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Enhancing fauna habitat in grazed native grasslands and woodlands: use of artificially placed log refuges by fauna

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Abstract. To assess whether faunal habitat can be enhanced by using artificial refuges, and whether different species preferentially use refuges with differing structural characteristics, we monitored faunal usage of artificially placed log refuges in grazed semi-arid grasslands and woodlands in Terrick Terrick National Park in Victoria. In total, 1131 log refuges were placed at 91 sites across major vegetation types in the reserve. The effect of refuge age was assessed by comparing faunal usage between new refuges and 271 old refuges that had lain *in situ* for more than 15 years. Refuges were surveyed for fauna monthly between June 2000 and January 2001. Different species preferred refuges with different characteristics. Overall terrestrial fauna, and three native species (*Diplodactylus tessellatus*, *Morethia boulengeri* and *Suta suta*) in particular, were significantly more abundant beneath old refuges, whereas the introduced *Mus musculus* was significantly more abundant beneath new refuges. Five species (*Crinia signifera, Morethia boulengeri*, *Menetia greyii, Sminthopsis crassicaudata* and *Suta suta*) were significantly more abundant beneath *Eucalyptus* logs that were large, wide, partially decayed, contained many holes and/or covered many subterranean invertebrate holes. This study demonstrates the effectiveness of installing log refuges in grassy landscapes as a survey method for vertebrate fauna and as a potential habitat-restoration technique to help conserve grassland fauna.

Introduction

Structural habitat heterogeneity is an important determinant of terrestrial faunal diversity. Management activities that diminish structural heterogeneity and complexity often reduce faunal diversity (Hecnar and M'Closkey 1998; Goldingay and Newell 2000), whereas activities that enhance these features can promote diversity (Read 1995; Laven and Mac Nally 1997; Brown 2001). In production landscapes, agricultural and grazing activities usually simplify vegetation structure and remove ground debris (such as logs and surface rocks), leading to declines in habitat diversity and local extinctions of plants and animals (Kitchener and How 1982; Webb and Shine 2000).

A number of studies have demonstrated that degraded faunal habitats can be enhanced artificially by re-establishing ground refuges, such as natural logs and rocks, or by introducing artificial structures such as roofing tiles, paving stones or corrugated iron sheeting (O'Shea 1996; O'Shea and Hocking 1997; Reading 1997; Webb and Shine 2000). However, relatively little information is available on how refuge utilisation is influenced by subtle variations in refuge characteristics, such as size, shape, volume or decomposition status (Huey *et al.* 1989; Schelesinger and Shine 1994*a*, 1994*b*; Shine *et al.* 1998). These attributes could strongly influence how different species use refuges, and could therefore influence the value of refuges for habitat restoration. In this study, we compare faunal use of log refuges (recycled fence posts) in native grasslands and open woodlands in northern Victoria, Australia. Reused wooden fence posts are readily available in large quantities, and their natural aesthetic qualities make them more suitable for use in conservation reserves than refuges composed of artificial materials.

The study was conducted in semi-arid grasslands and grassy woodlands in Terrick Terrick National Park. Until acquisition as a conservation reserve in 1998, this reserve was managed as a grazing property, which resulted in declines in tree densities and woody debris in some areas. Despite a century of production grazing, the reserve contains large areas of high-quality native grasslands, which are an

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endangered and greatly depleted vegetation type in south-eastern Australia (McDougall and Kirkpatrick 1994). These grasslands provide habitat for many species of threatened fauna, including *Pedionomus torquatus* (plains wanderer), *Burhinus grallarius* (bush stone-curlew), *Diplodactylus tessellatus* (tessellated gecko), *Delma impar* (striped legless lizard), *Pygopus schraderi* (hooded scaly-foot) and *Suta suta* (curl snake), all of which are rare or threatened in Victoria (Bennett *et al.* 1998; Michael *et al.* 2003).

