 1 documents the outcomes of aggressive interactions between starling, myna, crimson rosella, eastern rosella and red-rumped parrot, totalled over both sites. Records relate to the period from the beginning of

September to the end of December 1994 and therefore cover periods of hollow-inspection and selection, nest-building and reproduction. The myna was the dominant aggressor, winning significantly more encounters than it lost overall ($p < 0.001$), particularly against the starling ($p < 0.001$) and the eastern rosella ($p < 0.001$). The crimson rosella was successful in encounters with the eastern rosella ($p < 0.001$). The eastern rosella lost significantly more encounters than it won overall ($p < 0.001$). Very few interactions involving the red-rumped parrot were recorded, there being only small numbers of this species in the study sites.

Use of nest-boxes

Inspection

Inspection of nest-boxes started as early as June and became more intensive from August onwards. Table 2 shows the monthly totals of inspections of all boxes recorded for starling, myna, crimson rosella and eastern rosella during August to November 1994 inclusive. There were significant differences between species in overall total of inspections and in monthly inspections for August, October and November ($p < 0.001$). The starling was most active early in the breeding season, while the myna dominated box inspection later. Both rosellas inspected boxes consistently from August onwards. Red-rumped parrots were not seen to inspect nest-boxes.

Table 3 shows the number of inspections recorded for each species in Edge, Interior and Woodland areas of Red Hill Nature Park over the period August to November 1994 inclusive. There were significant differences between the introduced sturnids and the native parrots for inspections of boxes in different areas ($p < 0.001$). Compared to the introduced species, the native parrots

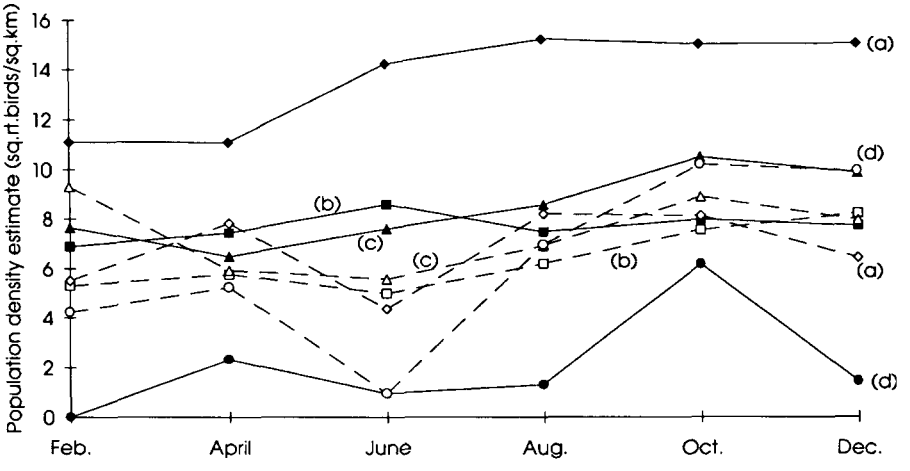

Fig. 3. Population density estimates over time of Introduced species (closed symbols and full lines) and Native species (open symbols and dashed lines) on Red Hill Nature Park transects (East Edge ◇ (a); West Edge □ (b); Interior Δ (c); Woodland ○ (d)). Least significant differences between means for Introduced versus Native species for each area, at the $p = 0.05$ level, are: East Edge 1·784; West Edge 1·586; Interior 1·626 and Woodland 3·094. Transect locations are shown in Fig. 1.

