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ORIGINAL PAPER

Differential influence of urbanisation on Coccidian infection in two passerine birds

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Abstract Urbanisation has the potential to increase the risk of parasitism on wildlife. Although some ectoparasite groups appear unaffected, different responses are hypothesised for parasites with simpler life histories such as gastrointestinal parasites. Red-browed finches (RBF) and the superb fairywrens (SFW), two native passerine birds affected by urbanisation, were examined for Coccidian parasites along an urbanisation gradient in New South Wales, Australia, in order to detect if prevalence might be directly related to the degree of urbanisation. Influence of urbanisation on Coccidian infection was differential. In RBF, the prevalence of *Isospora* increased significantly in more urbanised areas but prevalence did not change between breeding and non-breeding seasons. In contrast, in SFW, the degree of urbanisation did not significantly change with the degree of urbanisation, and season exhibited no significant effects on the prevalence of coccidians. Diet, behaviour and habits are suspected to be the most influential factors on the variation seen between both species where granivorous and gregarious species are significantly infected. Since the dynamics of urban wildlife-pathogen interactions is largely unexplored, more studies are needed to corroborate if this pattern of *Isospora* infections can be extended to other passerine birds in cities from Australia and overseas.

Keywords Biotic interaction · *Isospora* · Parasite-host relationship · Australia · Urban wildlife

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Introduction

New cities are created every year and the already established ones expand in area and population (Evans et al. 2009), causing significant impacts on biodiversity through a range of processes. While the effects of urbanisation on some species have been well studied, interactions and relationships amongst species living in cities are virtually unknown (Delgado-V. and French 2012).

Parasite infection has been an important issue of study in natural ecosystem, but parasite ecology in urban areas has not received enough attention yet. So that the extension of how urbanisation influences the prevalence and impact of parasites has not been studied in detail (Delgado-V. and French 2012), despite the fact that changes in host-parasite interactions have the potential to be one of the most important consequences of urbanisation (Bradley and Altizer 2006).

Birds are one of the most prevalent animal groups in urban areas. As they are ubiquitous in the urban environment even in highly urbanised areas, they facilitate the study of parasitism and its relation to urban development (Delgado-V. and French 2012). In addition, they are the most studied vertebrate in cities around the world, so they offer further possibilities about parasite comparison amongst urban centres. Even though the same species are not found amongst cities, comparison might be conducted between biologies, guilts or behaviours.

Passerine birds are host to a variety of parasites which exhibit a diverse array of forms and life history, and where obligate and non-obligate taxa are recognised as vectors of pathogens and diseases. Passerine birds are mainly infected by Coccidia of the genus *Isospora* (Apicomplexa: Coccidia), a cosmopolitan protozoan, which is transmitted via oocysts that are excreted along faeces of the host and infected by ingestion of sporulated oocysts (Dolnik et al. 2010). This is a group of parasites that can reduce weight, affect intestinal nutrient resorption, and reduce fertility (Atkinson et al. 2008). Pathogens as *Isospora* parasites are capable of infecting multiple host species, and some pose serious threats to human health and wildlife populations (Atkinson et al. 2008).

Comparative studies on parasites such as ectoparasites and blood parasites have been carried out amongst natural and urban sites (Delgado-V. and French 2012), but studies that had monitored changes in prevalence of other parasites along urban gradient are scarce (Reperant et al. 2007; Sitko and Zalésny 2014). For example, coccidians parasiting birds have kept virtually understudied in urban areas (Giraudeau et al. 2014) despite the fact that they are relatively easy and inexpensive to monitor.

Delgado-V. and French (unpublished data) documented a decrease of ticks and louse flies while lice kept unaffected by the degree of urbanisation. However, Evans et al. (2009) hypothesised that avian parasites and pathogens with more simple life cycles, such as some gastrointenstinal parasites, might exhibit a different response. This situation has been recently corroborated in the house finch (*Haemorhous mexicanus*), an urban-tolerant bird (Giraudeau et al. 2014) in the USA, but there is still no information about Coccidian infections in urban-sensitive birds or other less urbanised birds.

