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Keywords

urban, non, vegetation, cyaneus, habitats, urbanised, edge, malurus, wrens, fairy, superb, requirements

Disciplines

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The vegetation requirements of Superb Fairy-wrens (*Malurus cyaneus*) in non-urban edge and urbanised habitats

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Abstract. Urbanisation has created an environment with a broad spectrum of habitats of differing quality for birds. Understanding habitat characteristics is necessary for effective conservation of species in urban environments. We investigated the vegetation requirements of a small, shrub-nesting, Australian bird, the Superb Fairy-wren (*Malurus cyaneus*), and the relative quality of urban habitats in the Illawarra region of New South Wales. Vegetation was assessed in three different habitats: suburban sites within Superb Fairy-wren territories ($n = 20$ sites), suburban sites where Fairy-wrens were absent ($n = 20$), and rural–woodland edge in which Fairy-wrens were present ($n = 17$). This third habitat represents a habitat assumed to be the best possible habitat for this species within the landscape. We analysed structure and floristics of the vegetation. The three habitats were significantly different from each other both in vegetation structure and floristic composition. While there was some variability in habitat selection in suburban areas, Superb Fairy-wrens were largely restricted to areas that have a dense layer of native shrubs surrounding grassy areas. They were absent from suburban sites where there were either few shrubs in total or sites with exotic shrubs, regardless of abundance. It was predicted that non-suburban habitats (habitat located on the rural–remnant edge) would be of a higher quality than suburban habitats (habitat within residential housing) owing to a prevalence of native vegetation. However, these sites were dominated by a single exotic species, *Lantana (Lantana camara)*. Despite this plant replacing native vegetation, it was an important habitat feature. Either this plant or native shrubs must be available for this species to colonise a site.

Introduction

The urban environment encompasses a broad spectrum of habitats, from highly developed industrial and commercial zones to fragmented remnants and expansive green spaces (Jokimäki 1999). The composition of the bird communities living within these habitats varies along this urban gradient (Beissinger and Osborne 1982; Catterall *et al.* 1989; Blair 1996; Savard *et al.* 2000) with highly urbanised habitats often supporting exotic birds that have a long history of human cohabitation (Case 1996). Some native birds also exploit urban habitats, becoming more prevalent than in their natural habitats (Parsons *et al.* 2003). Studies from Europe (Huhtalo and Jarvinen 1977; Jokimäki *et al.* 1996; Fernández-Juricic 2000; Fernández-Juricic and Jokimäki 2001; Palomino and Carrascal 2006), North America (Emlen 1974; Guthrie 1974; Walcott 1974; Beissinger and Osborne 1982; Rosenberg *et al.* 1987; Green and Baker 2002) and Australia (Jones 1983; Green 1984, 1986; Catterall *et al.* 1989, 1991; Munyenyembe *et al.* 1989; Parsons *et al.* 2003) have shown that as vegetation becomes more prevalent in urban areas, the ability to support a wider range of native species also increases, although the bird assemblages remain distinct from those historically present before human development.

Heterogeneous urban landscapes do not limit all birds to isolated patches of suitable habitat within a hostile matrix

(Hansson *et al.* 1995; With *et al.* 1997). Within the urban matrix a range of habitats may be tolerated by a species, and fulfil different requirements such as foraging or breeding (With *et al.* 1997). Local factors play a significant role in the structure of habitat occupied by individuals (Davis and Glick 1978; Jokimäki *et al.* 1996; Fernández-Juricic 2000), though the requirements of a population must be met at a landscape scale in order to sustain the population (Wiens 1985; Jokimäki *et al.* 1996; Clergeau *et al.* 2006). Therefore, understanding the habitat requirements of individuals at a small scale is a vital first step for managing the landscape and promoting the survival of less common species (Savard *et al.* 2000).

Habitat structure and availability have a large influence on the probability of occurrence of individuals at a site (Jokimäki and Huhta 1996; Mörtberg 2001). The loss of vegetation cover has been associated with a reduction in urban bird diversity (Hooper *et al.* 1975; Hohtola 1978; Lancaster and Rees 1979; Beissinger and Osborne 1982; Mills *et al.* 1989; Munyenyembe *et al.* 1989). In natural forests, a variety of different plants of different ages creates complex structural layers, in contrast to the urban park and garden design of open lawn space and tall trees, which is reminiscent of some natural grassy woodland habitats (Jokimäki and Huhta 2000). In Australia, urban habitats that replicate grassy woodland are dominated by larger, more

aggressive avian species (Catterall 2004; Parsons *et al.* 2006). The limited availability of habitat suitable for smaller, cover-dependant species such as those that traditionally occupy shrubby woodlands, heaths and forests is thought to be at least partly responsible for the decline of small birds in urban Australia (Catterall *et al.* 1989; Munyenyembe *et al.* 1989; Bass 1995; Sewell and Catterall 1998).

The floristics of the remaining urban vegetation is also thought to influence species use. It is generally accepted that native birds prefer native vegetation (Green 1984, 1986; Parsons *et al.* 2006) though some studies have indicated that this is not always the case. Catterall *et al.* (1989) and Green *et al.* (1989) suggest that native birds are simply more selective in their use of both native and exotic plants than introduced birds. Differences in both food availability and the structure of exotic vegetation may be responsible for native birds avoiding such vegetation (Green 1984; Bhuller and Majer 2000).

The Superb Fairy-wren (*Malurus cyaneus*) is a small (9–11 g), native, insectivorous bird that is considered to be an edge species (Rowley and Russell 1997; Berry 2001). It is also found in urban habitats, where it is a permanent resident year round, though it is not generally common (Veerman 2002; Parsons *et al.* 2003, 2006; Catterall 2004). One reason why it is relatively uncommon might be the dependence of this species on shrubs for shelter and nesting sites (Rowley and Russell 1997). Given that this species is both highly territorial and a weak flier (Rowley and Russell 1997), competition for good-quality patches would be strong if high-quality habitat is limited in availability. Therefore the ability to select and occupy the highest quality habitat would have large implications for the future fitness of individuals. For Superb Fairy-wrens, edge habitat along rural–remnant boundaries is considered high-quality habitat. Densities of individuals are higher in this habitat than in the interior of traditional woodland habitats, as foraging opportunities are thought to be increased in the open habitat adjacent to the habitat edges (Berry 2001). Density is not always a good indicator of habitat quality expressed in terms of overall fitness (van Horne 1983) as rural–remnant edge habitat may act as a reproductive sink. However, for the purposes of this study of foraging habitat, comparisons will be made between this edge habitat (hereafter referred to as non-suburban habitat) and suburban habitat.

