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Species distribution models derived from citizen science data predict the fine scale movements of owls in an urbanizing landscape

Nick Bradsworth[a], John G. White[a], Bronwyn Isaac[b], Raylene Cooke[a,*]

[a] Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, Geelong, Australia
[b] School of Biological Sciences, Monash University, Clayton, Victoria 3800, Australia

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ABSTRACT

Apex predators are critical to ecological function, however their life history traits are often not conducive to survival in urban environments. While this can result in the loss of some apex predators, others are able to inhabit and utilize urban environments. Understanding predator resource requirements and the factors driving their distribution is often difficult due to their cryptic nature, however, this understanding is essential, given the current rate of urban expansion. In this research we use a threatened apex predator, the powerful owl (*Ninox strenua*) as a case study. Specifically, we aim to (1) develop a Species Distribution Model (SDM) to ascertain environmental variables driving habitat suitability across an urban gradient (2) determine fine scale spatial movements of powerful owls using GPS telemetry; (3) validate the SDM against collected GPS movement data; and (4) evaluate habitat predicted by the SDM against current reserve systems to establish whether they are adequate for the future protection of this species. We used MaxEnt and citizen science data to produce SDMs that predicted habitat suitability for powerful owls and identified the environmental variables driving habitat across the landscape. Fine-scale spatial movements for urban powerful owls, gained via GPS telemetry, were used to establish home-range sizes, validate models and assess the fit of telemetry data against SDM predictions. Rivers, vegetation (particularly dense tree cover) and distance to riparian areas were the ecological variables driving predicted habitat for powerful owls across the urban gradient. There was a strong relationship between habitat predicted by the SDM and the fine scale movements of powerful owls in urbanized environments. Home-ranges within this urban study were notably smaller than previous estimates established for forested environments. The powerful owls in our study were also shown to utilize considerable amounts of habitat outside of the reserve system. This has severe conservation implications because it is often the space outside of reserves that are at most risk from urban intensification. Conservation of the powerful owl in urban environments, therefore, needs to focus on both habitat management within existing reserves, and on establishing clear vegetation management strategies in the surrounding urban matrix.

1. Introduction

The global loss of apex predators, due largely to anthropogenic threats, is having pervasive impacts on natural ecosystems throughout the world (Cardillo et al., 2004; Estes et al., 2011; Ripple et al., 2014). Apex predators are critical in maintaining ecosystem structure and function (Wallach et al., 2015) as these typically large bodied consumers structure faunal communities by applying top-down pressure on the dominant prey and smaller predator species (Ripple et al., 2014; Sergio et al., 2014; Wallach et al., 2015). This pressure results in trophic cascades where the densities of mid-level consumers or mesopredators are suppressed, resulting in a higher abundance of basal producers and increased biodiversity (Pace et al., 1999; Estes et al., 2011). The role of apex predators within ecosystems is often not realised until they have disappeared, at which point the capacity to restore the balance is significantly compromised (Estes et al., 2011). Apex predator populations generally exist at low densities but their density can be further reduced in disturbed urban landscapes (Sorace and Gustin, 2009).

Despite their lower abundance, some predator species are able to exist in urban environments, and others are increasingly colonizing urban landscapes (Chace and Walsh, 2006; Wang et al., 2015). Maintaining predators in urban landscapes has potentially important implications for urban species conservation as a whole. Using predators as umbrella species to provide a focus for urban conservation strategies is a useful conceptual approach (Wilcox, 1984; Lambeck, 1997; Roberge and Angelstam, 2004; Sattler et al., 2014; Sergio et al., 2014). Many

* Corresponding author.
E-mail address: raylene.cooke@deakin.edu.au (R. Cooke).

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predators have large spatial requirements and require access to habitat that supports a reasonable prey base, therefore by maintaining and enhancing populations of predators in urban environments numerous, less resource demanding species, gain conferred protection (Ripple et al., 2014). The challenge, however, with this approach is that our knowledge of predators in urban environments is extremely limited when compared to more conspicuous, higher density groups of animals. Their naturally low population densities, large home-range sizes, often nocturnal or cryptic behaviours and the difficulty in detecting or capturing predators has the potential to compromise any conservation strategies built around predators (McKinney, 2002; Cardillo et al., 2004; Santos et al., 2006). New approaches to modelling habitat suitability using presence-only datasets, increasing development of citizen science databases and significant advances in tracking technologies have the potential to revolutionise our understanding of predators in urban landscapes.

Species Distribution Models (SDMs), using presence-only datasets, are an approach that has gained popularity throughout the past decade (Guisan et al., 2013; Radosavljevic and Anderson, 2014; Ochoa-Ochoa et al., 2016). SDMs have greatly improved many aspects of conservation, including: translocation, understanding biological invasions, reserve selection and the identification and protection of critical habitat to maintain habitat connectivity (Guisan et al., 2013). Collecting presence and absence data on cryptic species such as apex predators can be labor and cost intensive due to their inherently low detection probabilities (Wintle et al., 2005). The use of presence-only data sets collected by citizen scientists, however, provides a viable alternative to presence/absence field surveys for apex predators (e.g. Santos et al., 2006; Isaac et al., 2014a; Angelieri et al., 2016). These datasets are also readily available through museums and government agencies and are an important source of public and private investment in biodiversity monitoring (Weston et al., 2006; Elith et al., 2011). This data however, may be unreliable in representing a whole population, or providing a complete coverage of their habitat use (Santos et al., 2006; Monterroso et al., 2009). Urban environments could benefit from citizen science datasets as this is where the vast majority of the human population resides, and also where many species records are reported by the public (Barrett et al., 2003). Species of public interest are also more likely to be reported by members of the public compared to common widespread species, adding value to such datasets for predators (Bonney et al., 2009; Geldmann et al., 2016).