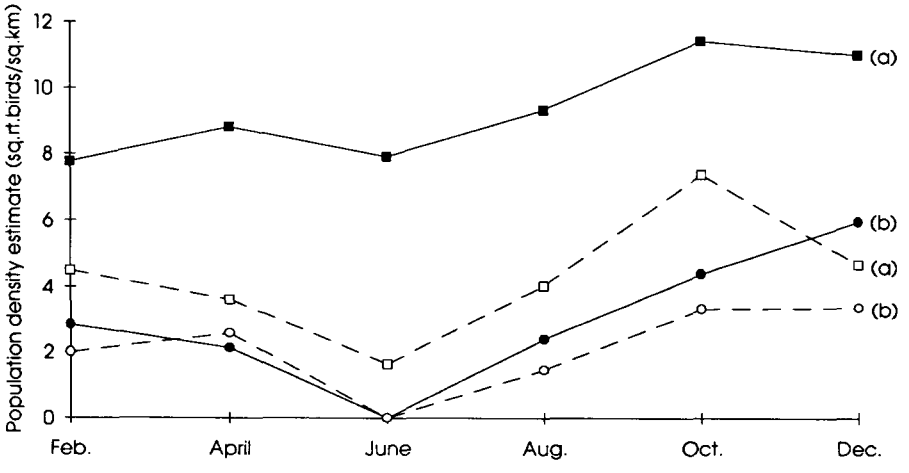

Fig. 4. Population density estimates over time of Introduced species (closed symbols and full lines) and Native species (open symbols and dashed lines) on Oakey Hill Nature Park transects (West Edge □ (a); East Edge ○ (b)). Least significant differences between means for Introduced versus Native species for each area, at the $p = 0.05$ level, are: Western edge 1·168; Eastern edge 1·792. Transect locations are shown in Fig. 2.

inspected Woodland boxes more frequently, while the converse was true for boxes in Edge and Interior areas.

Use for reproduction

Table 4 and Figs 1 and 2 show the use of boxes for reproduction by the four species across the various areas of the two Nature Parks. Use for reproduction is defined as production of chicks within a box (or the production of eggs in a box taken over by bees). There were significant differences in rate of use between species and across habitats ($p < 0.05$). Mynas were the dominant users of boxes, making significantly greater use of boxes ($p < 0.001$) in Red Hill Edge and Oakey Hill Savannah areas. Additionally, 10 myna nests were built in boxes but not used further. The possible strategic significance of this is discussed later. Crimson rosellas had a low rate of usage of boxes in all areas, while eastern rosellas only used boxes in Red Hill Interior and Woodland. Starlings made no use of boxes in Woodland areas, and had only a low rate of usage in Red Hill Edge and Interior areas. Although not included in this analysis, bees were an aggressive competitor for nest-box use, occupying approximately 10% of available boxes.

Change of box 'ownership'

Instances of change of 'ownership' of boxes are illustrated in Figs 1 and 2. Across both sites there were three known instances in which rosella clutches were lost to mynas, and one instance each of crimson rosellas superceding starling and eastern rosella clutches. One crimson rosella clutch was lost to bees. The behaviour of mynas in the attempted eviction of rosellas was documented. The aggressive myna pair perched on the box or box-entrance for extended periods of time, repelling any attempts by the resident rosellas to enter. When at the box-entrance, the invading mynas frequently pecked inside the box, presumably at the resident chicks or eggs. This behaviour does not always completely eliminate the resident brood. For example, one eastern rosella pair reared one chick from an initial clutch of six eggs, while experiencing considerable aggression from a myna pair.

Use of natural nest-hollows

The usage rates of natural hollows in Oakey Hill Savannah, Red Hill Edge and Red Hill Interior are presented in Table 5. There were significant differences in usage rate of natural hollows between species ($p < 0.001$). In all three areas, starling and myna were the major users of natural hollows. Rosellas used smaller numbers of hollows in all sites, while red-rumped parrots used three hollows in the Red Hill Interior study area.

DISCUSSION

Breeding success of hollow-nesting parrots is dependent initially upon the obtaining of suitable nest-sites. Newton (1994) reviewed evidence that shortage of tree hollows limits breeding densities of hollow-nesting birds. Such evidence is both circumstantial and experimental. Circumstantially, the number of breeding pairs in different areas has been shown to correlate with the numbers of local nest-sites. Further, the number of breeding pairs has been shown to change when numbers of nest-sites changed. Experimentally, nest-site provision or removal has been followed by a corresponding change in breeding density. Breeding success can be threatened by other

Table 1. Outcomes of interspecific interactions on Red Hill Nature Park and Oakey Hill Nature Park, September – December 1994
Columns give numbers of interactions won by the respective species, rows give numbers of those lost (Ambrose, 1982).