The proposal of this paper is to document if other parasites may exhibit different responses to urbanisation that those recently found for ectoparasites (Delgado-V. and French unpublished data). We tested the hypothesis that natural and human-altered locations present different levels of *Isospora* parasite infections on two passerine species which are both sensitive to urbanisation. Particularly, we explored the hypothesis that the overall *Isospora* infestation will be greater in areas with higher urban development.

Parasites are a diverse group which is fundamental in influencing ecological and evolutionary processes, therefore parasitism could contribute greatly to the structure, diversity, conservation, function, and health of biodiversity (Nichols and Gómez 2011). Knowing the relative frequency of occurrence of these pathogens in the two species of urban-sensitive passerines with different biology and behaviour is essential for proper epidemiological studies, disease modelling and basic surveys that can subsequently be used as tools for species conservation programs in urban areas.

Methods

Our study focused on two small passerine species known to be less abundant in urban areas (Parsons et al. 2006). Superb fairywrens (*Malurus cyaneus*; SFW, hereafter) are small (14 cm), sedentary and territorial birds. The species lives in cooperatively breeding groups which usually occupy small (c. 13–24 ha) territories. SFW typically occur in various types of habitat with dense and shrubby understory, including grasslands with scattered shrubs, gardens and urban parks. SFW mainly eats insects (Mulder 1995). Red-browed finches (*Neochima temporalis*; RBF, hereafter) is a sociable small estrildid finch (11–12 cm long). It inhabits the east coast of Australia and is found in open and semi-open woodland. This species is sedentary or nomadic. RBF feeds mostly on seeding grasses but it also uses bird feeders. It is found in weedy areas along railway tracks, roads, creek lines and urban parks (Todd 1996).

We chose five sites that differed in their degree of urbanisation. The degree of urbanisation was quantitatively determined by using satellite images via Google Earth (2014), which were analyzed using ArcGIS (10.2.1 version) ESRI (Redlands, CA, USA). We calculated an approximate percentage cover of urban areas (buildings, infrastructure and sealed roads) surrounding study sites and used it to develop an Urbanisation Index (UI) as described in Gómez et al. (2008) and Hamer et al. (2012): UI=(100 % − % green space + % impervious surface)/2 for the area within 1000 m of the sampling point. Artificial structures such as asphalt, concrete, brick and rooftops were considered impervious surfaces. Green space was defined as land having tree, shrub or grass cover.

The sites ranged from natural woodland (UI=1.05 %) to heavily urbanised areas (UI=48.41 %). Sites were a minimum of 3 km apart located near the coast where high infection has been found in Australia due to the wet environment (Oorebeek and Kleindorfer 2009). Sampling sites were (1) Murramarang National Park (35° 32′ 46″ S 150° 21′ 49″ E), a natural site situated ca. 300 km far from Wollongong to ensure the birds were well removed from urbanisation effects, UI=1.05 %; (2) Mount Keira (34° 24′ 48″ S 150° 51′ 19″ E) was a sub-natural area located relatively close to urban development (i.e. 10 k from Wollongong city), UI=12.23 %; (3) Ecological Research Centre at the University of Wollongong (34° 24′ 17″ S 150° 52′ 15″ E) was a woodland edge surrounded by human-altered habitats (e.g. urban gardens, paddocks and edge habitats), where there is a dense, shrubby understorey, UI=28.12 %; (4) Dalton Park (34° 23′ 47″ S 150° 53′ 55″ E) was a city park surrounded by a matrix of house blocks with variable amounts of mowed grass and ornamental shrubs with occasional large trees, UI=41.83 %; and (5) Green House Park (34° 26′ 31″ S 150° 53′ 31″ E), a small park situated between the industrial and commercial centre of the city which exhibits high traffic streets and scarce trees and bushes, UI=48.41 %.

Field work was conducted over a year in breeding and non-breeding seasons. Birds were sampled from February 2012 to March 2013 using mist nets. Nets were checked for captured birds every 10 to 15 min. Birds were examined for signs of unusual stress upon capture in mist nets (e.g. panting, collapse, extreme shock moult), and any individuals judged to be in extreme distress was immediately released without processing. Birds were individually transported in a clean cotton bag to the nearby processing station where a faecal sample was collected over a 20-min period. Birds were fitted with an aluminum leg band (supplied by the Australian Bird and Bat Banding Scheme) and released at the capture site immediately after processing and not included in the analysis if caught again.