As local habitat characteristics play a vital role in the fitness of individuals within territories (Luck 2002), choice of habitat in modified landscapes may be limited by a loss of both dispersal ability and high-quality patches (Garshelis 2000; Luck 2002; Maguire 2006). In modified habitat, such as in urban areas, we would expect that a loss of shrubby habitat would lead to fewer territories and restrict cover-dependant species to more vegetated areas. This is likely to have an impact on the abundance and fitness of the population. The availability of fewer high-quality territories owing to a lack of suitable habitat would lead to an overall reduction in the fitness of the total population as more individuals are forced into poorer quality territories. Isolation of territories would be predicted to cause dispersal difficulties. Recruitment into available territories, both of high and poorer quality, would be slow, leading to an overall lower density of individuals across the landscape.

If the distribution of Superb Fairy-wrens is limited in suburban areas owing to a shortage of suitable habitat patches we would expect:

- (1) The structure or floristic composition, or both, of vegetation of sites within suburban Fairy-wren territories to be different to sites in urban areas without Fairy-wrens.
- (2) The vegetation of suburban territories to be more similar to the vegetation in non-suburban territories than to suburban sites without Fairy-wrens. The habitat requirements of the birds would require them to settle in suburban territories that have a similar structure or floristic composition to good quality territories in other habitats.
- (3) A hierarchy in shrub availability and floristic composition across the habitats to be observed:
 - highest quality habitats that are non-suburban territories will have most shrubs and the greatest proportion of native plants;
 - mid-quality habitats that are suburban territories will have equivalent or a lower density of shrubs and mixed floristic composition; and
 - poorest quality habitats that are suburban areas without Superb Fairy-wrens will have fewest shrubs and most exotic vegetation.
- (4) Urban territories to have a high degree of similarity to each other as there is a limited range of habitat characteristics that are suitable for them in these urban areas. Conversely there would be more variation in the habitat characteristics of urban areas without Superb Fairy-wrens.

The aim of this study was to test these predictions by measuring habitat characteristics of areas occupied by Superb Fairy-wrens and unoccupied habitat in urban habitats and non-urban edges.

Materials and methods

Habitat characteristics

Superb Fairy-wrens were observed in Wollongong, in the Illawarra region of New South Wales (NSW), Australia (34.26°S, 150.53°E) in September 2005. A total of 17 pairs or groups were located in non-suburban habitats, which were edges located along rural–woodland boundaries. Despite extensive searches, we could find no individuals of this species in the interior of woodlands in the area, suggesting that edges were preferred habitat. There were 20 pairs or groups of Superb Fairy-wrens located in suburban areas. Suburban areas were dominated by residential housing (mainly single or two-storey housing and gardens) and parkland (open recreational park space with lawn, some shrubs and trees in various proportions). We used observations of the Superb Fairy-wrens in the week before the vegetation assessments to determine approximate territories in the suburban and non-suburban habitats by mapping points where the birds were seen. Previous radio-tracking data of some Superb Fairy-wren territories were also used. The shapes of the suburban territories were then used to randomly allocate 20 suburban sites of the same shape where Superb Fairy-wrens were absent (habitat without Fairy-wrens).

To investigate habitat characteristics of these three groups, 40 quadrats, each 2×2 m, were established within the approximate boundaries of each territory. From the intersection of lines drawn between the furthest four corners of the approximate territories, a central point was established. The position of quadrats from this central point were determined using bearings and distances selected at random. The quadrats were never placed in locations where Fairy-wrens had not been observed and were never >50 m from the central point. The presence of the following habitat variables within each quadrat was recorded:

- *Concrete/Road.* Driveways and paths as well as tarred and untarred roads.
- *House.*
- *Fences.*
- *Grass.* Categorized as either short when shorter than the height of the Fairy-wren (<10 cm), or long.
- *Herb.* Herbaceous layer <1.5 m in height.
- *Native shrub.* A native plant 1–4 m tall with trunk branched close to the ground.
- *Exotic shrub.* A plant introduced from outside Australia that measured 1–4 m tall with trunk branched close to the ground. Lantana was not included as an exotic shrub but was put in a category of its own.
- *Lantana.* *Lantana camara*, a dense exotic woody shrub that was prevalent at many sites, particularly the non-suburban sites.
- *Native tree.* Native plant >1 m in height with a trunk that did not branch near the ground.
- *Exotic tree.* A plant introduced from outside Australia that measured >1 m in height with a trunk that did not branch near the ground.

The composition of each of the above categories at each of the sites was represented as the percentage occurrence (in 40 quadrats) rather than percentage cover per quadrat.

Statistical analysis

Both univariate and multivariate methods were used to examine the habitat characteristics of non-suburban territories, suburban territories and habitat without Fairy-wrens. To determine if the overall structure of the vegetation differed or if floristic origin also played a role in Superb Fairy-wren habitat requirements, analyses compared 'all shrubs' (native + exotic + Lantana) and 'all trees' (native + exotic) and also native and exotic categories (with Lantana separate from exotic shrubs). Differences between each of the individual variables were determined using one-way analysis of variance (ANOVA) with *post hoc* Tukey–Kramer tests. Data were not normally distributed in all cases. The habitat variable 'house' was square-root transformed, whereas 'fence', 'short grass' and 'exotic shrubs' were $\log(x+1)$ transformed. Four habitat variables, 'long grass', 'herb', 'native shrubs' and 'Lantana' were not normally distributed regardless of any transformation. Therefore a Kruskal–Wallis test was conducted for each of these. The Kruskal–Wallis test is the non-parametric equivalent of a one-way ANOVA. Values are transformed into ranks to determine if there is no shift in the centre of the groupings. While non-parametric tests have a greater probability of making a Type 1 error, when data for these four

variables were viewed graphically the differences between habitat types were evident.

To determine the differences in overall structure between the three habitat types, non-metric multidimensional scaling using Bray–Curtis similarity indexes and a one-way single-factor analysis of similarity (ANOSIM) were performed. Non-metric multidimensional scaling graphically demonstrates the differences between all sites within the three habitat types while the ANOSIM tests the hypothesis that differences between sites across habitat types are greater than between sites within habitat types, using permutation–randomisation tests on the Bray–Curtis similarity indexes. The variables that contributed the most to up to 50% of the similarity between the habitats were calculated using the SIMPER function (Clarke and Gorley 2001).

