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SCATTING BEHAVIOUR OF THE SLEEPY LIZARD, *TILIQUA RUGOSA*

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Abstract

The use of chemical signals for communication is wide spread in many animal taxa. Squamates in particular have a highly developed vomeronasal system and investigate chemical signals through tongue flicking. In some lizard species, individuals have been shown to be able use chemical signals, including those from faeces (scats), for discriminating between kin and conspecifics and members and non-members of social groups. The Australia scincid lineage *Egernia*, is one group that has an unusually high number of species reported to produce scat piles close to their refuge sights. In this paper we explore the scattng behaviour of the sleepy lizard, *Tiliqua rugosa*, a member of the *Egernia* lineage to determine whether there is any evidence of an aggregated deposition pattern of scats by this lizard, similar to other member species in the lineage. We found that unlike related species that appear to use scat piles as social markers, sleepy lizards do not deposit scats in any systematic latrine system, or in piles to indicate occupancy of an area. Rather, they appear to be scattng haphazardly inside their home range. A conclusion from this comparison is that

scat piling in the *Egernia* lineage is associated more with refuge defence than with social aggregation.

KEY WORDS: *Egernia*, scats, home range, conspecific cues, territory marking

Introduction

The use of chemical signals from faeces (scats) for communication and territory marking is wide spread in many taxa, including mammals (Taylor, 1993; Vila *et al.*, 1994), amphibians (Simon & Madison, 1984; Guillaume, 2000;) and reptiles (Aragón *et al.*, 2000; Fenner & Bull, 2010). Some species have specific defecation sites or latrines, that provide information to conspecifics about territory boundaries, occupancy and reproductive status, both within and between social groups or individuals (Bull *et al.*, 1999; Sneddon, 2001; Chapple, 2003; Roper, 2003; Fenner & Bull, 2011b). Chemical signals are effective markers of territory and social status over a longer period of time than visual or auditory displays, as the signal persists and remains effective even when the signaller is not present (Aragón *et al.*, 2001a; Martins *et al.*, 2006).

Lizards, like other animals, use scats for chemical communication between conspecifics (Bull *et al.*, 2001; Fenner & Bull, 2010). Lizards have a highly developed vomeronasal system and investigate chemical signals through tongue flicking (Cooper, 1996). In some lizard species, individuals have been shown to be able to discriminate between scats of male and female conspecifics (López & Martin, 2005; Fenner & Bull, 2011b), between scats of familiar and unfamiliar conspecific neighbours (Aragón *et al.*, 2001b; López & Martín, 2002), and between scats of members and non-members of a social group (Bull *et al.*, 2001; O'Conner & Shine, 2006). This ability results from variation in the composition of the chemical signal among scats from different individuals (López & Martin, 2005; López *et al.*, 2006). Hence, scat-based chemical communication can form the basis of complex social

interactions and communications in lizards (Bull *et al.*, 2001; Fenner & Bull, 2010; Fenner & Bull, 2011b).

One Australian lineage of scincid lizards, the *Egernia* group, has an unusually high number of species reported to produce scat piles close to their refuge sites (Bull *et al.*, 1999; Bull *et al.*, 2001; Chapple, 2003). Many members of this group also form stable social aggregations, an unusual form of social behaviour in most other lizard families (Duffield & Bull, 2002; Chapple, 2003; Gardner *et al.*, 2007). Their scat piles seem to play a role in the recognition of the spatial boundaries of the social groups, and for social cohesion within the groups (Bull *et al.*, 1999; Bull *et al.*, 2000; Fenner & Bull, 2010). Even the more solitary living species of this lineage, such as the pygmy bluetongue lizard, *Tiliqua adelaidensis* and the eastern bluetongue lizard, *T. scincoides*, have been shown to recognise and respond to conspecific scat cues (Graves & Halpern, 1991; Fenner & Bull, 2011b), and pygmy bluetongue lizards appear to use scats as burrow ownership markers by aggregating their scats in the direction of burrows occupied by neighbouring conspecifics (Fenner & Bull, 2010). In this paper we explore the scatting behaviour of the sleepy lizard, *Tiliqua rugosa*, a member of the same *Egernia* lineage of Australian skinks (Greer, 1989; Chapple, 2003). We ask whether there is any evidence of an aggregated deposition pattern of scats by this lizard, similar to other member species in the lineage. This will help with our understanding of whether scat piling in this lineage is tightly linked to social complexity, or whether it is more conserved and linked more with resource availability, such as shelter sites.

