1990. The Journal of Arachnology 18:241

RESPONSES BY SCORPIONS TO FIRE-INITIATED SUCCESSION IN ARID AUSTRALIAN SPINIFEX GRASSLANDS

Scorpions are successful inhabitants of arid and semi-arid grasslands, where they may reach densities of 5000/ha and biomasses of 5-20 kg/ha (Polis et al. 1986). Such grasslands are usually burnt frequently, either by lightning-initiated fires or by Aboriginal people, and yet the responses of scorpions to fire and the subsequent changes in vegetation are unknown. Indeed, in their review of the responses of grassland arthropods to burning, Warren et al. (1987) did not cite any studies of scorpions. In this note, we examine the relative abundance of scorpions in different vegetation states following fire in spinifex grasslands of arid central Australia.

Work was conducted at eight sites in the Tanami Desert, Northern Territory, within 50 km of The Granites (20 32′ S, 130 24′E) and 500 km northwest of Alice Springs. Three samples were taken: from 4 April to 2 May 1985; from 18 October to 14 November 1985; and 25 March to 22 April 1986. There was little rainfall during this period, and vegetation declined slightly in cover. Each site was on flat sandplain dominated by feathertop spinifex, *Plectrachne schinzii*, but vegetation varied markedly because of successional change following fire. Two sites each were in areas burnt in the summers of 1983-84 (state 1, burnt about one year prior to the beginning of the study), 1982-83 (state 2), 1979-80 (state 5), and 1976-77 (state 8). Cover of spinifex measured by wheel-pointing (see Griffin 1989a) averaged 6%, 15%, 37% and 39% in states 1, 2, 5, and 8 respectively during the three sampling periods discussed in this paper. Cover of other forbs and grasses averaged 10%, 8%, 1%, and 1% at those times; the principal species were *Leptosema chambersii, Scaevola parvifolia, Rulingia loxophylla, Eragrostis setifolia*, and *Aristida holathera*. Mean cover of shrubs increased from 1% to 8% from states 1 to 8; the dominant shrub species was *Acacia coriacea*. The vegetational changes caused by fire on these sites (i.e., a flush of forbs and grasses followed by regeneration of the spinifex and shrubs) were very similar to those described for *P. schinzii* from a broader region by Griffin (1989b). In this part of the arid zone, *P. schinzii* dominates the ground layer within about five years of a fire and is usually burnt again within 10 years.

Scorpions were captured in pit-traps set for small vertebrate animals. Traps were opened at only one site at any one time, but the order in which the sites were visited was varied in each sample to minimize the chances of systematic error due to changing temperatures over the month-long sampling periods. The traps operated for three days and were set 5 m apart in groups of 10. In the first sample, three groups of pit-traps were spaced about 200 m apart along a transect, but four groups were employed in the second and third samples; thus, the number of pit-trap days was 90 in the first sample but 120 in the other two. A mixture of plastic buckets 15 cm and 29 cm in diameter was used; details are given by Morton et al. (1988). Scorpions were removed from the traps each morning and then preserved in alcohol.

Five species of scorpions were present, but four —*Lychas variatus* (Thorell) and *Isometroides vescus* (Karsch) (Buthidae), and *Urodacus armatus* Pocock and

Table 1.—Numbers of *Lychas alexandrinus* captured in pit traps, and sex ratios of adults, in four different successional states following fire. State 1 was burnt in 1983/84 (1 year since fire), state 2 in 1982/83 (2 years), state 5 in 1979/80 (5 years), and state 8 in 1976/77 (8 years). There were two replicates for each state. Thirty traps were used at each site for the first sample, but 40 for the final two samples; in sample 1, numbers in brackets show the scaled-up data used in subsequent analysis of variance.

	Vegetation state			
	1	2	5	8
Numbers				
Sample 1	12(15)	26(35)	23(31)	13(17)
Sample 2	40	64	39	26
Sample 3	6	58	30	19
Total	58	148	92	58
Sex Ratio (M:F)				
Sample 1	0.75	0.40	0.33	0.29
Sample 2	0.44	0.81	0.67	0.91
Sample 3	0.25	0.23	0.35	0.13
Total	0.45	0.47	0.46	0.41

U. hoplurus Pocock (Scorpionidae)—were seen in small numbers only. Only the buthid *Lychas alexandrinus* Hirst was collected in sufficient numbers to allow statistical analysis (Table 1). *Lychas alexandrinus* is widely distributed in arid and semi-arid Australia. It is a small animal (total length 30 mm) that, in the sandplain environment of the Tanami Desert, shelters in abandoned burrows or nests of other invertebrates. As only three groups of traps were used in the first sample, the numbers of *L. alexandrinus* were scaled up to allow comparison with the later samples. The numbers of individuals were transformed by natural logarithms to normalize variances, and then a two-way analysis of variance was conducted to compare the numbers of *L. alexandrinus* caught in different vegetation states and samples.

