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The importance of forest area and configuration relative to local habitat factors for conserving forest mammals: A case study of koalas in Queensland, Australia

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ABSTRACT

The loss and fragmentation of forest habitats by human land use are recognised as important factors influencing the decline of forest-dependent fauna. Mammal species that are dependent upon forest habitats are particularly sensitive to habitat loss and fragmentation because they have highly specific habitat requirements, and in many cases have limited ability to move through and utilise the land use matrix. We addressed this problem using a case study of the koala (*Phascolarctos cinereus*) surveyed in a fragmented rural–urban landscape in southeast Queensland, Australia. We applied a logistic modelling and hierarchical partitioning analysis to determine the importance of forest area and its configuration relative to site (local) and patch-level habitat variables. After taking into account spatial autocorrelation and the year of survey, we found koala occurrence increased with the area of all forest habitats, habitat patch size and the proportion of primary *Eucalyptus* tree species; and decreased with mean nearest neighbour distance between forest patches, the density of forest patches, and the density of sealed roads. The difference between the effect of habitat area and configuration was not as strong as theory predicts, with the configuration of remnant forest becoming increasingly important as the area of forest habitat declines. We conclude that the area of forest, its configuration across the landscape, as well as the land use matrix, are important determinants of koala occurrence, and that habitat configuration should not be overlooked in the conservation of forest-dependent mammals, such as the koala. We highlight the implications of these findings for koala conservation.

1. Introduction

The conservation of forest mammals, as exemplified by the koala (*Phascolarctos cinereus*), depends upon understanding its ecology in the context of the multiple threats facing forests that are commercially valuable both as timber, as well as for other land uses, such as agriculture, urban areas and roads. The loss and fragmentation of forest habitats by human land

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use are recognised as important factors influencing the decline of forest-dependent fauna (e.g., McAlpine and Eyre, 2002; McGarigal and McComb, 1995; Rochelle et al., 1999). The loss of forests results in a reduction in the area of forest habitat, and fragmentation is the process by which forest habitat is broken apart, independent of pure habitat loss (Fahrig, 1997, 1999, 2003).

Some mammal species that depend upon forest habitats are particularly sensitive to habitat loss and fragmentation (Newell, 1999; Lindenmayer et al., 2000; McAlpine and Eyre, 2002). They are often characterised by highly specific habitat requirements and limited movement capabilities through the land use matrix (Lindenmayer et al., 1990; Incoll et al., 2001). An inability to utilise the matrix makes them particularly vulnerable to the effects of habitat loss and fragmentation (Laurance, 1990, 1991, 1994). Many forest-dependent mammal species (other than bats) also cannot cross, or are reluctant to cross, large areas of cleared land (Bakker and Van Vuren, 2004; van der Ree et al., 2004). Even where individuals do cross cleared areas, they are commonly subjected to elevated mortality due to factors such as predation and vehicle collisions (Goosem, 2004; van der Ree et al., 2004). Hence, the effects of isolation can increase rapidly as forest habitat is fragmented. These factors mean that it is important to understand the implications of habitat loss and fragmentation for forest-dependent mammal species, particularly where human populations continue to clear and fragment forest landscapes.

The koala provides an ideal case study for testing the relative importance of forest area and configuration relative to local (<1 ha) habitat quality. The majority of koala research has focused on habitat quality at the level of the individual tree or vegetation community (e.g., Degabriele, 1983; Cork et al., 1990; Phillips and Callaghan, 2000; Ellis et al., 2002; Moore et al., 2004a,b; Moore and Foley, 2005). Central to these studies is the hypothesis that the distribution of koalas is determined by the distribution of the more nutrient-rich foliage of preferred eucalypt species, especially when these trees occur on more fertile soils (Moore et al., 2004a). However, the effect of forest loss and configuration relative to these fine-scale habitat factors has not been tested. This is an important limitation because the koala has experienced population declines and local extinctions across its geographic range. The major underlying cause of koala decline is clearing of eucalypt forests for agricultural development of inland regions and continuing growth of the human population along the forested eastern coastal fringe (ANZECC, 1998; Melzer and Houston, 2001; Reed and Lunney, 1990). Rhodes et al. (2006) found that habitat area and anthropogenic variables, such as roads and dogs, are important for determining the distribution of koalas in the Port Stephens Shire (coastal New South Wales), but their effects vary spatially according to land use.

Koalas are considered to be sensitive to forest fragmentation, with much of their remaining high quality habitat now fragmented, and surrounded by urban and agricultural land use (Knott et al., 1998; Seabrook et al., 2003). Koalas can move from tree to tree where canopies overlap, but frequently come to the ground to cross non-forest gaps, including cleared land between individual patches of trees (Dique et al., 2003; Lunney et al., 2002; Rhodes et al., 2006). However, to cross gaps, the risk of mortality is much higher. In semi-urban landscapes, roads subdivide habitat, acting as barriers to koala movement, with road deaths recognised as a major source of koala mortality in fragmented urban landscapes (Lunney et al., in press). Dogs also gain a predatory advantage when the koala is forced to travel across open ground, such as when crossing a road or cleared areas.

This study addressed the question: how important are forest area and configuration relative to fine-scale habitat variables, such as tree species, for the occurrence of koalas in a fragmented rural–urban landscape of coastal Southeast Queensland (Australia)? We applied a logistic modelling and hierarchical partitioning approach to test the relative importance of forest area, configuration and roads at the landscape-level (100–1000 s ha), patch-size at the patch-level (1–100 s ha), and soil–substrate and the proportion of primary tree species at the local or site-level, plus the effect of spatial autocorrelation between neighbouring koala survey sites. We show that forest area, forest configuration, and roads at the landscape-level, and the proportion of primary tree species at the site-level, all have strong independent effects on the occurrence of koalas, with the proportion of primary tree species, road density, forest area, and forest mean nearest neighbour distance being the most important predictors.

1.1. *Study species*

The tree is the basic unit of survival for koalas. It has long been recognised that koalas demonstrate marked preferences for a relatively small number of the *Eucalyptus* species in any area (e.g., Phillips and Callaghan, 2000; Phillips et al., 2000; Ellis et al., 2002; Braithwaite, 2004; Moore et al., 2004a,b, 2005; Smith, 2004). Therefore, koala habitat generally consists of forest associations containing the preferred *Eucalyptus* tree species, although other factors, such as tree size, can also contribute to habitat quality (Smith, 2004). Koalas occupy home ranges, which vary widely between populations, and can range from as little as 3 ha in high quality coastal habitats to over 200 ha in semi-arid inland habitats. Although largely solitary animals, the home ranges of males and females generally overlap (Dique et al., 2003). Dispersal occurs at around 1–2 years of age, with dispersal distances of over 10 km being recorded.

2. Methods

2.1. *Study area*

The Study area was Noosa Shire (26.50 S, 152.50 E; 86,823 ha) in coastal southeast Queensland, Australia (Fig. 1). The climate is sub-tropical with vegetation communities ranging from coastal heaths on Pleistocene sand deposits to sub-tropical rainforests and wet eucalypt forests on granite intrusions and volcanic soils, and dry eucalypt forests on alluvium and sandstones (Thompson, 1975). Urban land use is dominant in the coastal southeast, with a mixture of low-density rural-residential and rural land use in the elevated western areas. Much of the remaining, relatively intact koala habitat occurs in State Forests (timber reserves) and National Parks, although the latter are concentrated on infertile sandy soils in the northeast of