	Winner					
Loser	Starling	Myna	C rosella	E rosella	RR parrot	Total lost
Starling	—	18	5	5	1	29
Myna	0	—	10	4	0	14
C rosella	4	18	—	1	0	23
E rosella	11	28	34	—	1	74
RR parrot	1	0	0	5	—	6
Total won	16	64	49	15	2	146

Table 2. Total nest-box inspections per month by four species on Red Hill Nature Park and Oakey Hill Nature Park
Areas are described in the text and are shown in Figs 1 and 2.

	Starling	Myna	C rosella	E rosella
August	36	12	21	10
September	21	23	15	12
October	21	47	9	17
November	5	42	13	5

Table 3. Nest-box inspections by four species in Edge, Interior and Woodland areas on Red Hill Nature Park, August – November 1994
Areas are described in the text and are shown in Fig. 1.

	Starling	Myna	C rosella	E rosella
Edge	42	77	23	13
Interior	38	39	20	19
Woodland	3	8	15	12

hollow-nesting species in the area if nest-hollows are in limited supply.

In the current study, some circumstantial evidence suggests that nest-sites may have been limiting in the study sites:

1. 96% (77 of 80) of boxes showed evidence of chewing around the box entrance, a behaviour characteristic of rosellas and galahs *Cacatua roseicapilla*. The large majority of observed instances of chewing were by rosellas, indicating a high level of initial interest by these species in this new resource (ultimately used predominantly by mynas);
2. the recorded rates of nest-box inspection indicated considerable interest by all four subject species in these additional nest-sites from the early breeding season on;
3. the high usage rate of available nest-boxes (*c.* 80%) may indicate that surplus birds were present in the vicinity and were now able to breed.

The above evidence is indirect and does not unequivocally demonstrate competition for limited nest-sites. Caution is needed in the interpretation of the nest-box data. An alternative explanation may be that nest-boxes were preferred to natural hollows as nest-sites, even though natural hollows were not limiting. Newton (1994) highlights a number of species which accept well-designed artificial nest-sites in preference to inferior natural sites, even though the latter were readily available.

We now discuss evidence produced in the current study relevant to the potential of introduced sturnids to influence the breeding success of native parrots.

Population density estimates

The introduced sturnids and the two native parrots were present in both study areas throughout the year. Estimated population densities increased generally during the breeding season, with birds presumably seeking nest-sites. Habitat preference differed, with the sturnids being found in greater numbers than the native parrots in edge and interior areas, while the native parrots were more prevalent in woodland areas. However the introduced sturnids, particularly the myna, did enter woodland areas during the breeding season, probably seeking nest-sites.

Aggressive interspecific interactions

The outcome of aggressive encounters between species may influence success rate in the process of hollow selection and occupancy. The myna was dominant in such interactions. This will contribute to its success in obtaining hollows when they are in short supply or prime nest-sites when they are not. The crimson rosella was dominant over the eastern rosella, but generally yielded to the myna.

The starling was only noticeably successful in agonistic encounters against the eastern rosella, winning 69% of such encounters. The eastern rosella won the majority of its encounters with the red-rumped parrot. Ambrose (1982) found that the red-rumped parrot in and around Melbourne engaged in many agonistic encounters with starlings and usually lost these (lost 80%, 12 of 15 encounters). Such outcomes may be of importance in determining the use of smaller hollows, not accessible to myna and crimson rosella. It is known (Moeed & Dawson, 1979) that entrance diameters < 45

Table 4. Numbers of artificial nest-boxes used by five species in designated study areas on Red Hill Nature Park and Oakey Hill Nature Park

Areas are described in the text and are shown in Figs 1 and 2.