The dataset was analysed on two levels using these multivariate techniques. The first looked at broad habitat structure whereby native and exotic shrubs were combined for shrubs (including Lantana) and trees. Second, to see whether floristics also influenced habitat selection, native and exotic origins were included as separate variables. As the data were not normal, $\log(x+1)$ transformations were also conducted for multivariate analyses with the PRIMER statistical package (version 6) (Clarke and Gorley 2001) used for calculations.

Results

Difference in vegetation between habitats

Analyses of individual habitat variables identified differences between habitats. Of the three anthropogenic variables (house, road and fence) only the proportion of houses showed a significant effect of habitat type ($F_{2,54} = 128.5$, $P < 0.001$). Suburban sites without Fairy-wrens had, on average, a much higher occurrence of houses than either the suburban sites with Fairy-wrens or, as would be expected, the non-suburban Fairy-wren sites (Fig. 1a). The percentage occurrence of short grass was lowest in non-suburban sites but similar in both suburban sites ($F_{2,54} = 10.3$, $P < 0.001$, Fig. 1b). The percentage occurrence of long grass was high in non-suburban sites, lower in suburban sites with Fairy-wrens and nearly zero in suburban sites without Fairy-wrens (Fig. 1c). While a Kruskal–Wallis test confirmed a significant difference between sites ($H_2 = 28.5$, $P < 0.001$), multiple comparisons could not identify where differences lay. A similar result was found for the herbaceous layer (Fig. 1d).

When the overall structure of the shrub layer and tree layer were considered, suburban sites without Fairy-wrens had the lowest percentage occurrence of both these layers (Fig. 1e,f). The percentage occurrence of the shrub layer was significantly less in the suburban sites without Fairy-wrens than both the suburban and non-suburban sites with Fairy-wrens ($F_{2,54} = 16.9$, $P = 0.000$, Fig. 1e). There was a smaller percentage occurrence of trees in suburban sites without Fairy-wrens compared with non-suburban sites, but no significant difference in occurrence of trees between suburban sites with Fairy-wrens and either of the other two habitats ($F_{2,54} = 3.8$, $P = 0.028$, Fig. 1f).

The floristic origin of shrubs and trees differed between habitats but did not show the predicted pattern. Despite having the highest proportion of shrubs overall, non-suburban Fairy-wren sites had fewer nativeshrubs (Fig. 1g; $H_2 = 17.8$, $P < 0.001$)

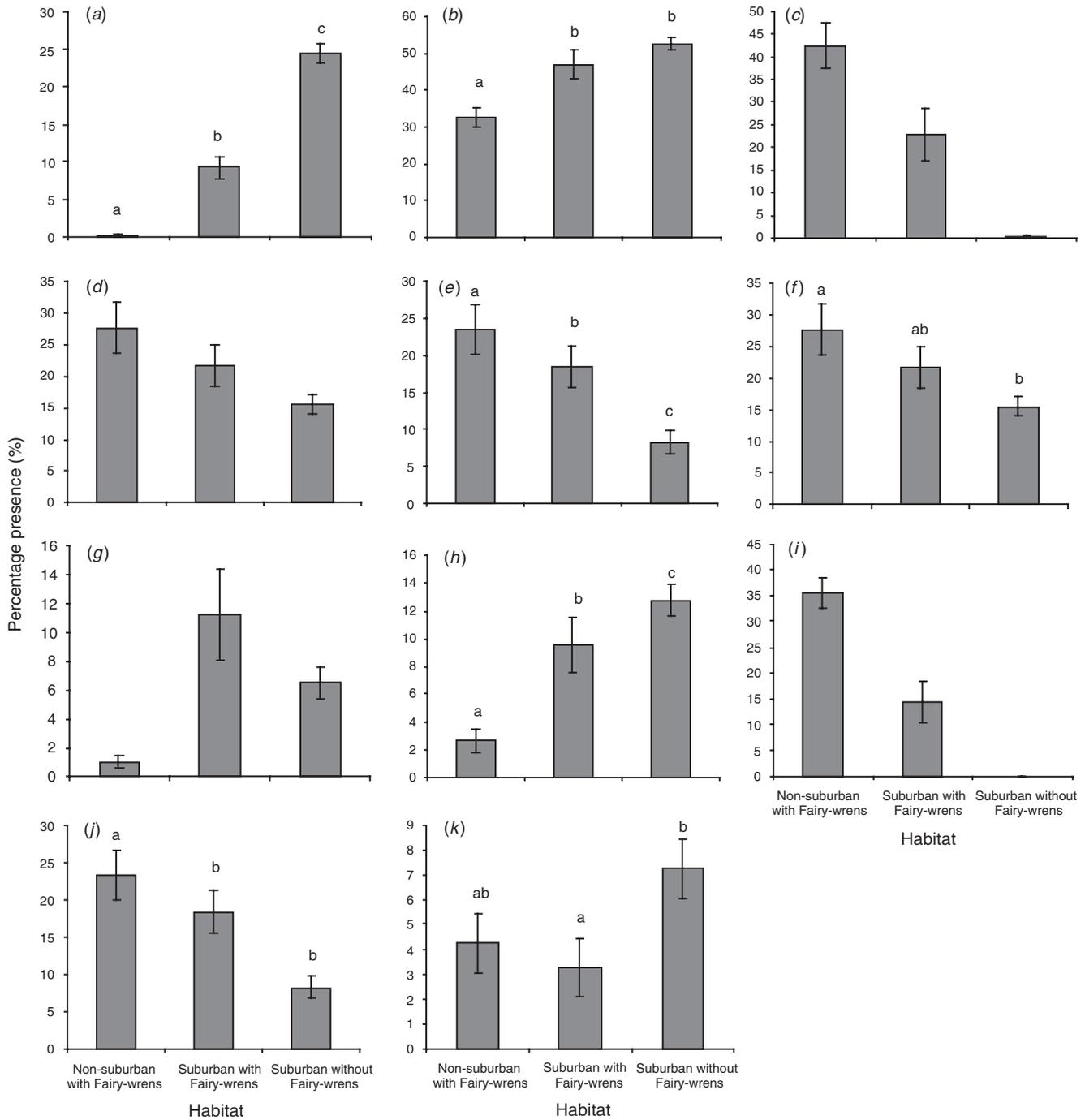


Fig. 1. Percentage presence of: (a) houses, (b) short grass, (c) long grass, (d) herbs, (e) all shrubs, (f) all trees, (g) native shrubs, (h) exotic shrubs, (i) Lantana, (j) native trees, and (k) exotic trees, in 40 quadrats in: non-suburban habitats with Superb Fairy-wrens, suburban habitats with Superb Fairy-wrens, and suburban habitats without Superb Fairy-wrens. Letters above the bars denote where habitats are statistically different from each other, though for long grass, herbs, native shrubs and Lantana non-parametric analyses meant habitat differences could not be distinguished. Error bars show standard deviation.