Fresh excreta were collected in small vials containing 2.5 % potassium dichromate ($K_2Cr_2O_7$) water solution following Dolnik (2006). The samples were stored at room temperature for at least 4 days until analysis. Oocysts of *Isospora* were extracted using the method described in Dolnik (2006). Oocysts were then transferred to a slide and examined under the microscope where we recorded the presence of oocysts. The prevalence of *Isospora* was determined as the percentage of birds infected at each study site.

Data were analyzed separately for each host. Logistic regression was used to examine the effects of the degree of urbanisation and season (breeding and non breeding) on parasite prevalence. Interactions were included in the initial models and model simplification carried out by stepwise removal of explanatory factors that did not contribute significantly.

Results

We sampled 278 birds; 138 SFW and 140 RBF. Overall, there were 55 SFW infected (19.78 %) and 66 RBF (47.14 %). RBF had a higher prevalence of *Isospora* than SFW (χ^2=18.201, df=9, P=0.0329).

In RBF, the prevalence of *Isospora* increased significantly in more urbanised areas (${\chi_1}^2$=4.09, P<0.005) (Fig. 1a). Prevalence did not change between breeding and non-breeding seasons (${\chi_1}^2$=3.16, P=0.075) but there was a significant interaction between the two (${\chi_1}^2$=12.09, P=0.005) (Fig. 1a). In contrast, in SFW, neither degree of urbanisation (${\chi_1}^2$=0.06, P=0.8010) nor season exhibited significant effects (${\chi_1}^2$= 0.03, P=0.9555) on the prevalence of coccidians (Fig. 1b).

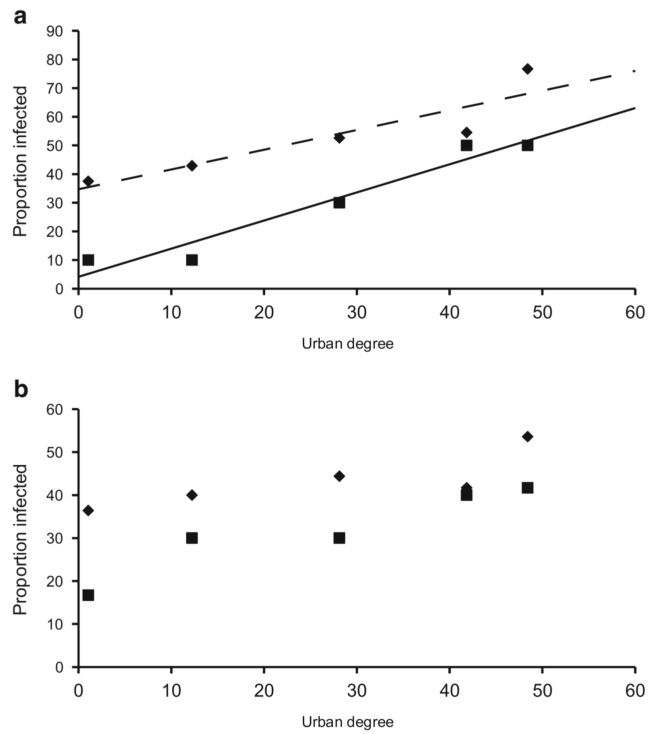

Fig. 1 **a** Coccidian prevalences for red-browed finch in breeding (*black diamond*) and non-breeding seasons (*black square*) and **b** superb fairy wren, along an urban gradient. Best fit lines for RBF is depicted. Degree of urbanisation exhibited no significant effects in SFW

Discussion

In this study, we tested whether the degree of urbanisation affects the occurrence of Coccidian infections in two urban-sensitive birds. We found that prevalence was differential between species, and that, contrary to the prediction, prevalence of *Isospora* increased in more urbanised areas on Red-browed finch, in both breeding and non-breeding seasons, but did not significantly change with degree of urbanisation in Superb fairy-wren. Diet, behaviour and habits are suspected to be more influential factors on the variation observed between both species, where granivorous and gregarious species being significantly infected.

This study provides the first quantitative baseline information of *Isospora* prevalence along an urban gradient in Oceania. It shows that Coccidians can respond differently depending on the host suggesting that these parasites might be more prevalent in urban areas in some birds but not all. In one species, parasite prevalence in the population increased with urbanisation suggesting that fitness may be affected in birds in more highly urbanised areas. These differences of parasite prevalence may be link to other life history features which need to be further explored.