Area	Starling	Myna	C rosella	E rosella	Bees
Oakey Hill Savannah	0	14	2	0	2
Oakey Hill Woodland	0	4	3	0	2
Red Hill Edge	2	11	2	0	2
Red Hill Interior	3	6	2	3	0
Red Hill Woodland	0	0	3	2	1

Table 5. Numbers of natural hollows used by six species in designated study areas on Red Hill Nature Park and Oakey Hill Nature Park

Areas are described in the text and are shown in Figs 1 and 2.

Area	Starling	Myna	C rosella	E rosella	RR parrot	Bees
Oakey Hill Savannah	11	14	2	2	0	6
Red Hill Edge	8	7	1	0	0	1
Red Hill Interior	7	7	3	3	3	1

mm exclude myna but allow access to starling. Further, in certain areas of Michigan, USA, the mountain bluebird *Sialis curricoides* is confined to cavities with entrances small enough to exclude starlings, while in the absence of starlings, bluebirds will use cavities with a wide range of entrance diameters (Pinkowski, 1976).

Use of nest-boxes

Inspection

The myna became dominant in box inspection from October on. The starling started nest-box inspection earlier than the other species (in line with its generally earlier breeding season) and began nest-building in numerous boxes. However, it was then aggressively excluded from the majority of boxes by mynas. This situation is similar to that noted by Wilson (1973) in New Zealand, where mynas were intolerant of starlings building within an established myna nest-site or in 'vacant' boxes within or adjacent to their territory. Further, of 10 starling clutches in the above New Zealand study, an average of only 0·8 chicks per clutch were successfully reared.

There were indications of potential nest-site partitioning. The sturnids preferentially inspected boxes in Edge and Interior areas, while the native parrots inspected Woodland boxes more frequently.

Use for reproduction

The myna was clearly dominant in the successful use of nest-boxes for breeding. It could be argued that this reflects a higher acceptability of the boxes to mynas than to native parrots. This is unlikely to be the case. In the previous breeding season, 1993, crimson rosellas occupied 88% (44 of 50) of nest-boxes of the same type in nearby areas of open forest, essentially free of mynas and starlings (E. Krebs, pers. comm.).

The myna was the dominant user in savannah and edge areas, and was also the major user in Oakey Hill Woodland. Of particular note is successful use of the two most distant Red Hill Interior boxes by mynas. These boxes were some 450 m from the suburban edge and over 500 m from the nearest myna roost (see Fig. 1).

There is some evidence of partitioning of the nesting resource. Eastern rosellas did not occupy boxes in edge areas but did use boxes in interior and woodland areas. Starlings made no use of boxes in woodland and had only a low rate of use in Red Hill Edge and Interior areas. Red Hill Woodland boxes reared only rosella broods. However, mynas were active in this woodland during the breeding season. Figure 1 shows a group of four myna nests constructed but not further used. These nests were close to a myna nest in a natural hollow in the edge of the woodland (Mnh, Fig. 1). It is possible that these nests, and a further six constructed but not used in other areas of the study sites (Figs 1 and 2), were built as deterrents to use by other species. If this is a strategy used to maintain territory, it appeared to work; in only one case (of 10) was the myna nest removed and a clutch of another species laid. Such a strategy would obviously increase pressure on limited nest-site resources.

Change of box 'ownership'

Evidence for interspecific destruction of eggs or chicks is difficult to obtain in field-work of this type. Often eggs or chicks disappear between visits and the culprit is undetected. Based on the limited evidence collected, the myna appears capable of disrupting the efforts of rosella parents to rear young.

Use of natural nest-hollows

Survey of usage of natural tree-hollows presented a similar picture to the usage of nest-boxes, but with one notable exception. The number of hollows used by starlings (26) was almost as great as that of mynas (28). The reason for this difference in usage rate between nest-boxes and natural hollows probably relates to entrance diameter. Nest-box entrance diameter was 65 mm, accessible to both myna and starling. In these circumstances, myna dominates starling. Many of the natural hollows used by starlings are of smaller entrance diameter. Available hollows in the reserves are therefore partitioned, at least in part, in this way. Small numbers of red-rumped parrots bred in the areas surveyed on Red Hill Nature Park, again in smaller hollows. It seems likely that the starling would be an important competitor to red-rumped parrot and would adversely affect the breeding activity of this species where natural hollow availability is limiting.