and fewer exotic shrubs excluding Lantana (Fig. 1h; $F_{2,54} = 13.3$, $P < 0.001$), though the Kruskal–Wallis *post hoc* analysis could not detect in which habitats the differences between native shrubs was significant. Native shrubs were, however, much more prevalent in suburban habitats with Fairy-wrens than in either of the other two habitats. The prevalence of Lantana within non-

suburban sites was contributing substantially to the overall high proportions of shrubs recorded here (Fig. 2a). Lantana was therefore substituting for native shrubs in these non-suburban areas. Lantana was found in an average of 91.9% of the quadrats in which some sort of shrubs were recorded in non-suburban habitats, 41.7% of suburban quadrats in which there were

shrubs and was totally absent from suburban sites without Fairy-wrens. The availability of Lantana was therefore significantly different between sites ($H_2 = 37.6$, $P < 0.001$). While the location of the significant difference could not be detected using the Kruskal–Wallis analysis, non-suburban habitats had more than twice the percentage occurrence of lantana than suburban sites with Fairy-wrens (Fig. 1i).

In suburban sites with Fairy-wrens, percentage occurrence of native shrubs in quadrats was slightly greater than other exotic shrubs (not including Lantana) (total occurrence 11.3% and 9.5% respectively) while in suburban sites without Fairy-wrens, the reverse was seen (6.5% and 12.8% respectively) (Fig. 2a). Native trees were much more prevalent than exotic trees in Fairy-wren habitats (total 18.4% and 3.3% of quadrats) (Fig. 2b). In suburban habitats where Fairy-wrens were absent there was a more even mix of native and exotic trees, with native trees present in 8.3% of quadrats and exotic trees in 7.3%. Non-suburban sites had a significantly lower availability of native trees than either suburban habitat with no difference between the two suburban habitats ($F_{2,54} = 8.9$, $P < 0.001$; Fig. 1j). Exotic trees were more

prevalent in the suburban sites without Fairy-wrens than the suburban sites with Fairy-wrens but non-suburban sites were not significantly different from either ($F_{2,54} = 3.2$, $P = 0.049$; Fig. 1k).

What characteristics distinguish differences among habitats? – Multivariate analyses

Overall structure

There was a high degree of variation between the non-suburban and suburban habitats, with the overall structure of the vegetation being significantly different between the three habitats (Global $r = 0.26$, $P = 0.001$; Fig. 3a). All groups of sites showed significant clustering although suburban habitats with Fairy-wrens had the most variation between sites (average similarity = 76.7%). This was contrary to our prediction that there would be the least amount of variation in suburban Fairy-wren territories. Both the non-suburban Fairy-wren sites and the suburban sites without Fairy-wrens had a greater amount of similarity within their habitat types (average similarity non-

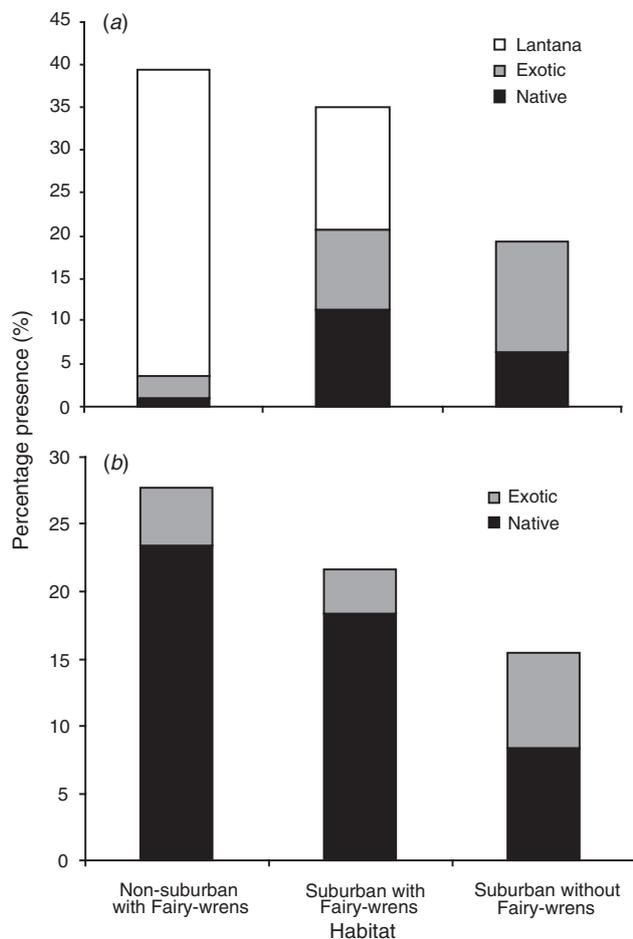


Fig. 2. The percentage occurrence of introduced and native vegetation in: (a) shrubs (native, exotic and Lantana) and (b) trees (native and exotic), sampled in 40 quadrats in: non-suburban habitats with Superb Fairy-wrens, suburban habitats with Superb Fairy-wrens and suburban habitats without Superb Fairy-wrens.