The analysis showed that captures of *L. alexandrinus* did not vary significantly with sampling time ($F = 2.585$, $df = 2$ and 12, $P > 0.2$), but that they did so with vegetation state ($F = 4.825$, $df = 3$ and 12, $P < 0.05$); there was no significant interaction ($F = 1.085$, $df = 6$ and 12, $P > 0.5$). Subsequent testing of means with the Welsch step-up procedure failed to identify unambiguously the states which differed, but more individuals were captured in vegetation state 2 than states 1 and 8, with state 5 appearing to be intermediate (Table 1).

In order to look more closely at the difference between states, we examined the condition of each scorpion by dividing the length of its carapace into the cube root of its wet weight (we were able to do this because there was a significant correlation between preserved wet weight and dry weight; $r = 0.93$). In both males and females, these indices of condition varied significantly across the four vegetation states; both sexes showed better condition in state 5 than elsewhere (Table 2). These data add weight to the conclusion that populations reacted significantly to changes in vegetation, and that the middle of the successional gradient supported more active and relatively larger scorpions.

The sex ratio of male to female scorpions fluctuated substantially between samples (Table 1). These discrepancies may be due to different activity patterns between the sexes in relation to breeding, or perhaps in response to short-term weather conditions. Although the mean ratios appeared to be similar across the

Table 2.—Condition of male and female *Lychas alexandrinus* in four vegetation states, as estimated by dividing carapace length into the cube root of wet weight. Means ± standard deviations are shown, with sample sizes below. Differences among states were examined with Kruskall-Wallis tests. $^{**}P < 0.01$, $^{***}P < 0.001$.

	Vegetation state				Chi square
Sex	1	2	5	8	
Male	0.131 ± 0.006	0.129 ± 0.006	0.132 ± 0.006	0.129 ± 0.005	11.805**
	24	80	53	31	
Female	0.132 ± 0.005	0.131 ± 0.006	0.137 ± 0.007	0.130 ± 0.008	12.452**
	9	33	23	13	
Total	0.132 ± 0.006	0.130 ± 0.006	0.134 ± 0.007	0.130 ± 0.006	21.798***
	33	113	76	44	

vegetation states, our results concerning the effects of burning must be interpreted with caution because they may be affected by patterns of foraging and reproductive behaviors.

Although our study does not fully explain all observed changes in capture rates, it does provide evidence that at least one species of grassland scorpion persists readily through fires. Our data indicate that *L. alexandrinus* was active a year after a fire in numbers that were statistically indistinguishable from those in areas of mature spinifex. Increased numbers in traps were observed two to three years after burning, and scorpions were in better condition five years after a fire. We suspect that scorpions generally have the capacity to withstand perturbations such as fire. Most live in burrows, either their own or those of other species, or beneath persistent shelters (Polis 1988). It is worth noting Eastwood's (1978) suggestion that burrowing scorpions in South Africa were abundant after fire, but that non-burrowing species were less likely to persist through frequent fires. Scorpions are able to eat large quantities of food at one time and to store excess energy in the hepato-pancreatic glands. This ability, coupled with their extremely low metabolic rates, allows scorpions to survive without food for many months (Polis 1988). These characteristics, together with their long life-spans, probably allow many scorpions to avoid the direct effects of disturbances such as fire and to take advantage of the subsequent altered conditions.

In summary, our information shows that *L. alexandrinus* is caught more frequently several years after spinifex grasslands are burnt. Populations did not appear to be reduced in numbers a year after fire, and so they seem capable of taking advantage of the habitat changes set in train by burning.

We thank K. Jones for collecting and sorting the samples, M. Gillam, M. Fleming, and P. Dostine for assistance during the work, and A. Andersen, J. Greenslade, G. Griffin and G. Polis for commenting on the manuscript.

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Manuscript received September 1989, revised February 1990.