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Research Paper

Understanding of avian assemblage change within anthropogenic environments using citizen science data

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ABSTRACT

Anthropogenic land use is a major driver of biodiversity loss, with different land use activities having a range of impacts on native communities. These myriad impacts make it difficult to identify the key drivers of species declines, especially across heterogenous anthropogenic environments. Our study aims to identify whether the species and traits being lost in disturbed environments differ across a land-use intensity gradient, in order to prioritise management effort in Greater Brisbane, Australia. We applied List Length Analysis (LLA) to standardise citizen-collected avian records, and model the change in prevalence for 182 bird species within urban, rural and forested environments. We then tested whether understorey-nesting, ground-nesting, insectivorous or small-bodied functional groups were significantly declining in prevalence within the entire avian assemblage. We found a greater probability of decline for small-bodied and understorey-nesting species in urban environments, lending support to established findings that, in urban environments of Greater Brisbane, competition with larger territorial birds and understorey loss are impacting communities. Our study also highlighted that the species declining and increasing in prevalence differed across the land use intensity gradient. Management approaches should therefore be targeted to mitigate the distinct impacts associated with particular land uses. In Greater Brisbane, managers should focus on maintaining urban understories and monitoring overabundant avian competitors. Where funds are limited, LLA represents a useful tool to harness non-standardised data, to guide early management and monitoring effort. Such tools equip managers to conserve biodiversity in anthropogenic environments.

1. Introduction

Population growth and development have led to rapid and ongoing urbanisation, transforming natural communities (Grimm et al., 2008; McKinney, 2008). Habitat clearing, introduction of non-native species, fragmentation, and various forms of pollution (sound, air, light, soil and water) interact to shape biotic communities, and have resulted in reduced assemblages of the regional species pool within cities (Aronson et al., 2014; Blair, 1996; Marzluff, 2001; Sol, Gonzalez-Lagos, Moreira, Maspons, & Lapiedra, 2014). These impacts however, are variable across the development gradient, thus resulting in distinct biotic communities forming within heterogeneous anthropogenic environments (Beninde, Veith, & Hochkirch, 2015; Blair, 1996; McKinney, 2008). Effective monitoring and analysis is therefore critical in order to a) differentiate between aspects of anthropogenic development and their associated impacts on biotic communities and b) manage those drivers having the greatest ecological impact (Aronson et al., 2014; Blair, 1996; Evans, Ryder, Reitsma, Hurlbert, & Marra, 2015; Lepczyk et al., 2017; Marzluff, 2016; Sol et al., 2014).

To distinguish between the multiple effects of land use change, studies both regionally and internationally have been examining the impacts of land use intensification on specific taxonomic and functional groups (Aronson et al., 2014; Chace & Walsh, 2006; Faeth, Bang, & Saari, 2011; Marzluff, 2016). An increase in the availability and volume of observational data on birds, has made trait analysis especially viable for avian taxonomic groups (Aronson et al., 2014; Chace & Walsh, 2006; Marzluff, 2016). A number of studies have identified that, in disturbed environments, birds with particular functional traits are either disappearing or beginning to dominate (Chace & Walsh, 2006; Croci, Butet, & Clergeau, 2008; Faeth et al., 2011; Kark, Iwaniuk, Schalimtzek, & Banker, 2007; Lepczyk et al., 2008; Lepczyk et al., 2017; van Rensburg, Peacock, & Robertson, 2009). In particular, a small

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subset of traits have demonstrated greater success in urban environments; with sociable, sedentary, long-lived, broadly-distributed, resource-flexible, phenotypically-plastic and species with small clutch-sizes having emerged as successful urban-exploiters (Aronson et al., 2014; Croci et al., 2008; Kark et al., 2007; Lepczyk et al., 2017; Marzluff, 2016). While these outcomes may suggest a homogenisation of species across cities, global-scale analyses have underscored that urban environments remain dominated by native species from the regional species pool (Aronson et al., 2014). Thus, understanding the processes occurring at a regional scale is important to manage biodiversity loss within anthropogenic environments (Aronson et al., 2014; Croci et al., 2008; Evans, Newson, & Gaston, 2009; Evans et al., 2015; Marzluff, 2016).

Within Australia, a few traits have repeatedly emerged as declining in disturbed environments. Understorey and ground-nesting traits are sensitive to development, due to these species' reliance on complex understoreys, usually the first vegetative layer cleared for development (Shanahan, Possingham, & Martin, 2011). With Australia's long history of co-evolution between Australian flora and invertebrates, the replacement of native understories by non-native flora results in reduced levels of insect diversity and abundance (Murray et al., 2007; White, Antos, Fitzsimons, & Palmer, 2005). Reductions in specialised invertebrates in turn, have placed resource-limitation pressure on insectivorous functional groups (McKinney, 2008). Small-bodied species have also been disproportionately impacted by habitat fragmentation. Compared to large-bodied birds, small birds are exposed to greater risk and energy costs crossing transformed areas (Shanahan et al., 2011). In addition, where there is a loss in low vegetative cover, small-bodied species, along with understorey- and ground-nesters, are more vulnerable to exclusion by larger aggressive competitors (Catterall, 2004; Kath, Maron, & Dunn, 2009). Loss of vegetative complexity also increases avian exposure to invasive mesopredators such as cats and foxes in Australia (Major, Christie, & Gowing, 2001; Olsen, 2008; Sewell & Catterall, 1998; Shanahan et al., 2011). Foxes in particular prefer the lower-levels of disturbance found in rural environments for hunting, compounding the impacts of habitat clearing in these environments (Saunders, Coman, Kinnear, & Braysher, 1995).

