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Tropical reptiles in pine forests: Assemblage responses to plantations and plantation management by burning

Beth Mott [1], Ross A. Alford, Lin Schwarzkopf *

School of Marine and Tropical Biology, James Cook University, Townsville, Queensland 4810, Australia

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ABSTRACT

Worldwide, the land area devoted to timber plantations is expanding rapidly, especially in the tropics, where reptile diversity is high. The impacts of plantation forestry and its management on native species are poorly known, but are important, because plantation management goals often include protecting biodiversity. We examined the impact of pine (*Pinus caribaea*) plantations, and their management by fire, on the abundance and richness of reptiles, a significant proportion of the native biodiversity in tropical northern Australia, by (i) comparing abundance and diversity of reptiles among pine plantations (on land cleared specifically for plantation establishment), and two adjacent native forest types, eucalypt and *Melaleuca* woodlands, and (ii) comparing reptile abundance and richness in pine forest burnt one year prior to the study to remove understorey vegetation with pine forest burnt two years prior to the study. We also examined the influence of fire on reptile assemblages in native vegetation, by comparing eucalypt woodland burnt two years prior to the study and unburnt for eight years. To quantify mechanisms driving differences in reptile richness and abundance among forest types and management regimes, we measured forest structure, the temperatures used by reptiles (operative temperature) and solar radiation, at replicate sites in all forest types and management regimes. Compared to native forests, pine forests had taller trees, lower shrub cover in the understorey, more and deeper exotic litter (other than pine), and were cooler and shadier. Reptile assemblages in pine forests were as rich as those in native forests, but pine assemblages were composed mainly of species that typically use closed-canopy rainforest and prefer cooler, shadier habitats. Burning did not appear to influence the assemblage structure of reptiles in native forest, but burning under pine was associated with increased skink abundance and species richness. Burned pine was not warmer or sunnier than unburned pine, a common driver of reptile abundance, so the shift in lizard use after burning may have been driven by structural differences in understorey vegetation, especially amounts of non-native litter, which were reduced by burning. Thus, burning for management under pine increased the abundance and richness of lizard assemblages using pine. Pine plantations do not support the snake diversity common to sclerophyllous native forests, but pine may have the potential to complement rainforest lizard diversity if appropriately managed.

1. Introduction

Presently, both native forests and plantations are used to provide the world's timber needs, but a growing proportion of the world's timber is sourced from plantations (FAO, 2007; Hartley, 2002). There has been a shift in thinking about the role of plantations globally in the last 15 years, with many forestry agencies identifying biodiversity conservation as a management priority, and moving towards managing plantation forests to fulfill multiple roles, including timber production and biodiversity conservation (e.g., Hartley, 2002; McDonald and Lane, 2002; Lindenmayer and Hobbs, 2004; Scott et al., 2006; The Australian Forestry Standard, 2007). An understanding of biodiversity in timber plantations, and factors that control it, is critical to this approach.

Pine (*Pinus* spp.) plantations comprise 15% of the world's plantation timber (FAO, 2007), and nearly 51% of the 1.9 million hectare plantation estate in Australia (Gavran and Parsons, 2009). There is a significant (albeit declining) rate of native forest clearing currently occurring in Australia, with 260,000 hectares of forest cleared yearly between 2000 and 2004 (Montreal Process Implementation Group for Australia, 2008). Pine plantations continue to expand in Australia, with 6038 new hectares planted in 2008, 12% of the total area of new plantations established (Gavran and Parsons, 2009). While in Australia new plantations are increasingly established on previously cleared land, elsewhere in the world land is cleared specifically for the purpose of plantation

* Corresponding author. Tel.: +61 0417201256; fax: +61 47251570.
E-mail address: lin.schwarzkopf@jcu.edu.au (L. Schwarzkopf).
[1] Present address: School of Biological Sciences, University of Wollongong, Northfields Ave., Wollongong, NSW 2522, Australia.

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development (FAO, 2007), as was usually the case in Australia until recently. The Australian forestry future plan is to treble the area of plantations by 2020 (Mercer and Underwood, 2002). There is much conservation concern about the value of reforestation with plantations for maintenance of biodiversity, especially in tropical forests, where much of the world's biodiversity resides (e.g., Kanowski et al., 2005; Lindenmayer and Hobbs, 2004). Outside Australia, much of this concern centers around reforestation with *Eucalyptus* sp. in areas where they are non-indigenous (Turnbull, 1999). Within Australia, there is longstanding concern about the effects on biodiversity of the historical replacement of native forest with exotic *Pinus* sp., and about the conservation value of exotic monoculture plantations for tropical fauna in the current landscape mosaic (reviewed by Lindenmayer and Hobbs, 2004; Kanowski et al., 2005).

Amazonian and Indo-Malayan rainforests are being destroyed more quickly than they can regenerate (FAO, 2007), but rainforests in other, more developed countries, such as Australia, are also affected (Kanowski et al., 2005). In many areas, plantations of non-native trees, particularly *Eucalyptus* and *Pinus* species (FAO, 2007), have replaced tropical rainforests (Kanowski et al., 2005), or are currently favored as a means of afforesting land adjacent to rainforest (Zanne and Chapman, 2001; Ashton et al., 1997).