In 2000, park managers deposited over 1000 recycled fence posts across the reserve, to act as monitoring points for terrestrial fauna, and to supplement woody debris in areas where the original debris is assumed to have been depleted over the past century. The aim of this study was to assess faunal usage of these refuges, and to compare faunal usage between logs with different structural characteristics. We hypothesised that different faunal species would prefer refuges with differing characteristics, and that faunal diversity would be maximised by using refuges of varying size and shape.

Methods

The study was conducted in the newly acquired eastern half of Terrick Terrick National Park (36°08′S, 144°17′E), ~60 km west of Echuca in the Victorian Riverina region. This 3780-ha study area is mostly native grassland, but contains small patches of remnant woodland. The western section of the Park (the old Terrick Terrick State Forest), dominated by *Callitris glaucophylla* (white cypress-pine), was not sampled. The study area contains three broad vegetation communities: (1) open woodland dominated by *Eucalyptus melliodora* (yellow box) and *Allocasuarina luehmannii* (buloke) on gently sloping, outwash slopes of the Terrick Terrick Range; (2) riparian woodland along Bendigo Creek, dominated by *Eucalyptus largiflorens* (black box), *E. camaldulensis* (river red gum) and *Muehlenbeckia florulenta* (tangled lignum); and (3) extensive open grasslands on the riverine plains, mostly dominated by native *Austrodanthonia* species (wallaby-grasses) (Michael *et al.* 2003).

Fauna were sampled at 91 permanently marked vegetation quadrats, stratified across major soil types. In May 2000 ~12 (and up to 20) logs of mixed species, size and condition were placed alongside each vegetation quadrat, giving 1131 log refuges in total. Refuges consisted of *Callitris glaucophylla* and *Eucalyptus* fence posts that had been salvaged when new fences were erected in the reserve. Half of the *C. glaucophylla* logs at each quadrat were buried to a depth of 2 cm to assess the effects of shallow burial on refuge usage. Additionally, a 2-km-long fallen fence line in the east of the reserve containing 271 fence posts was sampled to allow comparisons between newly distributed refuges and pre-existing refuges that had lain *in situ* for more than 15 years. These two treatments are termed ‘new’ and ‘old’ refuges in this paper. Vertebrates were surveyed monthly, between June 2000 and January 2001 and between 0800 and 2000 hours, by sampling beneath the individually numbered log refuges. Mark–recapture techniques were not employed.

A number of refuge features that were considered important to grassland vertebrates were measured, including log species, refuge dimensions (length and width), degree of senescence, and the number of cavities (fence-wire holes). Refuge dimensions were categorised into three lengths (<1 m, 1–1.5 m and >1.5 m) and three widths (<15 cm, 15–25 cm and >25 cm). Log decay was assessed using a system adapted from Hecnar and M’Closkey (1998), namely: (1) low: intact logs with cracks, exfoliations and fissures amounting to less than 35%; (2) medium: 35–65% of the log had cracks, exfoliations and fissures to 5 cm depth; and (3) high: structurally brittle logs with numerous cracks, exfoliations and deep fissures amounting to more than 65% of the total area. Small mammals and reptiles in grasslands are known to use invertebrate burrows in the soil for shelter (Hutchinson *et al.* 1994; Hadden 2002), therefore all soil invertebrate tunnels wider than 2 mm were recorded beneath refuges.

Habitat preferences were analysed for all fauna species that were observed on more than 10 occasions. Log-likelihood tests were used to compare differences in utilisation between refuge categories, as recommended by Zar (1984) for use when sample sizes are too small to give unbiased Chi-square calculations. All computations were weighted for the number of refuges in each category and performed using maximum-likelihood estimation in the GENMOD procedure in SAS© version 8.02 (SAS Institute 1993). Where the log-likelihood ratio was declared significant, frequencies within each level of the category were analysed using the Chi-square subdivision method (Zar 1984). To minimise Type I errors, only treatments declared significant ($P \leq 0.05$) by the log-likelihood test were analysed and only partial Chi-squares significant at $P \leq 0.01$ were declared. Old refuges occurred in only one grassland type (widespread grassland: Michael *et al.* 2003), so comparisons of faunal usage between new and old refuges were restricted to observations from widespread grassland.