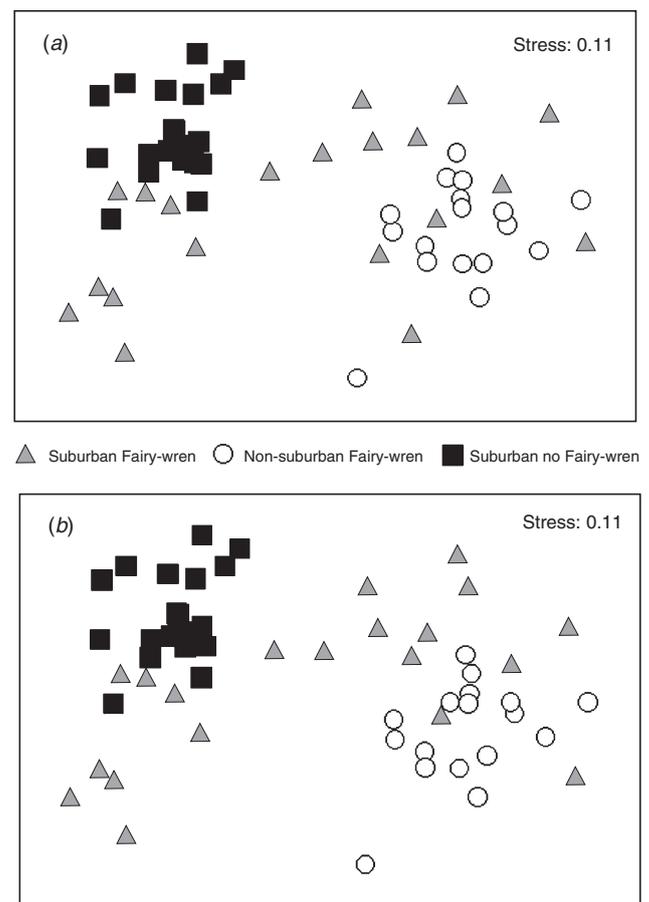


Fig. 3. Ordination (non-parametric multi-dimensional scaling, nMDS) of habitat variables in suburban Fairy-wren, non-suburban Fairy-wren and suburban no Fairy-wren habitats (stress = 0.11). Habitat variables are based on: (a) structure of the vegetation and (b) floristic origin. Points positioned more closely together to each other are more similar in the composition of their human structures and vegetation.

suburban sites = 82.8%; suburban sites without Fairy-wrens = 81.4%).

Multivariate analyses showed that the availability of a high occurrence of short grass (contributing 23.0% to average similarity) and shrubs (19.9%) as well as moderate percentage occurrence of trees (15.9%) in Fairy-wren territories was most important in characterising suburban Fairy-wren habitats. In contrast, non-suburban sites were characterised by having the greatest percentage occurrence of shrubs (contributing 20.7% to average similarity), only a small percentage occurrence of short grass (19.3%) and a high percentage occurrence of trees (16.9%). Suburban habitats without Fairy-wrens were distinguished by a high percentage occurrence of short grass, road and few trees (contributing 23.0%, 19.9% and 15.9% to the average similarity values).

Floristic origin

When floristic origin of plants was included in the models, the clustered pattern of sites was still evident, suggesting that structure was more important than floristic origin in distinguishing between habitats (Global $r=0.59$, $P=0.001$; Fig. 3*b*). Variability between suburban sites with Fairy-wrens and the other two habitat types was still high (average similarity = 66.7%). Suburban sites without Fairy-wrens and the non-suburban sites again had less variability (average similarity suburban without Fairy-wrens = 84.5%; non-suburban = 82.3%).

Habitats also differed in how the structure of the vegetation was influenced by floristic origin. The main distinguishing features of suburban sites with Fairy-wrens remained short grass (contribution to average similarity = 23.6%) but when floristic origin was considered, it was the occurrence of native trees (15.2%) (as opposed to trees overall) and a low percentage occurrence of road (13.5%) that also contributed to the similarity between sites. When floristic origin was considered, shrubs did not become a distinguishing feature of suburban Fairy-wren habitats. Non-suburban Fairy-wren habitats were characterised by the dominance of Lantana (17.5%), rather than shrubs overall, along with a low proportion of short grass (16.9%) and a high percentage occurrence of long grass (16.0%). The presence of a large percentage of trees did not contribute to the average similarity of non-suburban sites when floristic origin was considered. Floristic origin did not change the features that contributed most to the average similarity of suburban sites without Fairy-wrens. These sites were again typified by an abundance of short grass (21.8%) and road (18.2%). Therefore, when floristic origin of the shrubs and trees are considered, we see that Lantana became an important component in non-suburban sites and native trees became distinctive of suburban sites with Fairy-wrens.

Discussion

Determining habitat requirements for a species is vital for effective conservation, especially when the loss of habitat may be causing decline of the species. Superb Fairy-wrens show clear vegetation preferences in suburban and non-suburban habitats, with both structure and floristic origin influencing their occurrence. We found similarities between non-suburban and

suburban sites with Fairy-wrens. In both habitats they were found in sites with an extensive shrub and tree layer, though there was more short grass in the suburban Fairy-wren habitats and a greater proportion of long grass in the non-suburban habitats. In suburban habitats, Fairy-wrens showed a preference for native shrubs but Lantana was the predominant shrub species in non-suburban habitats. In both cases, native trees were a preferred habitat feature.

Superb Fairy-wrens were not found in suburban habitats that had little vegetation, with floristic origin also influencing their avoidance of these habitats. These sites were dominated by human structures, with very few shrubs and trees, and what little vegetation was available was largely exotic. The large proportion of short grass available is a habitat feature that Superb Fairy-wrens like, but its availability must be in conjunction with a suitable native or Lantana shrub layer. It appears that this shrub layer is an important determinant of the presence of Superb Fairy-wrens in suburban locations, but Lantana has replaced native shrubs in non-suburban locations. Unlike our predictions, the greatest variability was actually seen in their suburban territories, suggesting that suburban habitats have greater structural and floristic diversity than non-suburban habitats and these birds are able to adapt to these different vegetation parameters.

Vegetation structure is important for habitat selection by birds in urban areas (Lancaster and Rees 1979; Green 1984; Mills *et al.* 1989; Sewell and Catterall 1998; Fernández-Juricic *et al.* 2004; White *et al.* 2005; Sandström *et al.* 2006). A high degree of habitat complexity, which involves well-developed ground, shrub and tree layers, increases the availability of foraging, shelter and nesting locations for a range of species (Marzluff and Ewing 2001; White *et al.* 2005). However, it is the understorey layer in particular that is usually less prevalent in suburban locations (Savard and Falls 1981; DeGraaf and Wentworth 1986; Warkentin and James 1988; this study). White *et al.* (2005) found a loss of the insectivorous cover-dependent guild, which includes the Superb Fairy-wren, in the transition from native streetscapes to exotic and newly developed streetscapes was linked to the loss of suitable shelter locations. Research into the behaviour of Superb Fairy-wrens in suburban habitats has shown that whereas they use a full spectrum of vegetation structures from the ground through to the canopy, most time is spent in shrubs, which they also use for nesting (Rowley and Russell 1997). The loss of shrubs in urban areas could therefore expose these birds to increased nest predation as well as a lack of shelter locations.