With the disappearance of tropical forests, or their replacement by plantations, there is an associated loss of faunal biodiversity (Kanowski et al., 2005). Reptiles are an important element of the fauna in tropical forests worldwide, but their responses to tropical forest management are poorly understood (Alcala et al., 2004; Trainor and Woinarski, 1994; Gardner et al., 2007b; Cunningham et al., 2007). Reptile populations are especially sensitive to manipulations of the structure of vegetation communities (Vitt et al., 1998; Kavanagh and Stanton, 2005; Gardner et al., 2007a; Brown et al., 2008). Because plantation management strongly alters vegetation structure (McCullough, 1999), solar radiation levels, and environmental temperatures (Yirdaw and Luukkanen, 2004; Lemenih et al., 2004), the response of reptiles to plantations may be driven by their response to these environmental changes (Jäggi and Baur, 1999; Valentine, 2006). Understanding the mechanisms driving reptile responses to plantations will improve the ability of managers to assess the influence of changes to management regimes on reptile populations.

Specific aspects of management (e.g., burning, leaving slash and other coarse woody debris, etc.) are critical to maintaining faunal diversity in plantations (Wagner et al., 2004; Kanowski et al., 2005). This is particularly true when non-native trees are used for reforestation, because they are even less likely to support diverse faunal assemblages than are native plantations (e.g., Lindenmayer and Hobbs, 2004). Low-intensity burning is commonly used to control fuel load, weeds and understorey vegetation in plantations (Woods, 1990; Richardson, 1993) and native forests (Penman et al., 2007). Fire changes the structure of the vegetation (Gill, 1981; Singh et al., 2002), and can influence the size and dynamics of associated animal populations (e.g. Kutt and Woinarski, 2007), so burning for management can strongly affect biodiversity within plantations. Results from the few studies that have described the specific effects of burning regimes on ground-associated fauna have identified significant changes in species richness, and species-specific variability in response (Trainor and Woinarski, 1994; Penn et al., 2003). However, research that deals with the response of tropical reptile communities to management-associated control burning in plantations is scarce.

We compared the species richness and structure of tropical Australian diurnal reptile assemblages between native forests and plantations of *Pinus caribaea*. In our study, pine plantations were managed by low-intensity fuel reduction burning under the trees, a practice that alters understorey vegetation structure in native forests (Singh et al., 2002). Because reptiles are likely to be sensitive to such changes, we examined how burning in plantations affected reptile assemblage structure, and compared it to the influence of natural fire in native habitats. Finally, we examined the relationships between reptile abundance and richness, the amount of sunlight reaching the ground, and available thermal microclimates, in burnt and unburnt plantations and natural forest. By comparing these factors between plantations and native forests, we aimed to identify what effect plantations, and management within these, had on the structure of a tropical reptile assemblage.

2. Methods

2.1. Study sites

This study was conducted between August 1996 and March 1997 at Broadwater, Abergowrie State Forest logging area, in the northern Queensland tropics (18°28′S, 146°2′E), 47 km west of Ingham. The area is used primarily for the production of Caribbean pine (*P. caribaea*), which is grown as a monoculture. Pine plantations were established on land cleared of both rainforest and eucalypt woodland for plantation development, and were 14–15 years old. Native vegetation adjacent to pine plantations included paperbark (*Melaleuca viridiflora*) and blue gum (*Eucalyptus tereticornis*) woodlands, as well as riparian lowland rainforest connected to the southern end of the Wet Tropics bioregion. All sites established in the study were similar in aspect, slope and elevation. We described the reptile assemblages and vegetation structure in pine, eucalypt and *Melaleuca* forests. Rainforest was excluded from sampling as patches of this vegetation type were either radically different in slope and aspect from the rest of the forest types sampled, or occurred only in riparian strips.

We established two field sites in each of five habitat types: pine burnt 25 months before the study commenced (so-called "unburnt" pine sites), pine burnt 13 months before commencement of the study (burnt pine sites), eucalypt woodlands unburnt for eight years before our study (unburnt eucalypt sites), eucalypt woodlands burnt 22 months before the study commenced (burnt eucalypt sites), and *Melaleuca* woodland that had been burnt by a high intensity fire approximately 10 years earlier. Fires in eucalypt and pine (controlled burn) sites were of low intensity, with flames reaching no higher than 20 cms (G. Featonby, personal communication). Sampling areas were approximately 100 ha in size, were established at least 100 m apart, and were surrounded by forest of the same origin. Each site was at least 80 m from any forest edge, to minimize edge effects. As we could not orthogonally match fire histories of different forest types, or accurately date the last burning of the *Melaleuca* forest, investigations of effects of burning on reptiles and plant assemblage structures were restricted to within-forest comparisons in pine and eucalypt. Replication of field sites was necessarily limited in this study by the availability pine plantations and eucalypt forests in the study area that had experienced comparable fire intensity and time since burning.

2.2. Vegetation microhabitat descriptions

To characterize the vegetation structure in different forest types with different burning histories, four parallel transects 80-m long and 25-m apart were located at each site. Four 5-m^2 quadrats were randomly sampled from each transect three times during the study. Tree height was recorded with a range finder and crown separation was estimated using the methodology and photographs described by McDonald et al. (1990). One observer (BM) produced visual estimates of the following ground-level microhabitat features in each quadrat: shrub cover, leaf litter cover and depth, leaf litter composition (% non-native litter excluding pine needles),