Urban Forestry & Urban Greening 32 (2018) 21–31

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Site selection of urban wildlife sanctuaries for safeguarding indigenous biodiversity against increased predator pressures

Amin Rastandeh*, Daniel K. Brown, Maibritt Pedersen Zari

Faculty of Architecture & Design, Victoria University of Wellington, Wellington, New Zealand

ARTICLE INFO

Keywords:
Indigenous fauna
Landscape composition and configuration
Predator pressure
Rising temperatures
Urban biodiversity
Urban wildlife sanctuary

ABSTRACT

Biodiversity loss in urban landscapes is a global challenge. Climate change is a major driving force behind biodiversity loss worldwide. Using Wellington, New Zealand as a research site, the aim of this research is to show how the most suitable patches of vegetation in urban landscapes can be identified, ranked, and prioritised as potential urban wildlife sanctuaries. This is in order to protect vulnerable indigenous fauna from some of the indirect impacts of climate change such as increased predator pressures and the spread of diseases among urban fauna caused by rising temperatures. A GIS-based multi-criteria analysis of spatial composition and configuration of patches of vegetation was undertaken with reference to eight factors affecting the quality of habitat patches and accordingly fauna behaviours in urban landscapes. Results show that Zealandia, the Wellington Botanic Garden, the Town Belt, and Otari-Wilton's Bush are respectively the most important urban sites for establishing pest-free urban wildlife sanctuaries in the study area. This research reveals that patch size should not be considered as the single most important factor for the site selection of urban wildlife sanctuaries because the collective importance of other factors may outweigh the significance of patch size as a single criterion. Lessons learned in the course of this research can be applied in similar cases in New Zealand or internationally in order to facilitate the process of site selection for the establishment of urban wildlife sanctuaries in highly fragmented urban landscapes suffering from rising temperatures and other climatic changes.

1. Introduction

1.1. The importance of biodiversity

The quality of ecosystem functions and services depends in part on the overall level and health of biodiversity (Balvanera et al., 2006; Cardinale et al., 2006; Hector and Bagchi, 2007; Duffy et al., 2007; Isbell et al., 2011; Hooper et al., 2012; Pasari et al., 2013; Tilman et al., 2014; Lefcheck and Duffy, 2015). In line with research on biodiversity in natural and semi-natural areas, urban biodiversity has received increasing attention in recent years (Farinha-Marques et al., 2011; Müller and Kamada, 2011; Elmqvist et al., 2013; Murgui and Hedblom, 2017). Biodiversity loss in the Southern Hemisphere in particular is a challenge influencing the quality and quantity of ecosystem services and thereby the quality of human life (Chambers et al., 2013; Jupiter et al., 2014; Urban, 2015; Taylor and Kumar, 2016; Rastandeh et al., 2017b).

1.2. New Zealand as a fragile biodiversity hotspot

New Zealand has been recognised as one of the most unique biodiversity hotspots on the planet (Myers et al., 2000; Olson et al., 2001). New Zealand has been separated from other landmasses for around 85 million years, since dinosaurs were widespread on the planet but before early mammals (i.e. egg-laying mammal species) were present (Fleming, 1975; Parkes and Murphy, 2003). As a consequence, the long-term evolution of New Zealand indigenous fauna including birds and reptiles has occurred in the absence of mammals for millions of years. This geo-biological situation means that New Zealand indigenous fauna and flora did not develop natural defence mechanisms against predation by mammals over time. For example, although many birds' sense of smell typically helps them to recognise the odour of potential predators (Amo et al., 2008; Röder et al., 2016), a study of the ability of exotic and indigenous avifauna in identifying mammals'scents in New Zealand suggests that indigenous species cannot respond to predator scent in an effective manner, and for this reason, they are more vulnerable to predator pressures from exotic fauna (Stanbury and Briskie, 2015).

* Corresponding author.
E-mail address: amin.rastandeh@vuw.ac.nz (A. Rastandeh).

https://doi.org/10.1016/j.ufug.2018.03.019
Received 8 October 2017; Received in revised form 25 March 2018; Accepted 27 March 2018
Available online 29 March 2018
1618-8667/

1.3. The risk of predation in a New Zealand context

Evidence suggests that rising temperatures will increase the rate of predation upon indigenous fauna in New Zealand. According to the Ministry for the Environment (2014), the annual average temperature in the study area will increase by 0.9° C and 2.1° C, on average, by 2040 and 2090, respectively compared to 1990. For centuries, especially since the 1800s when Europeans came to New Zealand, indigenous biodiversity has been under a widespread biological attack across the country by invasive flora and fauna. Exotic mammals, in particular, are estimated to benefit from rising temperatures because rising temperatures lead to early flowering of flora, and the event of mast seeding phenomena which provide more food sources for these species. This, in turn, gives rise to a higher rate of reproduction among exotic mammals. This, consequently, increases the risk of increased predator pressures on indigenous fauna in New Zealand (Wilson et al., 1998; Pierce et al., 2006; McGlone and Walker, 2011; Christie, 2014). In addition, the outbreak and spread of diseases amongst indigenous fauna is very likely a result of an increase in the population of sources of infections triggered by rising temperatures (Baillie and Brunton, 2011; Ewen et al., 2012; Howe et al., 2012; Niebuhr, 2016).