In traditional woodland habitats, such as in Brigalow (*Acacia harpophylla*) and Wandoo (*Eucalyptus wandoo*) woodlands, many species of Fairy-wren (*Malurus*) are associated with a high density of understorey shrubs (Brooker and Rowley 1995; Chan and Augusteyn 2003). Lantana and other exotic brambles have also been shown to provide important (Nias 1984; Ligon *et al.* 1991; Nias and Ford 1992) so it is unsurprising in an urban setting that a similar habitat element is important. Further, a positive association between Fairy-wrens and native vegetation was found in comparisons within urban areas, similar to studies elsewhere (Jones 1983; Green 1984; Catterall *et al.* 1989; Mills *et al.* 1989; Day 1995; Sewell and Catterall 1998; Parsons *et al.* 2006). In the present study, native

shrubs were more prevalent in suburban sites supporting Fairy-wren territories than in non-suburban Fairy-wren territories and shrub occurrence was lower in suburban sites without Fairy-wrens, where the proportion of exotic shrubs available was greater, than in other habitats. It has previously been suggested that native birds may use exotic vegetation that is structurally similar to native vegetation in the absence of native vegetation (Emlen 1974; Mills *et al.* 1989). Only Lantana appeared to be a favoured exotic in our study.

Structure is not the only aspect of native vegetation that may influence the vegetation preference of an insectivorous bird. Native vegetation has been shown to support more invertebrate life than exotic shrubs and trees, and consequently, foraging birds have also shown a preference for native over exotic vegetation (Green 1984; 1986). However, the effect of urbanisation on invertebrate communities is not well studied relative to other habitats. Urbanisation and habitat fragmentation may alter interactions between invertebrates and other organisms and therefore interfere with the dynamics of food webs (Didham *et al.* 1996; Gunnarsson and Hake 1999). This may therefore explain the loss of many insectivorous bird species from Australian urban habitats.

Both suburban and non-suburban Superb Fairy-wrens showed a high affinity for the exotic noxious weed, Lantana. It invades the edges of woodland and forest habitat and forms dense thickets, usually replacing the entire understorey. The value of Lantana to a range of bird species both as a foraging and shelter location has previously been demonstrated (Crome *et al.* 1994). In the present study, as Superb Fairy-wrens forage largely on, or very close to, the ground (Tidemann 1983; Recher *et al.* 1985; Ford *et al.* 1986; Cale 1994), it is likely that Lantana is providing the birds with a dense and protective understorey layer rather than a foraging site. The use of Lantana by foraging insectivorous birds has not been investigated previously. In suburban locations, the presence of Lantana is therefore likely to have a substantial influence on the ability of Superb Fairy-wrens to occupy a site. Where absent from a site, the availability of native shrubs nearby is necessary in order to support this species. This also has implications for the removal of Lantana, with replacement with similarly dense native equivalents necessary for use by Superb Fairy-wrens.

Superb Fairy-wrens are thus likely to be limited in their distribution in urban environments by a lack of suitable habitat. While there is some variability in habitat selection in Fairy-wrens in suburban areas, in the present study Superb Fairy-wrens were largely restricted to those suburban areas with a dense shrub layer (of either native plants or Lantana) and surrounding grassy areas. If the characteristics of suburban habitats that this species requires are not commonly found throughout the urban matrix then we would expect that the distribution of Superb Fairy-wrens would be limited.

Increasing isolation of territories in urban areas is likely to have a significant effect on the population structure and breeding biology of this species. High rates of extra-pair paternity in continuous vegetation (Mulder *et al.* 1994), with males displaying to neighbouring females throughout the day and females leaving their territories before dawn to copulate with other males (Double and Cockburn 2000), occurs where territories abut. Where territories are isolated, such as in these urban habitats, birds are likely to be restricted in their movement,

resulting in an increase in monogamy. In addition, juvenile females are expelled from their territories to establish new ones once they are independent of adult birds. In an urban matrix that is largely unsuitable, these birds are likely to be lost from the population and new territories would rarely be established. In the present study, searches of the areas surrounding the territories of suburban Superb Fairy-wren (approximate radius of 1 km) usually failed to find any neighbouring Superb Fairy-wren territories. There was only one instance in which another territory was located near a surveyed territory, and a neighbouring male was observed displaying to the adult female. The planting of native shrubs and trees in suburban habitats surrounding existing Superb Fairy-wren territories could increase connectivity between territories and potentially allow the spread of Superb Fairy-wrens in urban areas through the establishment of new territories.

References

- Bass, D. A. (1995). The contribution of introduced fruits to the winter diet of Pied Currawongs in Armidale, NSW. *Corella* **19**, 127–132.
- Beissinger, S. R., and Osborne, D. A. (1982). Effects of urbanization on avian community organization. *Condor* **84**, 75–83. doi: 10.2307/1367825
- Berry, L. (2001). Edge effects on the distribution and abundance of birds in a southern Victorian forest. *Wildlife Research* **28**, 239–245. doi: 10.1071/WR00057
- Bhuller, S., and Majer, J. D. (2000). Arthropods on street trees: a food resource for wildlife. *Pacific Conservation Biology* **6**, 171–173.
- Blair, R. B. (1996). Land use and avian species diversity along an urban gradient. *Ecological Applications* **6**, 506–519. doi: 10.2307/2269387
- Brooker, M., and Rowley, I. (1995). The significance of territory size and quality in the mating strategy of the splendid Fairy-wren. *Journal of Animal Ecology* **64**, 614–627. doi: 10.2307/5804
- Cale, P. (1994). The effect of landscape fragmentation on the bird community of the Kellerberrin district of Western Australia's wheat belt. Ph.D. Thesis, University of Western Australia, Perth.
- Case, T. J. (1996). Global patterns in the establishment and distribution of exotic birds. *Biological Conservation* **78**, 69–96. doi: 10.1016/0006-3207(96)00019-5
- Catterall, C. P. (2004). Birds, garden plants and suburban bushlots: where good intentions meet unexpected outcomes. In 'Urban Wildlife: More Than Meets the Eye'. (Eds D. Lunney and S. Burgin.) pp. 21–31. (Royal Zoological Society of New South Wales: Sydney.)
- Catterall, C. P., Green, R. J., and Jones, D. N. (1989). Occurrences of birds in relation to plants in a subtropical city. *Australian Wildlife Research* **16**, 289–305. doi: 10.1071/WR9890289
- Catterall, C. P., Green, R. J., and Jones, D. N. (1991). Habitat use by birds across a forest-scrub interface in Brisbane: implications for corridors. In 'Nature Conservation 2: The Role of Corridors'. (Eds D. A. Saunders and R. H. Hobbs.) pp. 247–258. (Surrey Beatty: Sydney.)
- Chan, K., and Augusteyn, J. D. (2003). Relationship between bird-unit size and territory quality in three species of fairy-wrens (*Malurus* sp.) with overlapping territories. *Ecological Research* **18**, 73–80. doi: 10.1046/j.1440-1703.2003.00534.x
- Clarke, K. R., and Gorley, R. N. (2000). PRIMER v5: User manual/tutorial. (PRIMER-E Ltd.: Plymouth, UK.)
- Clergeau, P., Croci, S., Jokimäki, J., Kaisanlahti-Jokimäki, M., and Dinetti, M. (2006). Avifauna homogenisation by urbanisation: analysis at different European latitudes. *Biological Conservation* **127**, 336–344. doi: 10.1016/j.biocon.2005.06.035
- Crome, F., Isaacs, J., and Moore, L. (1994). The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands. *Pacific Conservation Biology* **1**, 328–343.