Results

In total, 346 observations of 15 species from eight vertebrate families were recorded from beneath refuges. Most records were of reptiles or amphibians, but two species of mammal were also found: the native *Sminthopsis crassicaudata* (fat-tailed dunnart) and introduced *Mus musculus* (house mouse). Three species listed as rare or threatened in Victoria (Bennett *et al.* 1998) were recorded beneath refuges: *Delma impar*, *Diplodactylus tessellatus* and *Suta suta*.

Variation in the use of old and new refuges

There was a significant difference in overall faunal abundance between new and old refuges (log-likelihood statistic $G = 17.63$, d.f. = 1, $P < 0.001$), with more animals than expected using the older logs (Table 1). Individually, three native species (*D. tessellatus*, *Morethia boulengeri* and *S. suta*) were significantly more frequent ($P \leq 0.05$) beneath old refuges (Table 1). By contrast, the exotic *M. musculus* was significantly more abundant beneath new refuges.

Variation in the use of new refuges

In general, species tended to prefer long (1–1.5 m), wide (15–25 cm), medium-to-highly decayed *Eucalyptus* logs (Table 2). However, many species showed individual preferences for refuges with particular combinations of habitat features. Three species were significantly more abundant beneath *Eucalyptus* than *Callitris* refuges (*S. crassicaudata,* $G = 29.23$; *M. boulengeri*, $G = 13.45$; and *Crinia signifera*, $G = 19.17$; d.f. = 2 and $P < 0.002$ for each comparison). *S. crassicaudata* preferred highly decayed logs ($G = 15.84$, d.f. = 2, $P < 0.001$), and was significantly more abundant beneath refuges that were greater than 25 cm wide,

Table 1. The number of observations of vertebrates beneath new and old refuges in widespread grassland
Species shown in bold differed significantly in refuge use at $P \leq 0.05$

Family	Scientific name	Common name	New refuges	Old refuges	G	*P*
Myobatrachidae	*Limnodynastes tasmaniensis*	Spotted grass frog	–	1	–	–
Gekkonidae	***Diplodactylus tessellatus***	Tessellated gecko	2	**6**	4.11	**0.043**
Pygopodidae	*Delma impar*	Striped legless lizard	1	2	–	–
	Delma inornata	Olive legless lizard	6	9	2.51	0.113
Agamidae	*Pogona barbata*	Bearded dragon	1	–	–	–
Scincidae	*Menetia greyii*	Grey's skink	23	9	2.03	0.154
	Morethia boulengeri	Boulenger's skink	6	**12**	5.39	**0.020**
Elapidae	*Pseudonaja textilis*	Eastern brown snake	–	2	–	–
	Suta suta	Curl snake	7	**38**	40.70	**0.0001**
Dasyuridae	*Sminthopsis crassicaudata*	Fat-tailed dunnart	20	9	1.03	0.311
Muridae	***Mus musculus***	House mouse	**10**	1	5.39	**0.020**
No. of observations			76	89	17.61	**0.0001**
No. of refuges			408	271		

Table 2. Variation in the use of new refuges by vertebrates at Terrick Terrick National Park
Values in bold were significantly higher or lower than their expected frequencies at $P < 0.01$, with underlined values being significantly lower than expected