The sturnids were the major users of natural hollows on both reserves. The use of a hollow does not necessarily indicate that a successful brood was produced. Direct confirmation was not possible. In the case of myna and starling it is possible that a number of nests were built in hollows but not used. This behaviour was noted above in discussion on the use of nest-boxes. Ambrose (1982) suggests that native parrots are reluctant to use hollows already containing nest material, so such nest-building would reduce availability of hollows to native parrots. While this may be the case, the current study documented one instance of an eastern rosella laying eggs on top of a starling nest in a nest-box, and one instance of eastern rosellas utilising a box after removing myna nest material. Further, rosellas were observed frequently to remove wood-shavings from inside boxes. Residual material in nest-boxes is therefore not a total deterrent to future use by rosellas.

CONCLUSIONS

Overall, the study has generated strong circumstantial evidence of the potenial of the introduced sturnids, particularly the common myna, adversely to affect the breeding success of crimson and eastern rosellas in

savannah and woodland areas, particularly those close to urban centres.

Both introduced sturnids were major users of natural hollows, with the starling probably making greater use of hollows of smaller entrance diameter. In this respect, starlings may have an important influence on the breeding success of the red-rumped parrot.

ACKNOWLEDGEMENTS

We thank Dr R. Cunningham and Ms C. Donnelly for valuable statistical advice and assistance; Mr M. Davanzo, Ms S. Hedenstroem, Ms L. Pell and Ms G. Slocum for technical support and the ACT Parks and Conservation Service for financial support. We are grateful for valuable comments on the initial draft by two referees.

REFERENCES

Ambrose, G. J. (1982). An ecological and behavioural study of vertebrates using hollows in eucalypt branches. PhD thesis, La Trobe University, Melbourne.

Counsilman, J. J. (1974). Breeding biology of the Indian myna in city and aviary. *Notornis*, **21**, 318–333.

Davey, C. (1991). Numbers and distribution of the common myna in Canberra in July, 1990. *Canberra Bird Notes*, **16**, 41–50.

Gregory-Smith, R. (1985). Introduction and spread of the common myna in Canberra. *Canberra Bird Notes*, **10**, 97–103.

Hone, J. (1978). Introduction and spread of the common myna in New South Wales. *Emu*, **78**, 227–230.

Lindenmayer, B. (1993). The use by common myna of a nesting hollow possibly used on previous occasions by galahs. *Canberra Bird Notes*, **18**, 45.

Moeed, A. & Dawson, D. G. (1979). Breeding of starling *Sturnus vulgaris* in nest-boxes of various types. *N. Z. J. Zool.*, **6**, 613–618.

Newton, I. (1994). The role of nest-sites in limiting the numbers of hole-nesting birds:a review. *Biol. Conserv.*, **70**, 265–276.

Pell, A. S. & Tidemann, C. R. (1994). Population densities of common mynas, common starlings, crimson rosellas and eastern rosellas in Oakey Hill Nature Park and adjacent suburbs. *Canberra Bird Notes*, **19**, 58–66.

Peters, F. & Peters, A. (1993). Common myna displaces eastern rosella from nest-hole. *Canberra Bird Notes*, **18**, 5.

Pinkowski, B. C. (1976). Use of tree-cavities by nesting eastern bluebirds. *J. Wildl. Manage.*, **40**, 556–563.

Taylor, M. & Canberra Ornithologists Group (1992). *Birds of the Australian Capital Territory. An atlas.* Canberra Ornithologists Group and National Planning Authority, Canberra.

Wilson, P. R. (1973). The ecology of the common myna *Acridotheres tristis L.* in Hawke's Bay. PhD thesis, University of Wellington.

Wood, K. A. (1995). Roost abundance and density of the common myna and common starling at Wollongong, New South Wales. *Aust. Bird Watcher*, **16**, 58–67.

Wright, H. & Wright, A. (1991). Common myna on the outskirts of Canberra. *Canberra Bird Notes*, **16**, 30.