Department of
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Environment

Ecological effects of repeated low-intensity fire on reptile populations of a mixed eucalypt foothill forest in south-eastern Australia

Research report no. 65

Effects of repeated low-intensity fire on reptile populations of a mixed eucalypt foothill forest in south-eastern Australia

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Foreword

The vegetation, topography and climate of south-eastern Australia combine to make the region one of the most wildfire-prone areas on Earth. Over tens of thousands of years, naturally occurring fires have been highly significant in shaping the distribution and composition of much of the region's native flora and fauna. The arrival of humans here is also considered to have had a more recent influence on these evolutionary processes. Paradoxically, it has been estimated that, in the last one hundred years, two-thirds of all human deaths related to bushfires in Australia and more than half of all significant related property losses have occurred in Victoria.

The severity of a bushfire depends on topography, weather and fuel conditions. Fuel is the only factor over which a land manager can exert some control. The strategic use of prescribed fire (under specified environmental and fire behaviour prescriptions), generally in spring or autumn, is the only practical method of reducing fuels over significant areas and has been a key component of park and forest management in Victoria since the late 1950s – early 1960s.

The threat posed by fire to life and property and the relationship between fire regimes and biodiversity are arguably the key on-going issues confronting the managers of Victoria's parks and forests.

In 1984, a multidisciplinary study was established in the Wombat State Forest, 80 km north-west of Melbourne (Victoria), to investigate the effects of repeated low-intensity prescribed burning in mixed eucalypt foothill forest. The study—the Wombat Fire Effects Study—is quantitative and statistically based and includes various aspects of fauna, flora, soils, tree growth, fuel management and fire behaviour.

On the same permanent plots, various methodologies are used to investigate the ecological impacts of fire on understorey flora, invertebrates, birds, bats, reptiles, terrestrial mammals, soil chemistry and the growth, bark thickness and defect development in trees. Local climate and weather, fuel dynamics and fire behaviour are also studied, along with their interactions. Numerous published papers and reports have been produced as a result of the work. Fire Management Research Reports comprising the current (2003) series are:

No.	Title
57.	Ecological effects of repeated low-intensity fire in a mixed eucalypt foothill forest in south-eastern Australia - Summary report (1984–1999) - Department of Sustainability and Environment
58.	Effects of repeated low-intensity fire on the understorey of a mixed eucalypt foothill forest in south-eastern Australia - K.G. Tolhurst
59.	Effects of repeated low-intensity fire on fuel dynamics in a mixed eucalypt foothill forest in south-eastern Australia - K.G. Tolhurst & N. Kelly
60.	Effects of repeated low-intensity fire on carbon, nitrogen and phosphorus in the soils of a mixed eucalypt foothill forest in south-eastern Australia - P. Hopmans
61.	Effects of repeated low-intensity fire on the invertebrates of a mixed eucalypt foothill forest in south-eastern Australia - N. Collett & F. Neumann
62.	Effects of repeated low-intensity fire on bird abundance in a mixed eucalypt foothill forest in south-eastern Australia - R. Loyn, R. Cunningham & C. Donnelly
63.	Effects of repeated low-intensity fire on terrestrial mammal populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, M. Westbrooke & M. Gibson
64.	Effects of repeated low-intensity fire on insectivorous bat populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, P. Prevett & M. Westbrooke
65.	Effects of repeated low-intensity fire on reptile populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, M. Westbrooke & M. Gibson

66. Effects of repeated low-intensity fire on tree growth and bark in a mixed eucalypt foothill forest in south-eastern Australia - K. Chatto, T. Bell & J. Kellas

The foreword to the summary report (Fire Management *Research Report* No. 57) sets out more fully the background to the research, the impact it has had on fire management in the State and the future of the program.

I would like to acknowledge the very considerable efforts of the scientists and technical officers who have contributed to this specific report and more generally to this most significant project.

Gary Morgan AFSM

CHIEF FIRE OFFICER
Department of Sustainability and Environment

2003

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Summary

Detailed ecological studies of Australian reptiles remain relatively rare, which impacts significantly on the community's ability to develop appropriate strategies to conserve them. Most information related to the effects of fire on reptiles has been from studies in mallee woodlands, heathlands and northern Australian savanna forests, where reptilian diversity is high. Few studies have been undertaken in southern temperate areas.

Reptiles were studied in three of five Fire Effects Study Areas (FESAs) in the Wombat State Forest. The aim of this study was to determine the effects of repeated low-intensity prescribed fire on the forest ecosystem, including reptiles. Five burning treatments were replicated in each FESA: long-unburnt, short-rotation spring burnt, short-rotation autumn burnt, long-rotation spring burnt and long-rotation autumn burnt.

Research on reptiles was conducted over the period 1985–94 by various students from Ballarat University. During this period, eight species of skinks and one species of elapid snake were observed. However, only five species of skink were observed in sufficient numbers to make any judgment on the effects of the burning treatments.

Four standard herpetological survey techniques were used by the researchers: pitfall-driftline trapping, opportunistic searching, transect counts and stationary census counts. Of these, the stationary census counts technique proved to be the most successful method in the foothill forest environment.

The abundance of the Southern Water Skink (*Eulamprus tympanum*) remained relatively stable following both spring and autumn fires. This is likely to be due to the abundance and condition of its primary habitat—fallen logs and branches—which was not significantly affected. Conventry's Skink (*Pseudemoia conventryi*) and Grass Skink (*Pseudemoia entrecasteauxii*) numbers were both significantly different between burning treatments. Numbers of both species were significantly less in burnt treatments than in the long-unburnt control; the most notable were the frequently burnt spring treatments, 32 months after burning and the frequently burnt autumn treatments, 18–32 months after burning. These species were found to forage in the grass/herb and litter layers—the microhabitats most affected by burning. McCoy's Skink (*Nannoscincus maccoyi*) was most common after burning, but this was probably due to the removal of its normal habitat—the surface litter. McCoy's Skink is a cryptic species and very difficult to find in unburnt areas. Garden Skink (*Lampropholis guichenoti*) inhabits moist gully areas; areas not frequently prone to low-intensity burning. This species was affected by the burning treatments only when a significant amount of the gully vegetation was burnt.

Fallen logs and unburnt litter are important refuges from fire. The small-scale mosaic of burnt and unburnt patches that generally result from low-intensity prescribed burning are crucial to local reptile survival and recolonisation.

Background

In 1984, the then Forest Commission of Victoria initiated a research program in response to growing community concern about the ecological effects of repeated fuel reduction burning. This research program looked at the effects of repeated low-intensity prescribed fire on the main elements of a mixed eucalypt foothill forest ecosystem in Wombat State Forest, west-central Victoria.