The prevalence and intensity of infection with Coccidian parasites in wild passerines is highly variable amongst species. In natural areas, Dolnik et al. (2010) and Zinke et al. (2004) found that ground feeder birds have the highest prevalence and intensity of infection, and that these parameters have lower values in insectivore passerines. Also, foraging in flocks may cause an aggregation of faeces at feeding sites, so that social foragers appear to be more exposed to coccidian infections (Giraudeau et al. 2014). Additionally, infection may also occur during bathing, collection of nest material or pairing where flocks facilitate the transmission of parasites and lead to higher intensities of Coccidians. Many birds foraging at the same area for extended periods of time can result in accumulation of faeces and posterior transmission (Dolnik et al. 2010; Zinke et al. 2004).

Our results contrast to other studies which have shown reduced parasite load in urban areas (Gregoire et al. 2002). For example, Geue and Partecke (2008) and Evans et al.

(2009) worked on the Eurasian blackbird *Turdus merula* and found a decrease in tick prevalence and intensity in cities. Sitko and Zalésny (2014) found a reduction in the helminth fauna in Eurasian blackbird in urban areas compared with forested sites. Fokidis et al. (2008) found that some urban passerines were less affected by haemoparasites than its rural counterparts in the US desert.

As life histories of parasites vary extensively, responses to urbanisation may also differ. Prevalence and intensity of avian parasites and pathogens with simpler life cycles might be higher in urban areas (Evans et al. 2009) as transmission is easier. Drastic environmental changes associated with urbanisation, habitat conversion, increased temperatures and fragmentation (McCallum and Dobson 1995; Daszak et al. 2000; Bradley and Altizer 2006; Cumming and Van Vuuren 2006; Calegaro-Marques and Amato 2014) might cause declines in microhabitats, water availability and the abundance of intermediate hosts and vectors which are likely to affect ticks, helminths and blood parasites with complex life histories (Evans et al. 2009; Reperant et al. 2007; Sitko and Zalésny 2014). However, *Isospora* and other parasites, viruses and pathogens might have a different response as transmission pathways are quite distinct. *Isospora* infections are passed between hosts by faecal-oral transmission where infective oocysts can contaminate the external environment, including food and water (Dolnik 2006; Dolnik et al. 2010). This suggests that urban aggregations of host species may encourage the spread of parasites that are transmitted by direct contact. For example, Hamer et al. (2012) found the avian exposure to West Nile virus increased with level of urbanisation. Similarly, Giraudeau et al. (2014) recorded an increase of prevalence of poxvirus associated with urbanisation degree.

Our results only partially support this hypothesis as prevalence was only related to urbanisation in one species, not both. Therefore, factors of exposure to parasites, such as diet, behaviour and environmental factors, need to be investigated to explain the variation seen between RBF and SFW. For example, larger communal roosts or reduced areas for foraging and feeders might provide more transmission opportunities (Giraudeau et al. 2014) facilitating contact rates and potential dispersal and transmission.

Differences in diet may also influence transmission rates. Dolnik et al. (2010) suggested that insects are less likely to be contaminated with sporulated oocysts than berries or seeds, resulting in both a lower probability of exposure and a lower dose for insectivores in comparison with granivores. Ground foraging granivores might be particularly susceptible to infection where birds may encounter faecal material. Granivorous passerines, such as RBF, might represent the most vulnerable birds under an eventual chronic prevalence of *Isospora* in urban areas (Giraudeau et al. 2014).

Alternative routes of uptake of transmission of oocysts might also explain differences in seasonal prevalence. During breeding seasons, nestlings and siblings can be infected by parents during ingestion of contaminated food (Dolnik et al. 2010), causing a higher prevalence of *Isospora* in the breeding season in RBF along the sampled gradient of urbanisation.

Urban areas are becoming important areas for conserving and managing urban wildlife (Kantsa et al. 2013). Parasites could contribute greatly to the structure, diversity, conservation, function and health of urban biodiversity, and future studies focusing on the understanding of the transmission dynamics and the ecology of wildlife pathogens in species will corroborate if this pattern of *Isospora* infection in granivorous and insectivore passerines can be applied more generally.

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