Refuge characteristics / Species		*Sminthopsis crassicaudata*	*Suta suta*	*Morethia boulengeri*	*Menetia greyii*	*Delma inornata*	*Crinia signifera*	No. of refuges
Refuge type	*Eucalyptus*	**34**	12	27	22	5	**16**	447
	Callitris buried	4	4	9	9	4	5	332
	Callitris surface	5	4	5	15	0	0	352
Senescence	Low	5	8	9	10	3	5	370
	Medium	14	2	17	20	3	5	416
	High	**24**	10	15	16	3	11	345
Refuge length	<1 m	0	0	1	1	1	2	57
	1–1.5 m	**36**	**18**	**20**	**27**	**7**	6	261
	>1.5 m	**7**	**2**	20	**18**	1	13	813
Refuge width	<15 cm	**1**	1	14	9	3	10	423
	15–25 cm	27	19	23	32	4	11	646
	>25 cm	**15**	0	4	5	2	0	62
No. of wire holes in refuges	0–2	**7**	6	24	19	4	18	547
	3–5	13	9	8	17	3	2	440
	6+	**23**	5	9	10	2	1	144
No. invertebrate tunnels beneath refuges	0	24	15	25	31	9	21	950
	1	**15**	4	5	**14**	0	0	127
	2+	4	1	**11**	1	0	0	54
Total no. of individuals		43	20	41	46	9	21	1131

and significantly less abundant under logs less than 15 cm wide (G = 58.53, d.f. = 2, $P < 0.0001$). By contrast, *S. suta* tended to be more abundant beneath refuges 15–25 cm wide and less abundant under narrower refuges (G = 15.52, d.f. = 2, $P < 0.001$); however, after correction for Type I error, no significant partitioning effects were found (χ^2 test, $P > 0.01$). Five species were most abundant beneath refuges that were 1–1.5 m in length (*S. crassicaudata*, G = 75.61; *S. suta*, G = 42.04; *M. boulengeri*, G = 13.56; *Menetia greyii*, G = 28.25; and *Delma inornata*, G = 14.99; d.f. = 2 and $P < 0.001$ for each comparison), even though many more longer refuges were available (Table 2).

Sminthopsis crassicaudata was also more abundant beneath refuges that contained many (>6) fence wire-holes (G = 46.93, d.f. = 2, $P < 0.001$), whereas *C. signifera* tended to be more abundant under refuges with few (<3) fence wire holes (G = 13.23, d.f. = 2, $P < 0.002$) although this was not significant after partitioning the effects and correction for Type I error (χ^2 test, $P > 0.01$). Furthermore, *S. crassicaudata* and *M. greyii* were both more abundant beneath refuges that covered only one subterranean invertebrate tunnel (G = 20.83 for *S. crassicaudata* and G = 13.44 for *M. greyii*; d.f. = 2 and $P < 0.002$ for both comparisons), whereas *M. boulengeri* was significantly

Table 3. Variation in the use of old refuges by vertebrates at Terrick Terrick National Park

Values in bold were significantly higher or lower than their expected frequencies at $P < 0.01$, with underlined values being significantly lower than expected. Only data for *Suta suta* were analysed statistically, owing to low capture rates for other species

Refuge attributes / Species		*Sminthopsis crassicaudata*	*Suta suta*	*Morethia boulengeri*	*Menetia greyii*	*Delma inornata*	No. of refuges
Refuge type	*Eucalyptus*	2	4	1	1	1	16
	Callitris	7	34	11	8	9	255
Senescence	Low	0	7	1	1	3	86
	Medium	4	23	10	8	4	159
	High	5	8	1	0	2	26
Refuge length	<1 m	1	2	0	0	0	16
	1–1.5 m	8	33	12	8	8	248
	>1.5 m	0	3	0	1	1	7
Refuge width	<15 cm	2	25	8	6	7	175
	15–25 cm	5	11	4	3	1	86
	>25 cm	2	2	0	0	1	10
No. of wire holes in refuges	0–2	2	11	3	3	4	84
	3–5	5	18	4	4	3	181
	6+	2	**9**	5	2	2	6
No. of invertebrate tunnels beneath refuges	0	6	**<u>0</u>**	3	4	4	116
	1	2	5	4	1	2	77
	2	1	**12**	3	1	2	35
	3+	0	**21**	2	3	1	43
Total no. of individuals		9	38	12	9	9	271

more abundant beneath refuges that covered two or more invertebrate tunnels (G = 24.56, d.f. = 2, $P < 0.001$). There were no significant differences in faunal usage between *Callitris* logs that were shallowly buried compared with those laid on the soil surface (Table 2).