The Wombat Fire Effects Study comprises five replicated Fire Effects Study Areas (FESAs) established at Barkstead, Blakeville, Burnt Bridge, Kangaroo Creek and Musk Creek within the Wombat State Forest. Five Treatment Areas were established within each FESA, comprising:

- frequent fires (approximately every three years) in spring—short-rotation spring, S3
- frequent fires (approximately every three years) in autumn—short-rotation autumn, A3
- infrequent fires (approximately every 10 years) in spring—long-rotation spring, S10
- infrequent fires (approximately every 10 years) in autumn—long-rotation autumn, A10
- fire exclusion (unburnt for more that 20 years)—long-unburnt control, C.

A full description of the program design and methodology is provided in Tolhurst (1992).

This report is a review of studies on reptiles undertaken by the University of Ballarat as part of the above research program.

Program objectives

- To assess and describe the effects of repeated fuel reduction burning in both spring and autumn and applied on short and long rotations (five fire treatments) on the composition and abundance of reptilian species.
- To have these findings incorporated into the Department of Sustainability and Environment’s fire protection and land management plans, policies and operations.

Introduction

The taxonomic description of herpetofauna has increased rapidly in recent years, with over 950 species now recognised in Australia. The Atlas of Victorian Wildlife records 21 reptile species within the foothill forest of the study area discussed here, including 12 skink, seven snake and two dragon species.

The largest family of Australian lizards is the Scincidae, encompassing species with a wide variety of body form, size and habits. Although most skinks are diurnal, many are nocturnal or crepuscular (Cogger 1994).

Thermoregulation

Reptiles are ectothermic, that is, they regulate their body temperature through their surrounding environment. Lizards that bask and use the sun as a heat source are called heliotherms. Shuttling heliotherms control their body temperature almost entirely by relocation, constantly moving between sun and shade when active. Posturing heliotherms tend to stay in a preferred area, but reduce or increase heat uptake by altering the preferred angle of the body to the sun, or adopt heat-absorbing or retarding postures (Hutchinson 1993). Species that track the temperature of the immediate environment by selecting substrates of a particular temperature are known as thigmotherms (Heatwole & Pianka 1993).

Reproduction

The Scincidae use several methods of reproduction. Skinks can be oviparous (egg laying), ovoviviparous (live young with no direct connection between foetus and mother) or viviparous (live-bearing with some form of placental connection between mother and embryo) (Cogger 1994). Oviparous species may require various microhabitats to provide suitable sites for oviposition.

Longevity

Few Australian skinks have been the subject to detailed life history studies. (Hutchinson 1993). In a study by Joss and Minard (1985), the breeding biology of *Lampropholis guichenoti* was found to have a demographic pattern of rapid maturity and high turnover, with no animals found to be as old as two years. In cool areas *L. guichenoti* grows more slowly and lives longer than in warm areas, possibly reflecting the shorter periods of activity. However, not all skinks follow this rapid-growth – high-turnover strategy. For example, Hudson (1989) found *Bassiana duperreyi* and *Pseudemoia pagenstecheri* mature slowly and are long-lived. Some may breed in their first year, while others take two years to mature. However, once mature, adults have a relatively long life expectancy—up to seven years (Hudson 1989). Tilley (1984) found that, although mortality is apparently severe, adult *Eulamprus tympanum* may survive for 15 years. Larger skinks, such as *Egernia cunninghami*, may take five years to mature. Bull (1987) estimated *Trachydosaurus rugosa* to mature in three years, and may survive for 20 years.

Ecology and fire

Detailed ecological studies of Australian reptiles remain relatively rare, which impacts significantly on the community's ability to develop appropriate strategies to conserve them (Cogger 1993). Most information about the impact of fire on reptiles has been derived from studies in mallee woodlands, heathlands and northern Australian savanna forests, where reptilian diversity is high. Few studies have been undertaken in southern temperate areas (Wilson 1996).

Australian skinks make use of the full range of habitats occupied by terrestrial vertebrates, with the possible exception of the outer tree canopy (Hutchinson 1993). Much of the physical forest habitat is at least partially consumed as fuel for fires. The degree to which different microhabitats are modified by a fire event, and the rate of its recovery in the post-fire period, will determine the impact of the fire and fire regime on different species (Wilson 1996). Members of the *Egernia whitii* species group are able to construct quite complex burrow systems (Hutchinson 1993) and may retreat from the immediate impacts of fire. Similarly, individuals of *Delma impar*, an endangered species, may also survive fire by burrowing. However, the loss of vegetation cover may threaten any survivors due to heat stress or vulnerability to predators (Wilson 1996).

Reptile research in the Wombat State Forest

Four reptile studies were developed within the framework of a long-term fire effects study in the Wombat State Forest in west-central Victoria (Tolhurst 1992). Early observations in the mixed eucalypt foothill forest of this area provided a partial species list for the Blakeville Fire Effects Study Area—FESA (Shultz 1985 unpublished). Lilley (1989 unpublished) added to the Blakeville FESA data and made further observations at the Barkstead and Musk Creek FESAs. Data collected by Lilley and Shultz were incorporated into a progress report (Humphries 1992) and Masters thesis (Humphries 1994). Moody (1991) studied the effects of fire on reptiles, but limitations relating to sample size meant few conclusions could be drawn from this data alone. By grouping data sets and comparing them with Humphries (1994) some trends were identified. An Honours thesis (Scuffins 1994) and Masters thesis (Humphries 1994) are the most comprehensive reptile studies within this fire effects research program. Both studies examine the effects of prescribed fire on reptile populations; Humphries investigating the effects of single fire treatments and Scuffins investigating effects of repeated fire treatments.

The fire effects research reported here related reptile species to microhabitats present within five different treatment areas at each of the five study areas throughout the forest (Tolhurst 1992). The fine and heavy fuels that were temporarily removed by fire are part of the habitat required by oviparous reptile species for thermoregulation, shelter, food and oviposition sites (Rawlinson 1971). The effect that fire had on these microhabitats was related to the effect fire had on each species through observations of reptiles prior to, and following, fuel reduction burning. Humphries (1994) summarised the relationship between five reptile species and their reproductive biology and microhabitat use (Table 1).

Table 1 Ecological data for scincid species studied (Humphries 1994)

Nomenclature follows Cogger (1994). Data for thermoregulation and reproduction after Rawlinson (1971). Data on microhabitat preference is from field observations by Humphries (1994).

Species	Method of thermoregulation	Mode of reproduction	Microhabitat
Nannoscincus maccoyi (Maccoy's Skink)	Thigmotherm	Oviparous	burrow/litter
Lampropholis guichenoti (Garden Skink)	Shuttling heliotherm	Oviparous	litter/logs
Pseudemoia coventryi (Coventryi Skink)	Shuttling heliotherm	Viviparous	litter/logs
Pseudemoia entrecasteauxii (Grass Skink)	Shuttling heliotherm	Viviparous	litter/logs
Eulamprus tympanum (Southern Water Skink)	Posturing heliotherm	Viviparous	logs/litter

Research objectives

The main objective of the Humphries (1994) study was to assess the impact of single spring and autumn prescribed fires on the ecology of reptiles. The short-term fire responses of five common scincid lizards to single spring and autumn low-intensity prescribed fires were examined. The main aim of the work by Scuffins (1994) was to determine the effects of repeated spring and autumn fuel reduction burning on populations of reptiles as well as their activity patterns and microhabitat utilisation. Scuffins (1994) also tried to relate abundance data to habitat variables. The effects of fuel reduction burning on reptiles at the Blakeville and Barkstead FESAs were also studied by Moody (1991). Scufffins (1994) collected data from all five FESAs.

