Biological Conservation 184 (2015) 174–181

Contents lists available at ScienceDirect

Biological Conservation

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

Reptile abundance, but not species richness, increases with regrowth age and spatial extent in fragmented agricultural landscapes of eastern Australia

C.A. McAlpine [a,*], M.E. Bowen [a], G.C. Smith [b], G. Gramotnev [a], A.G. Smith [a], A. Lo Cascio [a], W. Goulding [a], M. Maron [a]

[a] The University of Queensland, Landscape Ecology and Conservation Group, School of Geography, Planning and Environmental Management, Brisbane 4072, Australia
[b] Department of Science, Information Technology, Innovation and the Arts, Queensland Herbarium, Brisbane 4066, Australia

ARTICLE INFO

Article history:
Received 15 August 2014
Received in revised form 6 January 2015
Accepted 11 January 2015
Available online 12 February 2015

Keywords:
Landscape mosaic
Habitat loss
Fragmentation
Secondary forest
Movement
Vagility

ABSTRACT

The conversion of forested landscapes to agriculture commonly results in three main changes to landscape structure: forest loss, fragmentation, and the creation of novel habitats such as forest regrowth. Here we apply a landscape-level survey design to test how reptiles respond to patterns resulting from these three processes in the Brigalow Belt of eastern Australia, a region highly modified by recent agricultural expansion. We surveyed reptiles in 24 agricultural landscapes (each 2.5 × 2.5 km) that contained mosaics of remnant and regrowth vegetation of various ages and extents. We found that none of the landscape attributes significantly influenced landscape-level species richness of reptiles. On the other hand, the total abundance of reptiles per unit of sampling effort increased with remnant forest extent. In addition, abundance of small-bodied and less-vagile reptiles was positively affected by the extent of old regrowth. Fragmentation did not have important effects on the landscape-level species richness and total abundance of reptiles. Our finding that forest extent is the primary landscape attribute that influences reptiles suggests that, despite expectations to the contrary, the taxon responds in a manner similar to more vagile taxa, such as birds. However, the fact that total abundance but not species richness was the measure that responded suggests different mechanisms are in play. Allowing regrowth forests to regenerate beyond 30 years of age may be a cost-effective strategy for landscape-level conservation of reptiles in this region.

1. Introduction

Landscape change caused by anthropogenic land-use is pervasive in most biomes of the world (Pereira et al., 2004; Ellis et al., 2010). Habitat loss (the removal of habitat) and fragmentation (the breaking apart of habitat) are common elements of landscape change (Fahrig, 2003). A less well-understood form of landscape change is the addition of new or regenerating habitats resulting from changing land-use practices and land abandonment (Bowen et al., 2007; Cramer et al., 2008). Such secondary or regrowth forests, and novel ecosystems that are comprised of exotic and indigenous species, are becoming more widespread, particularly in tropical and sub-tropical regions (Bowen et al., 2007). The consequences of the addition of regrowth forests and novel ecosystems to landscapes for fauna conservation and recovery are receiving increasing attention (Bowen et al., 2007, 2009; Chazdon et al., 2009; Dunn, 2004; Bruton et al., 2013).

Empirical evidence collected at the scale of entire landscape mosaics is critical to understanding of the full effects of these landscape change processes on fauna (Radford et al., 2005; Swift and Hannon, 2010). The large body of research which focuses at the site or patch-scales does not allow landscape-level inferences about emergent properties of whole landscape mosaics (Bennett et al., 2006). These properties are the product of the number, extent, type and spatial arrangement of suitable habitat and land-use elements within a particular landscape (Bennett et al., 2006). Studies of birds suggest that landscape-level species richness in fragmented landscape mosaics is determined primarily by habitat extent, and that most species appear to be less affected by fragmentation (Betts et al., 2007; Radford and Bennett, 2007; Maron et al., 2012). There also is evidence that increasing the amount of regrowth forest in highly-modified landscapes can increase landscape-level bird diversity and abundance of forest-dependent species (Laiolo,

* Corresponding author. Tel.: +61 7 33656620; fax: +61 7 33656899.
E-mail address: c.mcalpine@uq.edu.au (C.A. McAlpine).

http://dx.doi.org/10.1016/j.biocon.2015.01.010
0006-3207/

2005; Bowen et al., 2009). However, our understanding of the relative importance of habitat extent and configuration in both remnant- and regrowth-dominated landscapes is drawn primarily from studies of highly-vagile taxa, such as birds (e.g. Radford and Bennett, 2007; Maron et al., 2012).

Of the vertebrate fauna, reptiles are comparatively poorly studied (Gardner et al., 2007). Globally, nearly one in five reptile species is threatened with extinction and another one in five is classed as data deficient (Böhm et al., 2013). Reptiles are particularly sensitive to habitat loss and degradation because of their comparatively low dispersal ability, morphological specialisation on substrate type, relatively small home-range sizes and thermoregulatory constraints (Kearney and Porter, 2009; Böhm et al., 2013). Whereas more-vagile taxa such as birds can often exploit fragmented habitat at large spatial scales and employ strategies of multiple-patch use, less-vagile reptile species are more likely to be restricted to a single patch (Fischer et al., 2003; Michael et al., 2010). Reptiles' ectothermic regulation makes them particularly vulnerable to temperature stress while traversing a less-hospitable matrix, and their relatively lower mobility may leave them open to predation (Andersson et al., 2010; Fischer et al., 2005). Thus, reptiles may be more vulnerable to the landscape-level effects of fragmentation independent of habitat loss than are birds, and their ability to re-colonise regrowth forests may be poorer.