Variation in the use of old refuges

The low number of observations beneath old refuges prevented statistical comparisons of refuge characteristics for all species except *S. suta* (Table 3). However, most species appeared to select old logs that had similar characteristics to their preferred new logs (cf. Tables 2, 3). *S. suta* was recorded significantly more often beneath old refuges that contained many (>6) fence-wire holes (G = 38.15, d.f. = 2, $P < 0.001$) and covered more than two invertebrate tunnels (G = 78.10, d.f. = 3, $P < 0.001$). It was never recorded beneath old refuges that covered no invertebrate tunnels (Table 3).

Temporal patterns in refuge use

During the first census (~1 month after the refuges were deposited), four vertebrate species (*M. greyii*, *M. boulengeri*, *S. crassicaudata* and *S. suta*) were observed beneath the new and old refuges (Fig. 1). Species richness and abundance beneath log refuges increased during the warmer months of spring, and most species peaked in abundance during October and November. However, 12 individuals of *S. crassicaudata* were observed in the first month, which was the second highest recording for this species during the study period. By contrast, *S. suta* colonised new refuges gradually. All observations of *S. suta* before September were from old refuges. The number of observations of *S. suta* beneath new refuges gradually increased after September whilst observations beneath old refuges decreased. This pattern was not evident for other species. The smaller skinks such as *M. greyii* and *M. boulengeri* were less commonly recorded during spring, when *S. crassicaudata* and *S. suta* were relatively abundant.

Discussion

These results illustrate high usage and rapid colonisation of artificially placed log refuges in grazed grasslands and woodlands by many fauna species, including three that are considered rare or threatened in Victoria. Indeed, one threatened species, *S. suta*, was one of the most commonly recorded species beneath refuges.

No native species preferred new refuges. However, three (*D. tessellatus, M. boulengeri* and *S. suta*) were recorded significantly more frequently beneath old refuges. Small insectivorous reptiles such as *D. tessellatus* and *M. boulengeri* are likely to have small home ranges when prey sources are abundant (Greer 1989; Melville and Swain 1999), often forming localised populations around ground debris. Consequently, these species may colonise new refuges slowly, especially when refuges are widely scattered across open grasslands. By contrast, the larger elapid, *S. suta*, is likely to forage over a larger area, and would be expected to encounter new refuges more frequently. This may explain the increase in the number of *S. suta* beneath new refuges in the later, warmer months of the sampling period.