Methods

A number of standard herpetological survey techniques were used by researchers in this study, including:

- pitfall-driftline trapping
- opportunistic searching
- transect counts
- stationary census counts.

Varying success rates were recorded for each of these techniques. Stationary census counts proved to be the most effective method in the foothill forest environment. The ecological information recorded with each survey technique included the vegetation community type, microhabitat, air and soil temperatures, cloud cover and the activity of the reptile.

Study areas are fully described in Tolhurst (1992) and experimental techniques are described in Humphries (1994), Scuffins (1994) and Moody (1991). The particular FESAs each author utilised for research are listed in Table 3.

Pitfall-driftline trapping

Pitfall-driftline trapping comprises a line of containers (pits) dug into the ground. Fauna are guided towards the pits by a small mesh fence approximately 20 cm high (the driftline). The fence is erected between and over the centre of 5–15 pits. The pits are dug at intervals of between 5 and 10 m. Reptiles, and sometimes other fauna, fall into the containers and become trapped. Traps were opened on days when the temperature exceeded 15 ºC; they were not baited and were checked twice daily. Captured fauna were released 10 m away from the drift line.

Humphries (1994) established pitfall-driftline traps in the control, spring fire and autumn fire treatment areas at the Musk Creek FESA. Due to low capture rates of a limited number of species, Humphries (1994) concentrated his survey effort towards walked transects and, later, stationary census counts. Moody (1991) also used pitfall-driftline traps at Blakeville and Barkstead FESAs in the spring, autumn and control treatment areas.

Voucher specimens of each species captured by Humphries (1994) were retained and lodged with the Museum of Victoria.

Opportunistic searching

Opportunistic sightings and data collecting were undertaken in each FESA (Moody 1991; Scuffins 1994; Humphries 1994). To ensure inactive and cryptic species were detected, all available microhabitats were searched (that is, under or in logs, under bark, discarded roofing iron, rocks, etc.).

Transect counts

Humphries (1994) employed transect counts to standardise reptilian abundance. Standard transects of approximately 1 km in length and 45 minutes duration were conducted in the control, single spring and single autumn treatments at the Blakeville, Barkstead and Musk Creek FESAs. The order and direction of transects varied from day to day, but all transects were walked at approximately similar times of the day and within similar temperatures ranges and cloud cover over the study period. All active reptiles within 5 m of the transect line were recorded during these transect counts. Microhabitats were also searched to detect inactive and cryptic species.

A total of 117 walked transects were conducted between April 1985 and April 1989 in the three FESAs studied. Unpublished transect data by Lilley (1989) and Shultz (1985) were incorporated into the results (Humphries 1994).

Stationary census counts

This involves reptile observations within defined quadrats of 20-m diameter. All reptiles observed within each quadrat over a 15-minute period were recorded. To detect inactive and cryptic species, active searching (slowly moving around, searching under debris) was undertaken in each quadrat at the end of the census period. During stationary census counts particular attention was paid to reptiles basking on logs, heads protruding from cracks and hollows in logs and stumps, and individuals foraging in bark at the base of trees and thick grass tussocks.

Moody (1991) and Scuffins (1994) also used stationary census counts. Following the 15-minute census period Scuffins, as well as searching underneath rocks and logs, used a rake to search through litter microhabitats.

Censuses were conducted only when the air temperature exceeded 15 ºC and in localities which were well-lit by the sun. Censuses were conducted between 1000–1700 hrs. At the completion of each census, cloud cover and temperature were recorded.

Schultz (1985) conducted 71 counts of 15 minutes within all five treatment areas at the Blakeville FESA in April 1985. Humphries (1994) incorporated this work into his study as part of his pre-burn data, adding a further 15 counts from between November l987 and January 1988 in the three treatment areas studied at Musk Creek FESA.

Microhabitats

At each of the 112 census sites at Musk Creek FESA, Humphries (1994) estimated the percentage cover of each microhabitat by line intercept (Brower et al. 1990), with an average of five lines, each 1 m long, per site. Seven microhabitats were recognised (Table 2). Scuffins (1994), having identified the same microhabitats as Humphries (1994), used a set of standard charts for comparison of percentage cover (McDonald et al. 1984). This method allowed all sites to be assessed efficiently. The use of each microhabitat by dominant lizard species was determined during the census counts at Musk Creek FESA by Humphries (1994), Blakeville and Barkstead by Moody (1991), and all five FESAs by Scuffins (1994).

Table 2 Microhabitats used for analysis by each researcher

Moody (1991)	Humphries (1994)	Scuffins (1994)
• litter	• litter	• litter
• plant ground cover	• herbs and gasses	• herbs and grasses
• logs	• shrubs < 1 m tall	• shrubs < 1 m tall
• bare ground (not used by reptiles)	• logs	• logs
	• stumps	• stumps
	• bare ground	• bare ground
	• rock	• rocks

Microhabitat use – repeated fire treatment

Scuffins (1994) tested the variation between reptile population estimates due to the effects of treatment. Correlations between each of the microhabitats and the frequency of captures or observations were made to determine broad habitat preferences.

Scuffins (1994) analysed the effect of temperature on reptile species from each treatment. Variation between temperature and cloud cover (a variable which affects the activity patterns of reptiles) between treatments was also analysed in an attempt to identify which factor most influenced the number of reptiles recorded. Scuffins (1994) also tested the proportion of dissimilarity using a simplified polar ordination technique whereby a reasonable prior knowledge of environmental gradients is assumed (Ludwig & Reynolds 1988). Data was pooled for this analysis.

Nomenclature

Cogger (1994) provides a revised account of Australian herpetofauna. All species names have been updated for this report based on this classification. The Appendix provides recent synonyms for scientific names of all reptiles species recorded.

Results

Species

Humphries (1994) recorded eight scincid lizard species and one elapid snake from the three FESAs (Table 3). He captured 529 individual reptiles using stationary census counts and walked transects. Basic ecological data for the five skink species for which adequate abundance data were obtained are shown in Table 1. The number of species recorded varied between FESAs, ranging from four at Barkstead to six at Blakeville. All species observed in control or pre-burn treatment blocks were also observed after both spring and autumn burning. Due either to their cryptic habits or low abundance, not all species were detected by walked transects or stationary census counts.