The question of scat distribution has relevance for three reasons. The first is for comparative purposes across species in the *Egernia* lineage. As we seek to understand how social aggregation behaviour evolved in so many species in this lizard lineage, but in so few species in other families of lizards, any comparative clues of socially relevant behaviours

from across species will become important. A phylogenetic comparison of taxa that do or do not pile scats will contribute to this process.

The second reason concerns our continuing investigation of the social system of the sleepy lizard itself. Although this species is largely solitary, close monogamous male and female partnerships are maintained over several weeks in the spring (Bull, 1988; Bull, 2000), and social networks among non-paired lizards are characterised by the apparently deliberate avoidance of contact with some close neighbours (Leu *et al.*, 2010b; Godfrey *et al.*, 2013). To find partners and avoid neighbours requires an ability to deduce the locations of other individuals, and we have already suggested that chemical trails are an important component of this (Bull *et al.*, 1993; Bull & Lindle, 2002). The current study will provide information to assess whether scats might also play a role in organising the sleepy lizard social structure.

The third reason is that this study could provide deeper understanding about the transmission and spread of gut parasites around wildlife populations. Lizards, like most other taxa, are hosts to a range of macro and micro-parasites of the gut. These typically have a faecal-oral mode of transmission from one host to the next, where the first host sheds infective stages in its faeces, and the second host ingests those parasites, often in association with feeding near to the faecal deposition site (Soulsby, 1982). In the case of lizards, another method of faecal oral transmission can occur as one individual inspects the scats of another, using tongue flicks to detect olfactory signals, and potentially ingesting infective stages of the parasite on the surface of the scat (Fenner *et al.*, 2011). We have already demonstrated that more socially connected lizards are at higher risk of infection of gut nematodes (Godfrey *et al.*, 2009) and bacteria (Bull *et al.*, 2012). The spatial pattern of scat deposition of sleepy lizards could determine the realm of infectivity of individual lizards.

The sleepy lizard is a large (average 28 cm snout-vent length (SVL); and 750 grams body mass at our study site), long lived (>25 yr), slow moving, diurnal scincid that occupies a

variety of habitats in southern Australia (Bull & Pamula, 1996; Cogger, 2000). It is primarily herbivorous, but will opportunistically eat invertebrates, bird eggs and carrion (Dubas & Bull, 1991). In our study area, lizards feed predominantly on exotic annual plants that grow during the early spring, but dry out and die during the summer. Lizard activity, and feeding in a typical year start to decline with diminishing availability of this food source, from November onwards. Early in the austral spring (September), sleepy lizards form monogamous pairs for 6-8 weeks, until mating in early November, after which the pair splits up, until reuniting in the following season (Bull *et al.*, 1998; Bull, 2000). Sleepy lizards are not territorial, but have overlapping home ranges (3 – 9 ha) (Bull & Freake, 1999), although they have exclusive core areas representing 20% – 33% of the total home range, that are strongly associated with refuge sites (bushes, accumulated leaf litter and wombat/rabbit burrows) (Kerr *et al.*, 2003; Kerr & Bull, 2006b). Male and female pairs also have strongly overlapping core home range areas (Kerr & Bull, 2006b), as do mothers and their offspring (Bull & Baghurst, 1998). There is very little intra-sexual spatial overlap within the inner core areas, suggesting intra-sexual defence of the core area, although aggressive behavioural interactions are rarely observed (Kerr & Bull, 2006b). We ask, in this study, whether scating behaviour could be associated with marking and maintaining home range core areas exclusive of other same sex conspecifics.

Methods

Study site and animals

The study was conducted in a 500 x 400 m area adjacent to Bunday Bore station (33°55'S, 139°21'E) in the mid north region of South Australia, during the austral spring and early

summer (Sep – Dec) of 2011. This is the time of year when the lizards are most active (Kerr & Bull, 2006a). The area has an average annual rainfall of 238 mm and is dominated by chenopod shrubland (Leu *et al.*, 2010a).

In September 2011, each of 10 adult lizards (5 male; 5 female) from the study area was fitted with a 5 g, two stage radio transmitter (Sirtrack) that represented < 1% of the lizard body mass. The transmitters were attached to the dorsal surface of the tail of each lizard using surgical tape (Leu *et al.*, 2010a; Godfrey *et al.*, 2011). The lizards were released at their point of capture, then relocated during tracking sessions with a Telonics TR-4 150/154 receiver and three element Sirtrack antenna.