An issue with SDM approaches is that while they may use internal validation (i.e. AUC within MaxEnt) or external statistical validation (i.e. AICc in ENMtools), they are rarely validated against independently collected spatial-use data. This is a significant issue, especially given that models are extrapolated to non-sampled areas, and wide-ranging species such as predators which often have large spatial requirements (Pinto et al., 2016). Adding to this problem is the lack of spatial-use research on predators in urban environments. This is generally associated with the difficulty of capturing predators in urban areas, and the inherent difficulty of tracking wide ranging species across urban landscapes where access to large areas of privately owned land is challenging. Significant improvements in automated tracking approaches such as the use of GPS telemetry may, in part, help to fill this substantial knowledge gap.

The powerful owl (*Ninox strenua*), Australia's largest owl, is non-migratory, maintains year-round territories (McNabb, 1996) and is of conservation interest both nationally and internationally (Appendix II CITES and IUCN (2012 IUCN Red List of Threatened Species)). The powerful owl has traditionally been perceived as a forest dependent raptor, preferring densely vegetated gullies of tall open forest (McNabb, 1996; Cooke et al., 2002a). This species does, however, persist in metropolitan reserves close to major cities such as Melbourne (Cooke et al., 2006), Sydney (Kavanagh, 2004) and Brisbane (Pavey, 1995) suggesting that they can exist in a more diverse range of environments than previously thought (Cooke, 2000). In urban environments, powerful owls exploit the abundant arboreal marsupial prey base (Cooke et al., 2006), and reside in areas that provide habitat for roosting and in some cases nesting (Cooke et al., 2002b). Few studies, however, have been able to examine powerful owl spatial ecology directly due to their elusive (nocturnal) behaviour, low population densities, high mobility and low detectability (Wintle et al., 2005). They are extremely difficult to capture, which has resulted in a paucity of spatial-use data in this species. The few studies that have been successful in capturing and tracking powerful owls are representative of forest/woodland environments, with no data available for urban owls (Kavanagh, 1997; Soderquist and Gibbons, 2007; Bilney, 2013).

Using powerful owls as a case study this research aims to investigate the accuracy of SDMs derived from substantial citizen science datasets in predicting the fine-scale spatial-use of powerful owls across an urban landscape. This paper provides a rare case study in the spatial ecology of an urban predator, and also demonstrates how GPS tracking data can be used to externally validate SDMs as well as investigate the adequacy of reserve systems for protecting predators.

2. Methods

2.1. Study area

Melbourne is the second largest Australian city (4.5 million people) and has the fastest growing population (2.1% annual growth) (Australian Bureau of Statistics, 2016). It therefore offers an ideal landscape to examine the impact of urbanization on a predator species of conservation priority. Our modelling study site covered 372,136 ha of Melbourne, Australia (Fig. 1). It covered the urban gradient, extending from the urban core (consisting of high levels of disturbance, impervious surfaces, and human population density), through the urban fringe (containing moderate to low disturbance, higher tree cover and a lower population density) to forested environments (lowest disturbance, lowest population densities and highest tree cover).

2.2. Development of SDMs based on atlas records

2.2.1. Powerful owl presence records

We collated powerful owl records from the BirdLife International Atlas, Department of Environment, Land, Water and Planning's Victorian Biodiversity Atlas, and from the Atlas of Living Australia. Additional records were sourced from BirdLife Australia's citizen science “Melbourne Powerful Owl Project”. New records were combined with presences from Isaac et al. (2013) in ArcGIS version 10.2.2 (ESRI, 2014). Presence records collected prior to 1997 were removed to limit historical environmental change and any duplicate presences (i.e. multiple records for the same location) were also removed to establish a presence layer with a single presence point per 20 × 20 m grid cell. The resulting presence layer was used in SDM development.

2.2.2. Ecological geographical variables and validation

Environmental layers originally collated by Isaac et al. (2013) were selected based on a priori understanding of powerful owl ecology. Eco-geographical variables used for modelling included lineal density of ephemeral and permanent rivers, Euclidean distance to riparian areas, riparian vegetation, slope position classification, Normalised Difference Vegetation Index (NDVI), land cover and density of tree cover (Table 1).

2.2.3. Species distribution model building

The maximum entropy modelling approach predicts habitat suitability based on the relationship between presence data and eco-geographical variables. We chose MaxEnt (Version 3.3.3k, Phillips et al., 2004), to establish habitat suitability for the powerful owl because it has consistently outperformed other models in terms of predictive performance, particularly for species foraging and presence only datasets (Elith et al., 2011; Yackulic et al., 2013; Fonderflick et al., 2015;