Scuffins (1994) recorded a total of 418 individuals, comprising five species of lizards, (Table 3) from the five FESAs. The number of species varied little between sites, with the three dominant species (*P. entrecasteauxii*, *P. coventryi* and *E. tympanum*) being present at all five FESAs. An opportunistic sighting of a single specimen of *Tiliqua nigrolutea* was made in the S10 treatment at Blakeville and five *Lampropholis guichenoti* were recorded by Scuffins (1994). These numbers were not statistically significant.

Using three survey methods at Blakeville and Barkstead FESAs, Moody (1991) recorded 103 individuals of five species (Table 3) from three different microhabitats. A single record of *Pseudechis porphyriacus* was discarded during analysis. Moody identified four microhabitats (Table 2).

During opportunistic searches, Moody (1991) measured several abiotic factors that were potentially important in reptile activity: air temperature, soil temperature and cloud cover. She found that reptiles were most active when soil temperature was between 15 °C and 25 °C, air temperature was 20–30 °C and there was little or no cloud cover.

Microhabitat preferences

Scuffins (1994) found significant differences in microhabitats between treatments. Figure 1 illustrates the observed microhabitat use of the three reptile species used in this analysis. The percentage cover of grasses and herbs was significantly different at Musk Creek, with pooled data for all five FESAs indicating an overall significant difference in grass/herb cover between treatments. Scuffins also found that, (based on pooled data) litter cover was significantly different between treatments. Bare ground also showed a significant difference between treatments, with less bare ground in control sites, S10 and A10 treatments respectively. Greater amounts of bare ground were found in the S3 and A3 treatments.

Scuffins (1994) showed *P. coventryi* numbers were positively linearly correlated with the abundance of grasses and herbs in the A10 treatments. Weak correlations were found between *P. coventryi* and grass/herb cover in S10 treatment and the control. Weak correlations also existed with litter in S3 treatments.

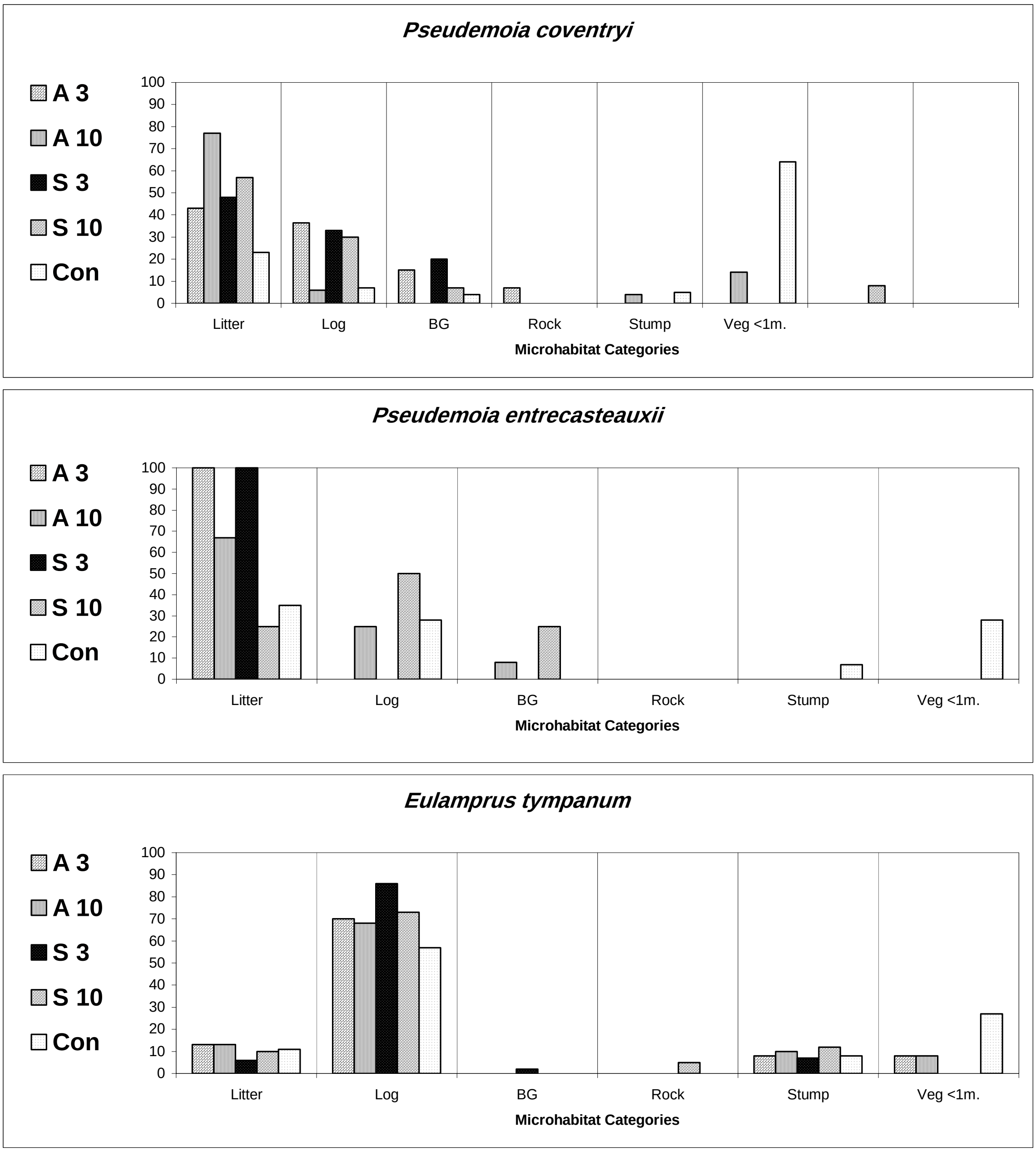
With the exception of a weak negative correlation between *E. tympanum* and litter in the S10 treatments, Scuffins (1994) found only a weak positive correlation with grass and herb cover in the same burning regime.

Pseudemoia entrecasteauxii observations were weakly correlated with the abundances of grasses and herbs in the A10 and control treatments. This species also showed a weak negative correlation with litter in A10, S10 and control treatments.