In each tracking session we used spools (3.1 g) of cotton thread (250 m) to track the exact path taken by active lizards during each day, over 3-5 consecutive days. For each lizard there were 7 – 11 tracking sessions spread evenly over the September – December study period, resulting in each lizard being tracked for a mean of 34.9 days (range: 26 – 40 days) over the spring and early summer. The variation among lizards in the number of days per session, and in the number of tracking sessions resulted from lizards sometimes refuging in inaccessible locations such as down the burrows of rabbits or wombats. We found each lizard in its overnight refuge on each morning of a tracking session, before lizard activity had started, and recorded the GPS location. We used locations of all detected overnight refuges to estimate the core home range area of each individual lizard following Kerr (2006), and using convex polygons derived from those locations in Ranges 8 v2.13 (Anatrack Ltd). To minimise disturbance to the lizards, they were only handled briefly while inactive, early in the morning when we removed the previous cotton spool, and attached a new cotton spool to the dorsal surface of the lizard tail with surgical tape, tied one end of the cotton thread to a nearby stick or shrub, and then released the lizard back to its refuge. Kerr *et al.*, (2004)

showed that lizards tended to remain inactive if only briefly disturbed, while they were in an inactive state early in the morning. In the evening, we followed each cotton thread track, removing the cotton thread and searching along the trail for scats that the lizard had deposited. We recorded the GPS location of the scats that we found. We are confident that all scats that were deposited by lizards during the cotton spooling periods were found, as the scats we located were all clearly visible either directly under or within 10 cm of the cotton thread track. Lizards normally changed refuge location from day to day (Leu *et al.*, 2010b), and we recorded the location of the new overnight refuge either by following the cotton spool trail to the lizard, or by relocating the lizard the following morning, using its radio transmitter signal, in cases where the lizard had moved beyond the 250 m length of the cotton thread (Figure 1).

In order to confirm that the scats we found along the cotton trails were from the lizards we were tracking, each lizard was induced to swallow between 40 - 50 small (4 mm diameter), plastic beads, of either a single unique colour or a unique combination of two colours, at the start and end of each tracking session. Lizards were observed for 2 mins once the beads had been offered to ensure they had swallowed the beads. We selected beads that were smaller in diameter than the 7 mm diameter Ward's weed, *Carrichtera annua*, seeds that are frequently ingested and passed intact into scats by sleepy lizards and other smaller related lizard species (Satrawaha & Bull, 1981; Duffield & Bull, 1998). Inspection of the beads that were found in the scats that we detected showed that we always correctly assigned scats to the individually tracked lizards.

We examined whether the lizards scatted more often in the early part of the study period (Sep – Oct) when the plant food was readily available or later in the season (Nov – Dec) when there was less food. We also examined whether male and female lizards differed

in their scatting behaviour over the season. In these analyses we calculated the number of scats per tracking day for each lizard. We used scats per tracking day rather than the total number of scats produced by a lizard, as not all lizards were tracked for the same number of days in each part of the study period. We conducted a repeated measures analysis of variance with number of scats per tracking day as the dependent variable, and using season (early or late) as the within subjects factor, and sex as the between subjects factor.

We then used the spatial distribution of locations of the scats to address two questions. First we asked whether the scatting behaviour of an individual lizard was related to its overnight refuge, and whether males or females tended to scat close to their refuge. We measured the distance between each scat location and the refuge that the lizard had used on the previous night, and then calculated a mean value for each lizard. We then compared between males and females the mean distance from refuge to scat, using an ANCOVA. Because lizards with larger home range area might be expected to travel further from their refuge, we used home range area (converted to natural log) as a covariate.

Second, we asked about the scatting pattern, and specifically if there was any evidence for clustering of scats by individual lizards and if there was any difference between sexes. For this analysis we first estimated the mean distance between each pair of scats deposited by a single lizard over the whole study period, and used that parameter in another ANCOVA to compare mean distance between scats for males and females, again using home range as a covariate. All ANCOVA's were performed using SPSS v20. Additionally, to examine whether scats from individual lizards were clustered or randomly scattered around their core home range, we used Ranges8 to identify the central point of the core home range of each lizard. We then divided each home range into four segments by drawing lines through the central point in a North-South and East-West direction. We used Chi square tests to test

the null hypothesis of equal numbers of scats in each segment. We considered that a significant test would provide initial evidence of scat clustering.

Results

Scatting behaviour

We recorded the locations of 164 scats from the 10 tracked lizards, of which 90 (mean 18.0; range 12 – 21 per lizard) were from female lizards and 74 (mean 14.8; range 9 – 23 per lizard) were from male lizards. Females produced a scat every second day on average (mean 0.51 scats/day, range 0.32 – 0.75 scats/day for the days observed), whilst males produced scats slightly less frequently (mean 0.41 scats/day, range 0.26 – 0.56 scats/day for the days observed).