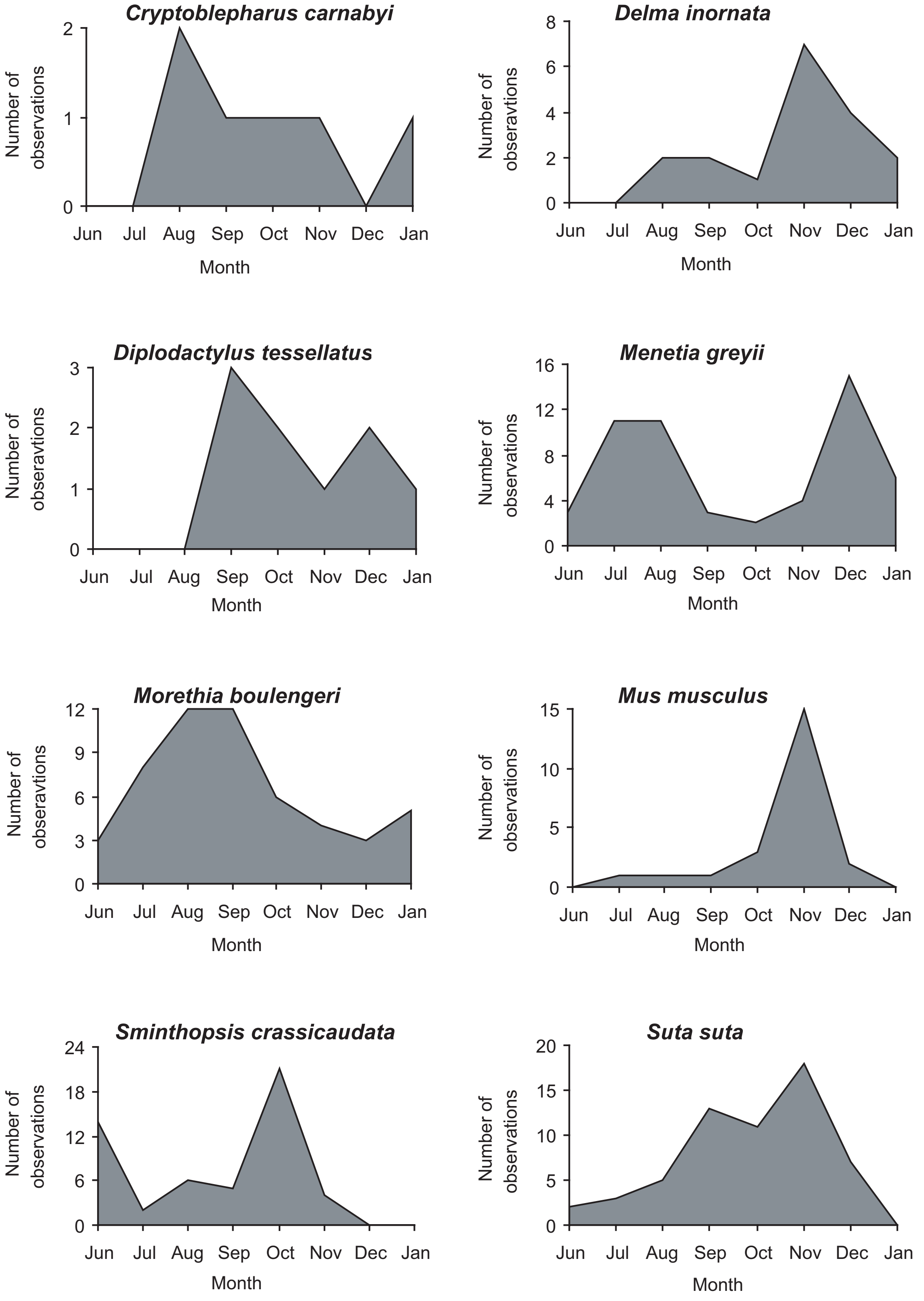

Fig. 1. Temporal patterns in use of new and old refuges by vertebrate fauna in Terrick Terrrick National Park. Amphibians and species observed fewer than 10 times are not shown.

The small mammal *S. crassicaudata* has a drifting home range and is not restricted to foraging around ground debris (Morton 1978). Consequently, it can disperse very rapidly; Read (1984) recorded an average rate of displacement of 1 km every 7 weeks. This dispersal ability allows new refuges to be rapidly colonised, which accounts for the high number of observations of *S. crassicaudata* in the first month.

Species preferences

Despite predictions for differing refuge usage among different species, most species utilised a wide variety of log types. Where significant preferences were apparent, species tended to select large, highly decayed *Eucalyptus* logs. The general trend for selecting large, highly decayed refuges may be due to greater microhabitat complexity, as many species were often found in the numerous cracks and crevices of decayed eucalypt logs.