Table 3 Reptile species recorded from surveys and survey techniques

Researcher	Fire Effects Study Area	Method	Survey period	Species recorded	
				Scientific name	Common name
Moody (1991)	Blakeville *	Pitfall-driftline	**All methods**: 1991 with the use of some data of Humphries (1994).	*Pseudemoia coventryi*	Coventry's Skink
	Barkstead *	Transect searching		*Pseudemoia entrecasteauxii*	Grass Skink
		Stationary census		*Nannoscincus maccoyi*	Maccoy's Skink
				Pseudechis porphyriacus	Red-bellied Black Snake
				Eulamprus tympanum	Southern Water Skink
Humphries (1994)	Blakeville	Pitfall-driftline	**Pitfalls**:	*Egernia whitii*	White's Skink
	Barkstead	Walked transects	Dec 1986–Mar 1987	*Lampropholis guichenoti*	Garden Skink
	Musk Creek *	Opportunistic		*Pseudemoia coventryi*	Coventry's Skink
		Stationary census	**Transects**:	*Pseudemoia entrecasteauxii*	Grass Skink
			April 1985–April 1989	*Nannoscincus maccoyi*	Maccoy's Skink
				Pseudechis porphyriacus	Red-bellied Black Snake
			Census:	*Eulamprus tympanum*	Southern Water Skink
			Shultz: April 1985 Humphries: Nov 1987–Jan 1988	*Tiliqua nigrolutea*	Blotched Blue-tongued Lizard
				Tiliqua scincoides	Eastern Blue-tongued Lizard
Scuffins (1994)	Blakeville	Opportunistic	**Census**:	*Pseudemoia coventryi*	Coventry's Skink
	Barkstead	Stationary census	Jan–May1994	*Pseudemoia entrecasteauxii*	Grass Skink
	Burnt Bridge			*Lampropholis guichenoti*	Garden Skink
	Musk Creek			*Eulamprus tympanum*	Southern Water Skink
	Kangaroo Creek			*Tiliqua nigrolutea*	Blotched Blue-tongued Lizard

Taxonomy is consistent with Cogger (1994).
**Pitfall-driftline traps used at these fire effects study sites only.*



A = autumn fire; S = spring fire; Con = control (long unburnt); 3, 10 = planned interval in years between burning treatments.

Microhabitat variables are: Litter = litter; Log = logs; BG = bare ground; Rock = rocks; Stump = tree stump; Veg < 1 m = vegetation less than one metre in height.

Figure 1 Microhabitat use (% of observations) by *P. coventryi*, *P. entrecasteauxii* and *E. tympanum* in all treatments
Source: Scuffins 1994

Lizards were most often recorded in the litter layer or on fallen logs (Fig. 1), however differences in microhabitat preferences were observed between species (Humphries 1994; Scuffins 1994). *Pseudemoia coventryi* displayed a distinct preference for the litter layer in the control—65% of observations, compared with 22% of observations on fallen logs (Humphries 1994). Humphries also showed the reverse association with *E. tympanum*—74% on fallen logs and 19% in the litter layer. These results are comparable to those obtained by Pengilley (1972) and Webb (1985).

All but one observation of *Nannoscincus maccoyi* were sheltering in damp soil and under logs. Jenkins and Bartell (1980) and Robertson (1981) describe the habitat of this species as deep, moist litter and water-soaked logs.

Reptiles used three of the four microhabitats (Table 2) identified by Moody (1991). Litter and logs were by far the most commonly used microhabitats in the spring, autumn and control treatments. In the control, 88% of *E. tympanum* were found amongst logs and branches with more than 70% of both *P. coventryi* and *P. entrecasteauxii* in the litter layer.

Effect of fire on microhabitats

At the Musk Creek FESA, Humphries (1994) found litter, grass/herbs and shrubs less than one metre in height formed more than 90% of the cover in the control. Thirteen months after the spring burn, the litter cover was similar to that in the unburnt control, but the grass/herb and shrub cover remained reduced (9% less bare ground in the control than the spring treatment). Nine months after autumn burning, litter cover was 35% lower than in the control, and bare ground was 13% less than the control.

Tolhurst et al. (1992) describes the reduction by burning and subsequent accumulation of the amount of fine fuel (litter). Humphries (1994) found no significant difference between the amounts of fuel reduced in the spring and autumn burns and no significant loss or gain in fallen timber over the period of study. Humphries concluded that trees and branches falling into the area replaced fallen timber consumed in the fire.

Changes in the relative proportion of microhabitat use by *P. coventryi* occurred following both spring and autumn burning (Humphries 1994). Sixty-seven percent of observations in the spring treatment and 78% in the autumn treatment were of *P. coventryi* on or under fallen timber, compared with 22% in the control. This change in microhabitat use reflects the short-term loss of the litter layer following burning. Although no pre-burn observations of microhabitat use by *N. maccoyi* were available to Humphries (1994), Robertson (1981) identifies its preferred microhabitat as deep, moist litter. All observations of this species were after fires, with almost all specimens found sheltering under fallen logs. The lack of *N. maccoyi* sightings in the control, even under logs, suggests a temporary shift in microhabitat selection after fire due to the loss of preferred foraging sites (litter). The decrease in observed abundance of this species after a further 12 months of post-burn recovery probably indicates the return of *N. maccoyi* to the recovering litter layer where this cryptic species is difficult to detect (Humphries 1994).

Effect of fire on reptile abundance

Humphries (1994) found total and individual observed lizard abundance appeared high in the first five months following spring burning at Musk Creek (Fig. 2). This is unlikely to have been a direct response to the spring fire, but is most probably a result of increased detection of lizards due to lack of cover. This is supported by a reduction in relative abundance of all species 11–14 months after spring burning when litter cover had increased. A similar apparent decrease in overall species abundance 7–10 months after autumn burning was observed. The observation of the previously unrecorded *N. maccoyi* and the increased visibility of *P. coventryi* increased total lizard abundance. The perceived abundance of *E. tympanum* remained relatively stable (Humphries 1994).

Figure 2 Skink abundance at Musk Creek at different times since fire in the spring and autumn treatments, and unburnt controls (months since treatment shown above each bar)

Source: Humphries 1994

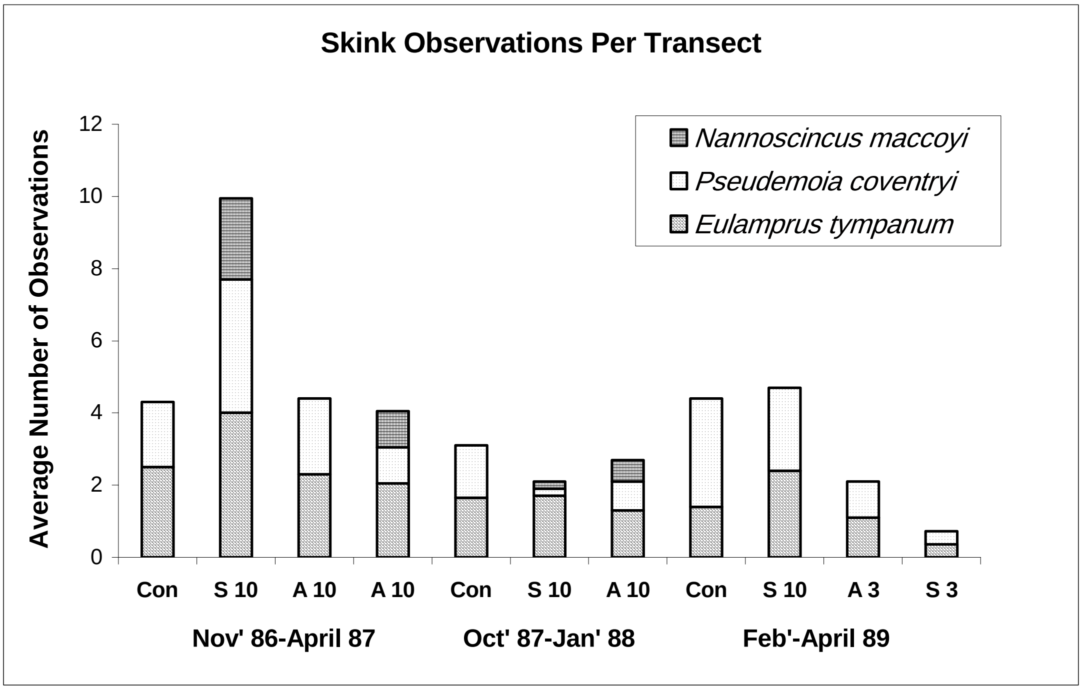


Table 4 shows lizard numbers for each treatment related to time since fire for each fire effects site as determined by Scuffins (1994).