- Davis, A. M., and Glick, T. M. (1978). Urban ecosystems and island biogeography. *Environmental Conservation* **5**, 299–304.
- Day, T. D. (1995). Bird species composition and abundance in relation to native plants in urban gardens, Hamilton, New Zealand. *Notornis* **42**, 172–186.
- DeGraaf, R. M., and Wentworth, J. M. (1986). Avian guild structure and habitat associations in suburban bird communities. *Urban Ecology* **9**, 399–412. doi: 10.1016/0304-4009(86)90012-4
- Didham, R. K., Ghazoul, J., Stork, N. E., and Davies, A. J. (1996). Insects in fragmented forests: a functional approach. *Trends in Ecology and Evolution* **11**, 255–259. doi: 10.1016/0169-5347(96)20047-3
- Double, M., and Cockburn, A. (2000). Pre-dawn infidelity: females control extra-pair mating in superb Fairy-wrens. *Proceedings of the Royal Society of London B* **267**, 465–470. doi: 10.1098/rspb.2000.1023
- Emlen, J. T. (1974). An urban bird community in Tucson, Arizona: derivation, structure, regulation. *Condor* **76**, 184–197. doi: 10.2307/1366729
- Fernández-Juricic, E. (2000). Bird community composition patterns in urban parks of Madrid: the role of age, size and isolation. *Ecological Research* **15**, 373–383. doi: 10.1046/j.1440-1703.2000.00358.x
- Fernández-Juricic, E., Erichsen, J. T., and Kacelnik, A. (2004). Visual perception and social foraging in birds. *Trends in Ecology and Evolution* **19**, 25–31. doi: 10.1016/j.tree.2003.10.003
- Fernández-Juricic, J., and Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. *Biodiversity and Conservation* **10**, 2023–2043. doi: 10.1023/A:1013133308987
- Ford, H. A., Noske, S., and Bridges, I. (1986). Foraging of birds in eucalypt woodlands in north-eastern New South Wales. *Emu* **86**, 168–179.
- Garshelis, D. N. (2000). Delusions in habitat evaluation: measuring use, selection, and importance. In 'Research Techniques in Animal Ecology'. (Eds D. N. Garshelis, L. Boitani and T. K. Fuller.) pp. 111–164. (Columbia University Press: New York.)
- Green, D. M. (1986). Native and exotic birds in the suburban habitat. In 'The Dynamic Partnership: Birds and Plants in Southern Australia'. (Eds H. A. Ford and D. C. Paton.) pp. 130–139. (The Flora and Fauna of South Australia Handbooks Committee: Adelaide, South Australia.)
- Green, D. M., and Baker, M. G. (2002). Urbanization impacts on habitat and bird communities in a Sonoran desert ecosystem. *Landscape and Urban Planning* **968**, 1–15.
- Green, R. J. (1984). Native and exotic birds in a suburban habitat. *Australian Wildlife Research* **11**, 181–190. doi: 10.1071/WR9840181
- Green, R. J., Catterall, C. P., and Jones, D. N. (1989). Foraging and other behaviour of birds in subtropical and temperate suburban habitats. *Emu* **89**, 216–222.
- Gunnarsson, B., and Hake, M. (1999). Bird predation affects canopy-living arthropods in city parks. *Canadian Journal of Zoology* **77**, 1419–1428. doi: 10.1139/cjz-77-9-1419
- Guthrie, D. A. (1974). Suburban bird populations in Southern California. *American Midland Naturalist* **92**, 461–466. doi: 10.2307/2424310
- Hansson, L., Fahrig, L., and Merriam, G. (1995). 'Mosaic Landscapes and Ecological Processes.' (Chapman and Hall: London.)
- Hohtola, E. (1978). Differential changes in bird community structure with urbanisation: a study in central Finland. *Ornis Scandinavica* **9**, 94–100. doi: 10.2307/3676143
- Hooper, R. G., Smith, E. F., Crawford, H. S., McGinnes, B. S., and Walker, V. J. (1975). Nesting bird populations in a new town. *Wildlife Society Bulletin* **3**, 111–118.
- Huhtala, H., and Jarvinen, O. (1977). Quantitative composition of the urban bird community in Tornio, Northern Finland. *Bird Study* **42**, 179–185.
- Jokimäki, J. (1999). Occurrence of breeding bird species in urban parks: effects of park structure and broad-scale variables. *Urban Ecosystems* **3**, 21–34. doi: 10.1023/A:1009505418327
- Jokimäki, J., and Huhta, E. (1996). Effects of landscape matrix and habitat structure on a bird community in northern Finland: a multi-scale approach. *Ornis Fennica* **73**, 97–113.
- Jokimäki, J., and Huhta, E. (2000). Artificial nest predation and abundance of birds along an urban gradient. *Condor* **102**, 838–847. doi: 10.1650/0010-5422(2000)102[0838:ANPAAO]2.0.CO;2
- Jokimäki, J., Suhonen, J., Inki, K., and Jokinen, S. (1996). Biogeographical comparison of winter bird assemblages in urban environments in Finland. *Journal of Biogeography* **23**, 379–386. doi: 10.1046/j.1365-2699.1996.00033.x
- Jones, D. N. (1983). The suburban bird community of Townsville, a tropical city. *Emu* **83**, 12–18.
- Lancaster, R. K., and Rees, W. E. (1979). Bird communities and the structure of urban habitats. *Canadian Journal of Zoology* **57**, 2358–2368. doi: 10.1139/z79-307
- Ligon, J. D., Ligon, S. H., and Ford, H. A. (1991). An experimental study of the bases of male philopatry in the cooperatively breeding superb Fairy-wren *Malurus cyaneus*. *Ethology* **87**, 134–137.
- Luck, G. W. (2002). The habitat requirements of the rufous treecreeper (*Climacteris rufa*). 1. Preferential habitat use demonstrated at multiple spatial scales. *Biological Conservation* **105**, 383–394. doi: 10.1016/S0006-3207(01)00222-1
- Maguire, G. S. (2006). Territory quality, survival and reproductive success in southern emu-wrens *Stipiturus malachurus*. *Journal of Avian Biology* **37**, 579–593. doi: 10.1111/j.2006.0908-8857.03757.x
- Marzluff, J. M., and Ewing, K. (2001). Restoration of fragmented landscapes: a general framework and specific recommendations for urbanizing landscapes. *Restoration Ecology* **9**, 280–292. doi: 10.1046/j.1526-100x.2001.009003280.x
- Mills, G. S., Dunning, D. B. Jr, and Bates, J. M. (1989). Effects of urbanization on breeding bird community structure in southwestern desert habitats. *Condor* **91**, 416–428. doi: 10.2307/1368320
- Mörtberg, U. M. (2001). Resident bird species in urban forest remnants; landscape and habitat perspectives. *Landscape Ecology* **16**, 193–203. doi: 10.1023/A:1011190902041
- Mulder, R. A., Dunn, P. O., Cockburn, A., Lazenby-Cohen, K. A., and Howell, M. J. (1994). Helpers liberate female Fairy-wrens from constraints on extra-pair mate choice. *Proceedings of the Royal Society of London. Series B. Biological Sciences* **255**, 223–229. doi: 10.1098/rspb.1994.0032
- Munyenyembe, F., Harris, J., and Hone, J. (1989). Determinants of bird populations in an urban area. *Austral Ecology* **14**, 549–557. doi: 10.1111/j.1442-9993.1989.tb01460.x
- Nias, R. C. (1984). Territory quality and group size in the Superb Fairy-wren *Malurus cyaneus*. *Emu* **84**, 178–180.
- Nias, R. C., and Ford, H. A. (1992). The influence of group-size and habitat on reproductive success in the Superb Fairy-wren *Malurus cyaneus*. *Emu* **192**, 238–243.
- Palomino, D., and Carrascal, L. M. (2006). Urban influence on birds at a regional scale: a case study with the avifauna of northern Madrid province. *Landscape and Urban Planning* **77**, 276–290. doi: 10.1016/j.landurbplan.2005.04.003
- Parsons, H., French, K., and Major, R. M. (2003). The influence of remnant bushland on the composition of suburban bird assemblages in Australia. *Landscape and Urban Planning* **66**, 43–56. doi: 10.1016/S0169-2046(03)00094-X
- Parsons, H., Major, R. M., and French, K. (2006). Species interactions and habitat associations of birds inhabiting urban areas of Sydney, Australia. *Austral Ecology* **31**, 217–227. doi: 10.1111/j.1442-9993.2006.01584.x
- Recher, H. F., Holmes, R. T., Schulz, M., Shields, J., and Kavanagh, R. (1985). Foraging patterns of birds in eucalypt forest and woodland on the tablelands of south-eastern Australia. *Austral Ecology* **10**, 399–419. doi: 10.1111/j.1442-9993.1985.tb00902.x
- Rosenberg, K. V., Terrill, S. B., and Rosenberg, G. H. (1987). Value of suburban habitats to desert riparian birds. *Wilson Bulletin* **99**, 642–654.
- Rowley, I., and Russell, E. (1997). 'Fairy-wrens and Grasswrens: Maluridae.' (Oxford University Press: Oxford, UK.)