Studies that have investigated reptile responses to landscape change report varied results. Negative responses to habitat loss and fragmentation have been reported (e.g., Alcala et al., 2004; Bell and Donnelly, 2006; Cardozo and Chiaraviglio, 2008; Driscoll, 2004), while other studies found little evidence of an effect (e.g., Jellinek et al., 2004; Santos et al., 2008; Schutz and Driscoll, 2008). Several studies have shown that reptile species richness and/or abundance in regrowth forests are midway between those of mature forest and cleared land, and the species richness increases with increasing regrowth age (Bowman et al., 1990; Green and Catterall, 1998; Pawar et al., 2004); although a recent study in sub-tropical woodlands found that regrowth habitats had similar species richness and abundance to mature remnant woodlands (Bruton et al., 2013). However, none of these studies explored landscape-level responses of reptiles to changes in landscape structure, including the contribution of regrowth forests at the landscape-level.

This study addressed the question: how do the landscape-level extent of remnant and regrowth forests of different ages, and forest fragmentation, affect the landscape-level species richness and total abundance of reptiles? We also examined patterns of total abundance of reptiles within body size and vagility classes. We predicted that the total abundance and species richness of reptiles would increase with the extent of remnant and old regrowth forest, and that fragmentation will become important only for the less-vagile and smaller bodied reptiles (sensu Fahrig, 2003; Bowen et al., 2007).

2. Methods

2.1. Study region

This study was conducted in the Brigalow Belt South bioregion of Queensland and New South Wales, Australia. It included three broad study areas: Condamine in the north; Tara in the centre; and Moree in the south (Fig. 1). The climate of all areas is sub-tropical with an average annual rainfall of 580 mm; peak rainfall occurs during summer (December, January, February) and the lowest rainfall over winter (June, July, August). Daily summer temperatures range between 18 and 32 °C, but sometimes exceed 40 °C; winter daily temperatures range between 0 and 20 °C. Native vegetation is predominantly brigalow (*Acacia harpophylla*) and eucalypt-dominated forest communities. Brigalow-dominated forests occurring on fertile cracking clay soils have been selectively cleared for dryland cropping and improved pastures for sheep and cattle grazing over the last 100 years (Seabrook et al., 2006). Brigalow forest communities are now listed as endangered, occupying less than 10% of their former range (Sattler and Williams, 1999). However, brigalow forests are highly resilient and readily re-sprout from damaged roots, quickly developing dense stands of regrowth (Johnson, 1964). While regrowth brigalow is floristically similar to the remnant forest (not previously cleared), its structure can differ considerably for long periods of time (Chandler et al., 2007; Johnson, 1964). Across the three study areas, remnant forests represent 9% of the region, regrowth 6%, and the remaining 85% is predominantly livestock pastures or dryland cropland.

2.2. Study design

Each study area was sub-divided into eight 2.5 × 2.5 km square landscapes ($n = 24$) with varying amounts of brigalow forest. The size of these landscapes is representative of the scale of movement of the region's reptiles, and is smaller than the 10 × 10 km square landscapes used by Radford et al. (2005) and Maron et al. (2012) for birds. Within each landscape, three reptile survey sites were located within remnant and regrowth forest using a random stratified design that ensured a range of forest patch sizes were sampled in each landscape. Our study landscapes were originally dominated by brigalow forests, and survey sites were only located within brigalow plant communities, to avoid the potential for non-brigalow habitat preferences to mask or confuse the effects of habitat loss, fragmentation and regrowth forest recovery (e.g., Michael et al., 2010). Sampling within the matrix (e.g., crops or pasture) was not possible due to interference from livestock and farm machinery. Thus, our survey design is similar to a 'multiple samples in a single patch type' mosaic-level sampling design (sensu Bennett et al., 2006), although our sample patches differed in forest age and patch size.

2.3. Reptile surveys

Reptile surveys were conducted by both pitfall trapping and active search methods in the warmer months of the year during two survey periods: December 2007 to April 2008; and September 2008 to April 2009. Each site was surveyed both early and late in the warm season. Pitfall traps were constructed of four 20 litre plastic buckets that were buried with the rim of the bucket level with the ground surface and spaced 5 m apart in a 'T' configuration. To direct reptiles to the traps, a total of 30 m of aluminium flywire drift fence (30 cm high) was positioned along the axis of the 'T', crossing over the centre of the pitfall trap buckets, and extending 5 m either side of each bucket. Pitfall traps were opened for a period of 3 days/nights in each survey period.

Active searches were conducted during daylight hours (morning or afternoon) on each day of the survey periods. A total of six active searches were conducted at each site within a 50 m × 20 m grid, positioned within 50 m of the pitfall traps. Active searches were conducted for 20 person minutes and involved turning logs, peeling loose bark, and searching through leaf litter and in crevices. All animals were released after sampling.

Reptile captures for both survey methods were summed across all surveys in each landscape to provide estimates of total abundance for a given sampling effort. Individuals were not tagged and so total abundance estimates could include re-captures of the same individuals, but the chances of this were similar across all sites and landscapes, and so do not bias the results. A total of 1034 reptiles from 46 species was recorded across the 24