Rather than differentiate between the Blakeville and Barkstead FESAs, Moody (1991) combined her data into autumn treatments, spring treatments and controls. This provided a larger sample for analysis.

Of the four lizard species analysed by Moody (1991), *P. coventryi* and *E. tympanum* were the dominant species across all three treatments. *Pseudemoia entrecasteauxii* was relatively common in the control and *N. maccoyi* only recorded in the autumn treatment.

Although the Moody (1991) data was limited, by using the Humphries (1994) species richness data for temporal analysis, she found richness appeared to decline. Moody found the number of reptiles recorded for each transect declined as time since fire increased. In spring treatments, numbers dropped from approximately two per transect when sampled four months after the fire, to less than one per transect four years after the fire. Records from autumn treatments dropped from approximately two to three per transect in 1987 after fire, to one per transect in 1991.Walked transects and census counts

Walked transects and census counts

Humphries (1994) identified problems associated with reptile counts due to both disturbance whilst conducting transects and the cryptic nature of reptiles. This is relevant to this study because of differences in habitat structure before and after fire.

Reptiles that had been flushed re-emerged from their respective shelters after one or two minutes if the observer remained stationary. Humphries (1994) made a total of 529 individual observations of five reptile species using transects and stationary census counts.

Table 4 a–e Lizard numbers for each treatment and time since fire for each fire effects study site

Table 4a Blakeville

Species Treatment	Control	A3	A10	S3	S10
Months since fire *	(since 1935)	22	81	26	98
Pseudemoia coventryi	19	2	14	2	2
Pseudemoia entrecasteauxii	4	0	2	0	4
Eulamprus tympanum	10	3	5	3	7
Lampropholis guichenoti	0	0	0	2	0
Unconfirmed spp.	3	2	2	0	8
Total	**36**	**7**	**23**	**7**	**20**
Number of counts	12	12	12	12	12

Table 4b Barkstead

Species Treatment	Control	A3	A10	S3	S10
Months since fire *	(since 1931)	33	81	26	97
Pseudemoia coventryi	1	0	3	3	2
Pseudemoia entrecasteauxii	3	0	0	0	0
Eulamprus tympanum	2	6	13	5	4
Lampropholis guichenoti	1	0	0	0	0
Unconfirmed spp.	2	3	0	0	1
Total	**9**	**9**	**16**	**8**	**7**
Number of counts	12	12	12	12	12

Table 4c Burnt Bridge

Species Treatment	Control	A3	A10	S3	S10
Months since fire *	(since 1953)	33	81	26	88
Pseudemoia coventryi	13	4	10	1	4
Pseudemoia entrecasteauxii	4	0	3	0	3
Eulamprus tympanum	5	3	7	3	8
Lampropholis guichenoti	0	0	1	0	0
Unconfirmed spp.	2	3	1	1	3
Total	**22**	**10**	**22**	**5**	**18**
Number of counts	12	12	12	12	12

Table 4d Musk Creek

Species Treatment	Control	A3	A10	S3	S10
Months since fire *	(since 1974)	33	82	26	98
Pseudemoia coventryi	20	5	4	4	6
Pseudemoia entrecasteauxii	10	1	4	1	3
Eulamprus tympanum	4	7	16	7	6
Lampropholis guichenoti	0	0	0	0	0
Unconfirmed spp.	0	1	0	0	0
Total	34	15	24	12	15
Number of counts	15	15	15	15	15

Table 4e Kangaroo Creek

Species Treatment	Control	A3	A10	S3	S10
Months since fire *	(since 1944)	21	81	26	98
Pseudemoia coventryi	25	3	5	5	12
Pseudemoia entrecasteauxii	8	1	3	2	6
Eulamprus tympanum	2	4	6	5	3
Lampropholis guichenoti	0	0	0	2	0
Unconfirmed spp.	1	3	2	2	1
Total	36	11	15	14	22
Number of counts	8	8	8	8	8

* As at January 1994
Control = long unburnt
Source: Scuffins 1994

Pre-burn abundance data at Blakeville FESA (Schultz 1985 unpublished data) showed considerable variation in total numbers of lizards between treatments before burning commenced. At Blakeville, the average number of lizards recorded per 15-minute census varied from 0.87 in a pre-burn autumn block to 4.95 in one of the pre-burn spring blocks. Also significant was the variation in lizard abundance between years, from 2.8 observations per transect in 1987–88 to 4.5 per transect in 1986–87, in the control at the Musk Creek FESA (Humphries 1994). These data demonstrate a number of limitations in reptile census techniques, including small-scale, local differences in microhabitat suitability between apparently similar treatment areas (i.e. vegetation cover, number and suitability of available basking and sheltering sites) and observer variability bias in these sites (Humphries 1994).

Discussion

Effects of fire on microhabitat and reptile abundance

Humphries (1994) found local differences in microhabitat suitability between apparently similar treatment blocks (i.e. vegetation cover, number and suitability of available basking and sheltering sites) that may explain variation in reptile numbers from site to site.

The abundance of *E. tympanum* remained relatively stable following both spring and autumn fires (Humphries 1994; Scuffins 1994). This is likely to be because the abundance and condition of its primary habitat (fallen logs and branches) were not significantly affected (Tolhurst et al. 1992). Scuffins (1994) noted that the highest numbers of *E. tympanum* were in the A10 treatments at Barkstead and Musk Creek seven years after burning. It is not known why this is the case, but it may be due to the degree of decomposition of logs in those treatment areas or inherent differences in the sites before burning. Webb (1985) found that *E. tympanum* was rarely more than 1 m away from a log. Scuffins (1994) also found this species depended on logs with 70% of individuals either on logs or immediately adjacent to them.

The percent cover of litter, shrubs and logs can all have an effect on the observability of reptiles (Scuffins 1994), especially when undertaking transect counts (Humphries 1992). Despite this, greater numbers of *P. coventryi* and *P. entrecasteauxii* were recorded by Scuffins in sites where it would be expected that detection rates would be low due to dense cover of litter, ground vegetation and logs.