Some species displayed additional, individual preferences for specific log characteristics. *S. crassicaudata* was significantly more abundant beneath new refuges that contained many fence-wire holes and which covered few soil invertebrate tunnels. One could speculate that *S. crassicaudata* selected refuges with many escape routes (i.e. fence-wire holes) and that covered few invertebrate tunnels within which ambush predators (e.g. *S. suta*) could hide. By contrast, *S. suta* was significantly more abundant beneath old refuges that covered many soil invertebrate tunnels. Subterranean invertebrate tunnels provide retreat sites for many species, including *S. suta*, especially in hot and cold weather (Hutchinson *et al*. 1994; Hadden 2002).

Seasonal patterns in refuge use

The number of animals recorded beneath refuges increased during the course of the study, and peaked in November, which coincides with the warmer ambient temperatures of spring. Species richness and abundance declined rapidly thereafter as temperatures during the day exceeded 35°C. The decline in captures after November may be due to high summer temperatures, and many animals apparently retreated into ground cracks that formed in summer.

Peaks in activity patterns for both mammals during October and November may coincide with dispersal of juveniles, as high numbers of juvenile *S. crassicaudata* were evident during October. It is possible that predator–prey interactions with *S. suta* may have influenced abundances of some species, especially beneath new refuges. For example, *S. crassicaudata* was rarely recorded from new refuges after *S. suta* appeared at the site. At 8 of 9 sites where *S. crassicaudata* and *S. suta* were both recorded, *S. crassicaudata* appeared before *S. suta*, and was not encountered at the site again after the appearance of *S. suta*. A similar pattern was evident between *S. suta* and the two skinks, *M. boulengeri* and *M. greyii*. Unfortunately, it was not possible to test these relationships statistically owing to low sample sizes. However, the patterns suggest that refuge utilisation may be influenced by the presence of predators such as *S. suta*. This could be due to either localised extinction (following predation) and an inability to recolonise isolated logs (in the short term at least) or, alternatively, prey species may avoid sites where *S. suta* occurs. Downes and Shine (1998) found that *Oedura lesuerii* (velvet gecko) avoided retreat sites that were tainted with the scent of *Hoplocephalus bungaroides* (broad-headed snake).

Projected trends in refuge use

Since fauna in general, and three native species (*D. tessellatus, M. boulengeri* and *S. suta*) in particular, were encountered more frequently beneath old than new refuges, the results suggest that new refuges would become more valuable for fauna with time. This trend may reflect both gradual changes in refuge characteristics (e.g. increasing decomposition and numbers of subterranean invertebrate holes) that may make refuges more suitable for fauna, or slow rates of immigration to isolated refuges, or both.

Suta suta increasingly used new refuges as time progressed after refuges were laid down, and clearly preferred old over new refuges. Furthermore, *S. suta* preferred old refuges that covered many soil invertebrate holes, into which it often retreated when disturbed. Since soil invertebrate holes occurred more frequently beneath old than new refuges (57% of old refuges covered ≤1 hole cf. 15% of new refuges), it is probable that invertebrate holes will eventually become more abundant beneath new refuges. This could further enhance the value of new refuges for relatively large predators such as *S. suta*. The long-term effect on smaller fauna of enhanced refuge availability for large predators is unknown, and may only be resolved with further monitoring and experimental manipulation.

Conclusions

These results indicate that artificially laid log refuges are rapidly utilised by many terrestrial fauna, including some rare species. Despite preferences by some species for logs with subtly differing characteristics (e.g. differing number of holes), many species appeared to prefer large, complex logs containing numerous splits and cavities. The comparison of old and new refuges suggests that new refuges may be used by more species and individuals in the future. These results support other studies that demonstrate that faunal habitat can be enhanced by placing refuges in areas where ground debris has been depleted by past agricultural activities (Webb and Shine 2000). Moreover, the use of large numbers of refuges (as in this study) provides an ideal opportunity to experimentally manipulate refuge availability, in order to further investigate spatial and temporal patterns of faunal abundances and species interactions.

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