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The impacts of historical land-use and landscape variables on hollow-bearing trees along an urbanisation gradient

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ABSTRACT

Hollow-bearing trees provide habitat for diverse taxonomic groups and as such they are recognised for their importance globally. There is, however scant reference to this resource relative within urban forest patches. The functional ecology of habitat remnants along an urbanisation gradient plays an important ecological, social and economic role within urban landscapes. Here we quantify the impacts of urbanisation, landscape, environmental, disturbance (past and present) and stand variables on hollow-bearing tree density within urban forest patches. This was undertaken by surveying 45 forest patches on the Gold Coast, south-east Queensland, Australia. Sites were categorised as; urban, peri-urban or rural along an urbanisation gradient, with an additional five control sites. Historical logging practices were found to be the driving factor influencing hollow-bearing tree density along the urbanisation gradient; while the impacts of urbanisation itself are not as yet discernible. These findings highlight the significance of incorporating historical land use practise into current and future urban planning, as these will have continuing impacts on remaining urban biodiversity values. These findings, will benefit natural resource managers and urban planners when making decisions about where and how best to manage for hollow-bearing trees along urbanisation gradients.

Introduction

Second only to agriculture, urbanisation is the single most damaging, persistent and confounding form of anthropogenic pressure exerted upon natural systems globally (Vitousek et al., 1997; McKinney, 2006; Gaston, 2010). Within Australia, approximately 50% of forests have been lost or severely modified since European settlement, with over 80% of eucalypt forests having suffered from anthropogenic activities, leaving much of Australia's remaining forest severely fragmented (Bradshaw, 2012). In heavily populated regions, urbanisation causes natural landscapes to become increasingly fragmented. Consequently, urban bushland remnants become 'stepping stones' within the landscape allowing certain species to move between urban, peri-urban, rural and forested areas (Manning et al., 2006). The processes driving fragmentation are greater in smaller patches, as they are more likely to be altered by changed environmental parameters (such as urbanisation) to a greater degree than large patches (*e.g.* edge effects) (Morgan and Farmilo, 2012). Such shifts may have implications for habitat structure and food web interactions in smaller remnant forest-patches (Morgan and Farmilo, 2012). Thus, the dynamics of forest-patches are principally driven by features from the surrounding landscape (Ewers and Didham, 2006; Morgan and Farmilo, 2012). Therefore, the management of, and research on, fragmented ecosystems should be directed at understanding and controlling these external influences as much as the biota of forest-patches themselves. This is particularly significant for habitats containing species that utilise specialised resources such as hollow-bearing trees (Lindenmayer, 2002; Rowston et al., 2002; Manning et al., 2006).

The urban landscape however, is never uniform, with impacts on remnant habitats determined by the type and intensity of the land-uses found within them (Brady et al., 2009). These impacts vary with the time since isolation (Saunders et al., 1991), distance from other remnants (Luck and Daily, 2003), degree of connectivity with other remnants (Lindenmayer and Fischer, 2006) and the abundance of suitable habitats to support ecological communities (Flynn et al., 2011). Consequently, the preservation of hollow-bearing trees within the urban landscape is essential for maintaining ecosystem function by providing critical habitat and the conservation of biodiversity in general (McKinney, 2006; Stagoll et al., 2012).

Urbanisation intensity correlates with increased disturbance and the structural simplification of remaining vegetation

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(McKinney, 2008). However, human-modified landscapes with heterogeneous matrix/remnant elements can provide supplementary habitat resources (Brady et al., 2011; Threlfall et al., 2011). Thus, the urban landscape can be of benefit to biodiversity when each site is assessed individually (McKinney, 2008). Individual species traits also determine how well a species adapts to urbanisation (Luck and Smallbone, 2010). When considering species responses to landscape change it is therefore important to move beyond focusing primarily on spatial attributes (size, isolation) to recognise that landscape change is the most important variable to consider when examining functionality (Holland and Bennett, 2009).

In urban regions there is a distinct transition in housing density along an urban–rural gradient (van der Ree and McCarthy, 2005), with the gradient model being a useful tool for examining the ecological consequences of urbanisation (McDonnell et al., 1997). Previous studies along urban gradients have demonstrated significant effects on floral and faunal assemblages; where communities are generally depauperate in the more heavily urbanised areas with smaller remnant forest-patches (Brady et al., 2009; Hahs and McDonnell, 2007; Moffatt et al., 2004). While these studies focus on species composition along the urban gradient, no studies have investigated the impact of the urban gradient on habitat resources such as hollow-bearing trees. However, management practices, landscape variables and ecological processes along the gradient will differ and potentially affect resource availability (McKinney, 2006; Pillsbury and Miller, 2008; Le Roux et al., 2014a,b; Treby et al., 2014). In sites managed for timber production, there has been a global recognition of the reduction in hollow-bearing trees (Poonswad et al., 2005; Holloway et al., 2007; Politi et al., 2009; Law et al., 2013), as well as increasing the rate of destruction of retained trees across the landscape (Smith et al., 2009; Law et al., 2013). Le Roux et al. (2014b) predicted that important habitat structures such as hollow-bearing trees would decline in managed urban greenspace while remaining relatively stable in natural habitat remnants. However, there is still little understanding of whether such stability would be uniform along the urban gradient. As such, we put forward the hypothesis that there is likely to be a difference in the size and availability of hollow-bearing trees along the urban gradient. We predict that urban patches will have a greater number of these trees due to their longer isolation from historical land-use practices.