The introduction of more than thirty exotic mammals to New Zealand, often known as pests, (Parkes and Murphy, 2003), among other causes, has led to widespread indigenous biodiversity loss across the country (McGlone, 1989; Towns and Daugherty, 1994; Saunders and Norton, 2001; Ewers et al., 2006). Common brushtail possum (*Trichosurus vulpecula*), for example, is an Australian mammal introduced to New Zealand in 1837 (Wodzicki, 1950). This species competes with indigenous fauna for food sources (Innes et al., 2010) and has a negative impact on the life-cycle of endemic trees (Cowan et al., 1997). European hedgehog (*Erinaceus europaeus*) predation affects populations of some endemic reptiles, insects, and ground-nesting birds (Jones et al., 2005; Reardon et al., 2012). Stoats (*Mustela erminea*) were introduced to New Zealand to control rabbit populations on farms (King, 2017). The stoats'rate of reproduction is very high and they predate largely upon indigenous avifauna (King, 1983). This can be related to the size of specie's home range (Murphy and Dowding, 1994). Weasels (*Mustela nivalis*) were introduced for the same purpose. This species is regarded as one of the main predators of indigenous avifauna and reptiles (King, 2017), and widely benefits from the overproduction of the seeds of beech trees during mast seeding events and this, accordingly, results in an increase in the number of individuals and therefore greater rates of predation. The aforementioned species are currently widespread in urban New Zealand. On the other hand, vegetation is highly fragmented in urban New Zealand due to a specific history of the urban development (Freeman and Buck, 2003; Meurk and Hall, 2006; Stewart et al., 2009; Rastandeh and Pedersen Zari, 2018). These conditions have cumulatively led to a higher level of vulnerability of indigenous fauna and flora.

1.4. Urban wildlife sanctuaries

Due to the fragile nature of New Zealand's indigenous fauna, in line with spatial management of land cover patterns at the class and landscape levels (Rastandeh and Pedersen Zari, 2018), a number of pest-free urban wildlife sanctuaries are needed in order to ensure the survival of vulnerable indigenous fauna against increased predator pressures and the spread of diseases triggered by rising temperatures in urban New Zealand. There is a wide range of evidence to suggest that the successful conservation of New Zealand indigenous fauna depends profoundly on pest control (Brown, 1997; Gillies and Clout, 2003; van Heezik et al., 2008; Innes et al., 2012; van Heezik et al., 2010; Aguilar et al., 2015; Goldson et al., 2015; Russell et al., 2015). Research on little-spotted kiwi (*Apteryx owenii*) (McLennan et al., 1996; Robertson and, Colbourne, 2004), other avifauna (Duncan and Blackburn, 2004; Blackburn et al., 2005; Innes et al., 2015a), tuatara (*Sphenodon*) (Jarvie et al., 2016), and other reptiles (Reardon et al., 2012) indicates that the presence of introduced exotic mammals is a serious threat to the survival of the aforementioned species. Zealandia, the first pest-free urban wildlife sanctuary in New Zealand (Beatley, 2016), is a successful example of such strategies to respond to urban biodiversity loss. Zealandia was established in 1999 (Beatley, 2016) to support indigenous biodiversity in the Wellington urban landscape, but not necessarily as a refugium for indigenous fauna in the face of some impacts of climate change. This urban wildlife sanctuary, similar to other New Zealand examples (e.g. Travis Wetland Nature Heritage Park in Christchurch), has a special structure, a specific fence construction, a strategic visiting regime, and detailed management system that provide an isolated, pest-free, and accordingly disease-free, habitat for not only a wide range of vulnerable fauna, but indigenous flora in an urban context.

Although connectivity between patches of vegetation is essential to facilitate species movement and contribute to natural regeneration through seed dispersal and pollination mechanisms in urban New Zealand (Meurk and Hall, 2006; Meurk et al., 2016; Rastandeh and Pedersen Zari, 2018), pest-proof fencing is currently recommended by New Zealand experts for maintaining biodiversity in urban landscapes when biodiversity is to be addressed at the patch level (Burns et al., 2012; Innes et al., 2012; Empson and Fastier, 2013; Innes et al., 2015b; Norton et al., 2016). Although some of New Zealand's indigenous flying avifauna can still avail themselves of connectivity, highly vulnerable species such as little-spotted kiwi, tuatara, takahē (*Porphyrio hochstetteri*), hihi (*Notiomystis cincta*), and kākā (*Nestor meridionalis*),require active protection from predation pressures through the use of pest-proof fencing, or isolation on predator free offshore islands because they are not as mobile as New Zealand avifauna and/or their populations are not as large as other species. Therefore, site selection for suitable urban wildlife sanctuaries is vital to support the aforementioned vulnerable species in an era of climate change. Pest-free urban wildlife sanctuaries can simultaneously contribute to the presence and abundance of a wide range of other indigenous species endemic to New Zealand, accordingly.

2. Materials and methods

2.1. Study area

Wellington, New Zealand, a city with a population of more than 200,000 inhabitants, is one of the world's leading cities in urban biodiversity conservation (Clarkson and Kirby, 2016). The Wellington urban landscape is one of the most important hotspots for biodiversity conservation in urban New Zealand (Pedersen Zari, 2012, 2015; Rastandeh et al., 2017b). At the same time, the urban landscape of Wellington is highly fragmented. This area comprises of numerous patches of vegetation resulting from widespread urban development over the last two centuries (Rastandeh and Pedersen Zari, 2018). For this reason, it was selected as the case study area (Fig. 1).

2.2. Multi-criteria analysis

A six step process was designed, based upon Hill et al., 2005; Svoray et al., 2005; Wang and Hofe, 2008; Zucca et al., 2008; Huang et al., 2011; Fontana et al., 2013; Fernandez and Morales, 2015; Langemeyer et al., 2016,to perform a multi-criteria analysis of the most suitable patches of vegetation spatially capable of serving as urban wildlife sanctuaries in a New Zealand context under a climate that continues to becomewarmer. This is a cost-effective and relatively quick method to identify and rank candidate sites depending on expert knowledge, spatial data, and GIS analysis.

2.2.1. Step 1: identifying candidate sites

Approximately more than 60% of the Wellington urban landscape is covered by different types of green spaces ranging from indigenous,