- Sandström, U. G., Angelstam, P., and Mikusinski, G. (2006). Ecological diversity of birds in relation to the structure of urban green space. *Landscape and Urban Planning* **77**, 39–53. doi: 10.1016/j.landurbplan.2005.01.004
- Savard, J. P. L., and Falls, J. B. (1981). Influence of habitat structure on the nesting height of birds in urban areas. *Canadian Journal of Zoology* **59**, 924–932.
- Savard, J. P. L., Clergeau, P., and Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning* **48**, 131–142. doi: 10.1016/S0169-2046(00)00037-2
- Sewell, S. R., and Catterall, C. P. (1998). Bushland modification and styles of urban development: their effects on birds in south-east Queensland. *Wildlife Research* **25**, 41–63. doi: 10.1071/WR96078
- Tidemann, S. C. (1983). The behavioural ecology of three co-existing Fairy-wrens (Maluridae: *Malurus*). Ph.D. Thesis, Australian National University, Canberra.
- van Horne, B. (1983). Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* **47**, 893–901. doi: 10.2307/3808148
- Veerman, P. A. (2002). 'Canberra Birds: A Report on the First 18 years of the Garden Bird Survey.' (Philip A. Veerman: Canberra.)
- Walcott, C. F. (1974). Changes in bird life in Cambridge, Massachusetts from 1860 to 1964. *Auk* **91**, 151–160.
- Warkentin, I. G., and James, P. C. (1988). Nest-site selection by urban merlins. *Condor* **90**, 734–738. doi: 10.2307/1368372
- White, J. G., Antos, M. J., Fitzsimons, J. A., and Palmer, G. C. (2005). Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. *Landscape and Urban Planning* **71**, 123–135. doi: 10.1016/j.landurbplan.2004.02.006
- Wiens, J. A. (1985). Habitat selection in variable environments: shrubsteppe birds. In 'Habitat selection in birds'. (Ed. M. L. Cody.) pp. 227–251. (Academic Press, Inc.: San Diego, CA.)
- With, K. A., Gardner, R. H., and Turner, M. G. (1997). Landscape connectivity and population distributions in heterogeneous environments. *Oikos* **78**, 151–169. doi: 10.2307/3545811

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