The functional ecology of the urbanisation gradient, and specifically that pertaining to the availability of hollow-bearing trees, is being investigated in this paper. It does so by quantifying the impacts of urbanisation, landscape and environmental variables on hollow-bearing trees within natural, urban-forest, patches. In doing so, the ecology *in* and the ecology *of* urban areas was explored. The ecology *in* urban areas is closely affiliated with traditional ecology, in that it investigates ecological patterns and processes in urban areas. The ecology *of* urban areas is concerned with how those systems function as a whole. This system-oriented approach will deliver deeper insight into the role that urbanisation gradients play in conservation management (Gaston, 2010). The significance of these findings in regards to rapidly changing landscapes, such as those found along the urbanisation gradient, will be of benefit to biodiversity managers and urban planners when making decisions about where, and how to best manage for hollow-bearing trees within urban landscapes.

Methods

Study area

This study was primarily conducted on the Gold Coast, south-east Queensland, Australia. The Gold Coast is located approximately 70 km south of Brisbane occupying an area of 1451 km^2 stretching from the New South Wales border in the south to the Logan River in the north and from the coastline to the McPherson and Darlington Ranges in the west. The Gold Coast is also one of Australia's most rapidly developing urban regions (Graymore et al., 2008; Gurran, 2008) in an area of high biodiversity value (Young and Dillewaard, 1999). It is also important to acknowledge, that due to the rate of urbanisation on the Gold Coast in the past 50 years (Spearbritt, 2009), urban areas have had less exposure to historical land practices such as logging, than more rural areas.

The Gold Coast comprises a myriad of landscapes including a coastal plain consisting of beaches, dunes, river deltas, bays, estuaries and wetlands; supporting heath-land, melaleuca swamps. Wet and dry sclerophyll forest as well as rainforest vegetation communities located on rolling foothills and low mountain ranges. The topography rises from sea level up to 1010 m on the mountain escarpments of the hinterland (Gold Coast City Council, 2007). The average annual rainfall on the Gold Coast varies from 1500 mm on the coast to 3000 mm in the hinterland ranges (Gold Coast City Council, 2007) with an average temperature range between 0 °C and 35 °C (Bureau of Meteorology, 2009).

Study sites

The study was undertaken in patches of natural-forest habitat on the Gold Coast. Study sites were confined to wet and dry sclerophyll forest types as they are widespread across the study area and are eucalypt dominated communities (*i.e.* those typically containing hollows-bearing trees). Sites were restricted to those found ≤500 m above sea level, as above this altitude rainforest communities tend to dominate the landscape. Sites were also restricted to those ≥2 ha in size. The minimum threshold of 2 ha was chosen as the smallest area that would allow for sufficient environmental sampling to be undertaken. Fifty candidate natural-forest-patches were subsequently identified from within council Conservation Areas, National Parks, State Forests and on private land. We excluded urban parks or greenspace areas that are intensively managed or landscaped as these are not typically habitats considered by management authorities to be of high conservation value. Ground-truthing excluded those that had access issues, intensive livestock grazing or an artificial modified understory; as these were not representative of natural vegetation communities. Finally, as there was a relatively high number of small, forest-patches within urban areas, some of these were removed in order to get an even representation of site type along the gradient. Therefore, forty-five sites of varying size, shape and location were subsequently selected along an urbanisation gradient from the highly developed coastal region through to the more natural environments of the hinterland (Fig. 1). Five large, contiguous, forest-patches (>500 ha) were chosen as control sites. Three of the controls were located in peri-urban areas and two were within urban areas. Three of the five control sites were established within the southern suburbs of Brisbane, Logan and Redland Shires; to supplement the small number of large contiguous forest-patches below 500 m on the Gold Coast. A systematic grid was placed over all sites with sampling points (plots) identified at all intersection points. The number of plots to be surveyed at each site was determined by patch size using a hierarchical grid cell size, ranging from 250 m in small (∼2 ha) forest-patches to 2000 m in larger (∼1700 ha) sites to allow for sufficient environmental variation. In total 91 plots were selected from all 45 sites. At each plot a fixed area methodology was used (*sensu* Gibbons and Lindenmayer, 2002), to sample relevant parameters. Fixed area methodology allows for ease in determining if a tree should be sampled or not; plots can be permanently marked and all trees within a plot can be catalogued enabling the estimation of density. The general importance of landscape and environmental variables as drivers of biodiversity has been acknowledged in