Scuffins (1994) found litter levels were still significantly different from the control block 26 months after burning in the S3 treatment. The effects of spring and autumn low-intensity fires were similar. The combined differences in litter cover and the lower percentage cover of grasses and herbs in the S3 and A3 treatments may be responsible for the lower numbers of *P. coventryi* and *P. entrecasteauxii* found in these areas.

Pseudemoia coventryi and *P. entrecasteauxii* numbers were significantly different between treatments (Scuffins 1994). Scuffins also found numbers of both species recorded were significantly lower in burnt treatments (notably S3, 32 months after burning and A3, 18–32 months after burning) than in the control treatment block. Humphries (1994) found *P. coventryi* and *N. maccoyi* forage on and in the ground/litter layer, the microhabitat most affected by burning. The relatively high abundances of these species recorded immediately after burning were probably due to their increased detectability as a result of reduced cover (Humphries 1994). Webb (1985) observed 92% of *P. coventryi* in litter. Within the fire effects study, Scuffins (1994) observed 49% of *P. coventryi* in litter and 17% in association with grass/herb cover. The use of grasses and herbs was lowest in burnt sites (0–14%) and highest in control sites (64%), suggesting that this species will utilise any available cover at ground level, probably switching from one cover type to another when ground vegetation or litter is consumed by fire. This habitat switching may be responsible for the low correlation coefficients that were obtained (Scuffins 1994).

Sixty–five percent of *P. entrecasteauxii* were observed in litter, although grasses and herbs (28%) and logs (28%) were utilised in control areas (Scuffins 1994). The high dependence of *P. entrecasteauxii* and *P. coventryi* on litter and ground vegetation microhabitats may account for the lower numbers of these species in burnt sites. In sites where time since fire is greater (S10 and A10 treatments), numbers recorded were intermediate between those of S3 and A3 treatments and the control treatments (Scuffins 1994).

Humphries (1994) found the effects of single spring and autumn low-intensity burns were similar. Four of the five species he studied either depend on, or largely rely on, the litter layer and showed fluctuations in abundance. The rapid recovery rate of fine fuels following fire (Tolhurst et al. 1992) resulted in litter levels reaching pre-burn levels two to four years after burning. The importance of this rapid recovery of a major habitat component is shown by the increase in the relative abundances of *P. coventryi* 28 months after spring burning

(Humphries 1992). *Nannoscincus maccoyi* (a species dependent on deep litter) is likely to be locally eliminated by high-frequency and moderate- to high-intensity burning regimes (Humphries 1992).

The only species that Humphries (1994) found to show a preference for fallen logs, *E. tympanum*, showed little variation in abundance. It has been suggested that the species actually benefits in the short term from infrequent fires and some forest management practices which reduce shrub and ground cover thereby increasing available basking sites (Rawlinson 1971; Mather 1978).

Burning regimes

The impact of specific burning regimes on particular species will depend on the ecological requirements of the species in question. Some species are arboreal, some fossorial and others are surface dwelling (Heatwole & Taylor 1987). The degree to which each of these microhabitat types is affected by fire, and its relative rate of recovery, will largely determine the impact of a particular burning regime on the reptile community and species present. Fyfe (1980) and Caughley (1985) found that burrowing species in the arid interior were more common at recently burnt sites than long-unburnt sites. Burrowing species avoided the immediate impact of the fires, and the resulting openness of communities following burning favoured their foraging requirements. Species that depend on ground litter and vegetation were most affected by the fires; only one out of six species classified as requiring litter shelters was recorded after the fire in Fyfe's study.

Fires generally affect 60–80% of the area being burned (Hodgson & Heislers 1972). The unburnt areas left in the small-scale mosaic of burnt and unburnt areas resulting from a fuel reduction burn are crucial to local survival and can act as the source for recolonisation of burnt areas by both invertebrates (Leonard 1972) and small mammals (Leonard 1972; Heislers 1980). Humphries (1992) notes that these unburnt patches are also likely to act as refuges for small skinks.

Most lizard species studied have definite home-ranges (Heatwole & Taylor 1987). These permit lizards to familiarise themselves with their immediate environment and thus the nearest point of shelter in case of attacks from predators. The sizes of lizards' home-ranges vary considerably. Mather (1978) determined the mean home-range of *E. tympanum* to be 7.6 m^2 in open-forest at Toolangi in central Victoria. It is therefore likely that, in a low-intensity fire, entire or proportions of existing home-ranges of *E. tympanum* and other small skinks would be left relatively intact.

Clearly, no single fire regime is likely to be favourable to all species. There is no data on the optimum frequency of fire for conserving reptile species. However, a fire regime that allows the build up of litter and other microhabitats as well as adequate food supplies should enable reptiles to thrive (Suckling & Macfarlane 1984).

Direct effects of fire on reptiles

Lunney et al. (1991) noted that the survival of *L. guichenoti* from fire is attributed to its ability to take refuge underground. Scuffins (1994) recorded only five *L. guichenoti*; three that were associated with litter and two with logs. These observations are too few for reliable conclusions to be drawn.

The effect of temperature on the number of reptiles recorded during the census counts follows a normal distribution (Scuffins 1994). Preferred temperatures in burnt areas appear to be around 25 ºC and approximately 27–28 ºC in the control sites. The activity of lizards at higher temperatures in the control treatments is probably a factor of the vegetation cover in those areas (Scuffins 1994). Lunney et al. (1991) suggested that, after fire in the Mumbulla State Forest (southern NSW), the critical thermal maximum temperature of Australian scincid lizards would be quickly reached and sustained for longer in the exposed and blackened ridges of recently logged forest in the immediate post-fire weeks than in other habitats. It was noted in the Wombat State Forest that high survival rates of *L. guichenoti* in gullies was consistent with these being moister, less exposed habitats (Scuffins 1994).

Humphries (1994) made observations of species surviving or being killed by low-intensity fire. During the autumn burn at Barkstead in April 1987, the comparatively strong-limbed species, *E. tympanum*, was observed moving ahead of the fire front—which had a maximum forward rate of spread calculated at 1.2 m min^{-1} (Tolhurst et al. 1992)—and taking refuge in hollow logs and stumps. The security of these refuges depends on a number of factors, including their size, degree of decomposition, seasonal dryness and fire intensity. At Musk Creek FESA, Humphries (1994) collected numerous individuals of *N. maccoyi* from under large logs the day after both spring and autumn burns. *Nannoscincus maccoyi*, a short-limbed and slow-moving species, often showed signs of being burnt in the fire, with scales and limbs melted and fused together. Many individuals probably died as a direct result of the fire.

Predation

Increased predation due to the lack of suitable cover is often assumed to reduce lizard abundance following burning (Fox 1978). Skinks have the ability to drop their tails when alarmed, a trait known as tail autotomy (Jenkins & Bartell 1980). The obvious benefits of tail loss relate to escapes from predation attempts. The incidence of tail loss in a population of lizards can give an indication of predator pressure (Robertson 1981). Tail loss in skinks can also be caused by intraspecific competition. These interactions may have increased after burning due to competition for limited resources.