Whilst such insights underline the myriad impacts associated with anthropogenic activity, it remains difficult to prioritise management of these threatening processes within heterogeneous anthropogenic environments. Managers must consider controlling predators and overabundant competitors, improving landscape connectivity, mitigating pollution and restoring habitat; all with diminishing conservation funds (van Dijk, Mount, Gibbons, Vardon, & Canadell, 2014). Our study aims to prioritise management effort by identifying which functional traits are being lost across an anthropogenic landscape gradient in Greater Brisbane, Australia. We use time-series data for 182 species (see Table S1 in Supporting Information), to determine whether species and threatened functional groups are being equally affected in urban, rural and forested land. We test for changes in understorey-nesting, insectivorous, ground-nesting and small-bodied functional groups, all of which have repeatedly emerged as vulnerable in Australia (Catterall, 2004; Kath et al., 2009; Major & Parsons, 2010; Shanahan et al., 2011; Szabo, Vesk, Baxter, & Possingham, 2010).

We hypothesise that the species which exhibit the greatest decline and increase in prevalence will differ across the land use gradient (H1), and that different functional groups will decline in prevalence at each land use intensity (H2). Specifically, and based on the literature for Greater Brisbane, we predict that:

- in forested environments, where anthropogenic disturbance is lowest, there will be no detectable reduction in prevalence for any functional group (H3),
- in rural environments, where predation pressure is high (Saunders et al., 1995) there will be a reduction in the ground-nesting functional group (H4) and
- in urban environments, where there are a range of pressures and a high level of disturbance, all four functional groups will decline (H5).

Through gaining an understanding of which functional groups are being lost within each land use, we will be able to highlight where management effort should be allocated.

2. Methods

2.1. Study site

In order to test our research hypotheses, we evaluated bird assemblages across Greater Brisbane, Australia. The Greater Brisbane region has a diverse vegetative community, including eucalypt woodlands, wet and dry rainforest, melaleuca and mangrove forests. Brisbane is one of Australia's most biologically diverse State capitals (Catterall & Kingston, 1993; Catterall, Cousin, Piper, & Johnson, 2010). However, over two thirds of Brisbane's native vegetation has disappeared, partly due to sprawling suburban development (Coleman, 2016). Brisbane is now one of the fastest growing cities in Australia, with a 25% growth in human population from 2001 to 2011 (ABS, 2011). Given the regions' biological importance and extensive land transformation, the Greater Brisbane region is an ideal study area to examine the extent to which avian functional groups are being threatened by human development.

We chose to classify Greater Brisbane into three levels of land use intensity. To accurately classify the region we used landsat-image derived vegetation maps created by Lyons, Phinn, and Roelfsema (2012). These maps, covering an area of 14,600 km^2, classified South-East Queensland into 11 land cover types, are high-resolution (25–30 m^2) and have a calculated accuracy of at least 80% (Lyons et al., 2012). The entire record of maps span from 1972 to 2010. However, imagery was not available for every year. Thus, we selected the largest series of continuous annual maps, ranging from 1999 to 2008, for our land use classification.

We combined the 11 original land cover classifications into three land use intensities, to represent a gradient of urban activity (Fig. 1, Fig. S2 & Table S2). Urban (high intensity) land had a high to moderate density of human settlement, rural (moderate intensity) land had low canopy cover, but also sparse human settlement, and forested (low intensity) land had high to complete vegetative cover (see Lyons et al., 2012 in conjunction with Table S2 for further detail). Although these maps would have permitted additional land categories, it was important to maximise the number of bird lists available within each land use, to ensure robust outputs from our selected analysis method.

2.2. Avian citizen survey data

We used presence-only bird lists, available from 1999 to 2008, from the New Atlas of Australian Birds (hereafter the Atlas). The Atlas is Australia's largest and longest-running bird survey database (Barrett, Silcocks, Barry, & Cunningham, 2003). Volunteers are free to choose the location, date, time, search method and area covered by their survey, and do not use checklists. These details are included, along with the species list, record ID, observer ID and GPS survey locational accuracy, within the Atlas (Barrett et al., 2003).

The Atlas surveys are conducted using one of four methods: 2-ha area searches for 20 min, area searches within a radius of 500 m or 5 km, for at least 20 min, or incidental observations. Our study followed the methodology set out by Szabo et al. (2010) to filter records. We excluded records which did not include information on survey location, accuracy, method or area covered, or had a GPS survey locational accuracy of less than 500 m. We also excluded incidental sightings, poorly sampled species (< 10 observations or < 1 observation/year) and species lists of five or fewer species. Incidental sightings were removed because they may have introduced species' bias if observers only