Although using a small sample size, Humphries (1994) found a statistically significant difference between burnt treatments and control treatments of lizards with and without tails.

Raptors, such as the Brown Goshawk, were observed running over bare ground looking for reptiles after the spring burn at Burnt Bridge (Loyn et al. 1992). Kookaburras and Sacred Kingfishers have also been seen feeding on reptiles in the Wombat State Forest, with the numbers of Kookaburras feeding from bare ground generally increasing after fire (R. Loyn, Arthur Rylah Institute, pers. comm. 2000).

Limitations of survey techniques

Scuffins (1994) found significant differences in skink abundance between treatment areas. Humphries (1994) found significant differences in skink abundance between treatment areas for a given year, as well as between years within a single treatment area. This finding accords with the findings of Webb (1985) and Heatwole and Taylor (1987). The variation in reptile activity and subsequent detection in relation to temperature, cloud cover and suitable microhabitat availability observed by Webb (1985) indicates that a standard, repeatable census method with equal sampling intensity is crucial, particularly when comparisons are required between relative abundance in sites with different treatment histories. Any variation in sampling intensity or method (i.e. technique used or observer) or abiotic factors between study areas and/or treatments can lead to inconsistencies when analysing data. These differences are practically impossible to eliminate. Stationary census counts combined with active searching under logs, rock and other debris was found to give the best estimates of species abundance (Scuffins 1994). Scuffins found no significant difference in temperature or amount of cloud cover, suggesting that variation in skink numbers was due to other factors.

Conclusions

None of the reptile species studied was favoured by a particular burning treatment. If diversity and rapid recovery of reptile populations are management objectives, fuel-reduction burning needs to be managed to ensure that refuges of suitable microhabitat remain.

All species observed before burning were still present following a single spring or autumn low-intensity fire. However, abundance of each species was influenced. The conclusions discussed below have been drawn from knowledge produced from research in mixed eucalypt foothill forests. The success of reptiles in these forests depends on the management of their habitat and, as such, issues relating to microhabitats are repeatedly raised.

The microhabitat components available govern whether a particular species can properly thermoregulate. Thus the thermoregulation strategy used will determine a species' preferred microhabitat. Of the reptiles studied, *N. maccoyi* is likely to be the most vulnerable to low-intensity prescribed burning, as these burns reduce or remove the deep litter upon which it depends.

The availability of a range of microhabitats will benefit a range of reptile species. Fallen logs and unburnt litter are important refuges from fire, providing food, shelter and oviposition sites for oviparous species in the post-fire period. The availability of these resources will be scarce in areas where a high percentage of the burn area is fire-affected. Unburnt microhabitats present immediately following a burn (particularly logs, leaf litter and areas not frequently prone to low-intensity fire, such as gullies) will aid survival of reptile species in both the short and long term. Whilst some reptiles that survive fire are able to utilise alternative microhabitats, the rapid recovery of preferred microhabitat components is also important in post-fire survival and recovery of reptiles.

Lampropholis guichenoti inhabits moist gully areas not frequently prone to low-intensity burning. Unless the burn is of such an intensity that gully habitat is consumed, of the species studied, this species is the least effected by fire.

The small-scale mosaic of burnt and unburnt areas that generally results from low-intensity fires is crucial to local reptile survival. The home-range of small skinks is thought to vary considerably and, because the home-range can be as small as 7.6 m^2 (*Eulamprus tympanum*), some species are likely to be eliminated from local areas by high-frequency and moderate- to high-intensity burning regimes.

Burns with a widespread patchiness are beneficial to reptile survival and recovery. Burns with a large perimeter-to-burn ratio are preferred because they contain more refuge areas inside the burn and allow for recolonisation by individuals from adjacent unburnt areas, as habitat recovers.

Some reptile species (*Eulamprus tympanum* and, to a lesser extent, *Pseudemoia coventryi* and *P. entrecasteauxii*) may benefit, in the short term, from infrequent fires and some forest management practices that reduce shrub and ground cover, thereby increasing available basking sites. This benefit to some species may be to the detriment of others. The impact of silviculture (including regeneration burns) on reptiles and other forest fauna therefore requires further investigation.

The impact of specific burning regimes on particular species will depend on the ecological requirements of the species in question. While burrowing species (such as *Nannoscincus maccoyi*) can avoid the immediate impact of fires, species that depend on ground litter and vegetation are most affected. Some skinks (*Eulamprus tympanum* in this study) are able to outrun low-intensity fire. Others, however, are injured and many individuals probably die as a direct result. Direct mortality, increased predation and intraspecific competition are thought to be the major factors for the reduction in lizard abundance during the first 12 months after burning.

Choosing an appropriate survey technique is paramount in obtaining useful results. The rarity or absence of some species in survey results discussed here is a reflection, at least in part, of their cryptic nature rather than their relative abundance. The somewhat dense cover of microhabitat prior to burning, such as leaf litter, logs and ground vegetation, conceals these cryptic species, making definitive statements regarding reptile abundance somewhat artificial. Whilst not easily quantifiable in this study, future research should attempt to negate this factor through carefully chosen survey techniques. Stationary census counts were the most effective survey technique used here as it reduces problems associated with cryptozoic species.

The survey techniques used did not provide sufficient data for analysis of all species observed. To fill the information gaps in relation to the effects of fire on all species present, other techniques need to be developed.

The longevity of small skinks can vary from one to seven years and is probably influenced by environmental factors, such as the climate of the particular region. Further research into the life histories of reptiles is required to avoid generalisations in the application of longevity knowledge to the management of prescribed fire.

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Appendix

Synonyms for scientific names used throughout the report

Previous scientific name	Revised scientific name (Cogger 1994)	Common name
Egernia whitii	*Egernia whitii*	White's Skink
Egernia cunninghami	*Egernia cunninghami*	Cunningham's Skink
Lampropholis guichenoti	*Lampropholis guichenoti*	Garden Skink
Leiolopisma entrecasteauxii	*Pseudemoia entrecasteauxii*	Grass Skink
Leiolopisma coventryi	*Pseudemoia coventryi*	Coventry's Skink
Leiolopisma duperreyi	*Bassiana duperreyi*	
Nannoscincus maccoyi	*Nannoscincus maccoyi*	Maccoy's Skink
Sphenomorphus tympanum	*Eulamprus tympanum*	Southern Water Skink
Pseudechis porphyriacus	*Pseudechis porphyriacus*	Red-bellied Black Snake
Pseudemoia pagenstecheri	*Pseudemoia pagenstecheri*	
Tiliqua nigrolutea	*Tiliqua nigrolutea*	Blotched Blue-tongued Lizard
Tiliqua scincoides	*Tiliqua scincoides*	Eastern Blue-tongued Lizard
Trachydosaurus rugosa	*Trachydosaurus rugosa*	Shingle-Back