There were no significant differences in the mean number of scats deposited per day between early or late in the study period ($F_{1,8}=0.000$, $P = 0.985$), or between males and females ($F_{1,8}=1.884$, $P = 0.207$) nor was there a significant interaction effect of sex x season ($F_{1,8}=2.180$, $P = 0.178$).

The mean core home range area was not significantly different between male (mean 7591.5 m²; S.E = 2189.3) and female (mean 11663.1 m²; S.E = 2533.0) lizards ($F_{1,8}=1.479$, $P = 0.259$) (Figure 2). The mean distance between an overnight refuge and the location where a lizard deposited its scats varied from 18-49 m (mean 33.02 m; S.E 4.71 males, and 30.03 m; S.E 5.84 for females) (Figure 3), with most scats deposited more than 20 m from the overnight refuge (Figure 4). However, we found no significant effect of lizard sex or interaction effect of lizard sex x core home range area for the mean distance between overnight refuge and the location where a lizard deposited its scats (Table 1). The mean

distance between scats that an individual lizard deposited varied between 26 -92 m but was not significantly related to either lizard sex or core home range area (Table 1). The smallest recorded distance of 26 m between scats from a single lizard suggested that scat piling in one location was not a component of the behaviour of this lizard.

Additionally we found no significant difference in the number of scats in each segment, for nine of our ten lizards (Table 2). Indicating that lizards are randomly scatting and not clustering their scats in one particular area or direction within the core home range area.

Discussion

Four lines of evidence strongly refute the proposition that sleepy lizards use scat piles as social signals. First there was no difference in scatting rate between adult males and females, as might have been expected if one sex was more involved in social signaling. Second, the individual scats that we observed from individual lizards, were all deposited more than 20 m from each other. Third, the scats from most lizards were spread evenly, in all directions around their home range. And fourth, despite intensive searches over an extended period that covered most of the activity season of the species, we never found more than a single scat in any location. In addition, sleepy lizards do not appear to scat sufficiently close to their overnight refuges for that scat to be an effective marker of refuge occupancy. Leu *et al.*, (2010) showed that sleepy lizards will frequently use the same refuges that other lizards have used previously, suggesting that even if scats are used to mark refuge occupancy, they are not effective in preventing refuge use by other lizards.

We started this study with three broad questions. The first concerned phylogenetic comparisons of scatting behaviour and social aggregations within the *Egernia* lineage. Unlike

other species of the *Egernia* lineage that utilize scats as social markers, sleepy lizards do not deposit scats in any systematic latrine system, or in piles to indicate occupancy of an area. Rather, they appear to be scatting haphazardly inside their home range. Most species in the *Egernia* lineage that produce scat piles do so outside of a defined and more permanent refuge sites, such as a rock crevice (*E. stokesii*) (Bull *et al.*, 1999) or a burrow (*Liopholis whitii*) (Chapple, 2003), where there is an incentive to defend those refuges from conspecifics or non-group members (Fenner & Bull, 2011a). Scat piling, apparently to indicate ownership of these refuges, happens in both socially aggregating species (*E. stokesii*) (Bull *et al.*, 1999) and solitary species (*T. adelaidensis*) (Fenner & Bull, 2010). In contrast, sleepy lizards have many more refuge sites available in their home range than they can occupy (Kerr *et al.*, 2003) and appear to tolerate both synchronous and asynchronous sharing of refuges (Kerr *et al.*, 2003; Leu *et al.*, 2011). A conclusion from this comparison is that scat piling in the *Egernia* lineage is associated more with refuge defence than with social aggregation. This is consistent with the observation that scat piling is regularly observed in other lizard (Shah *et al.*, 2003; Lancaster *et al.*, 2006) and snake families (Chiszar *et al.*, 1980; Heller & Halpern, 1982; Aubert & Shine, 2009) where social aggregations are rarely observed.

Our second question concerned the social structuring of sleepy lizard populations. In this study we did not attempt to observe whether lizards responded in any way to the deposited scats. Nevertheless, given the established use of olfactory cues in this species, and that sleepy lizard home ranges remain stable for many years (Bull & Freake, 1999), having scats located throughout the home range may be adequate indication to conspecifics that the core home range is occupied. The need to mark specific refuges may not be necessary. Perhaps lizards can also recognize the age of scats, and that may prove a useful signal to avoid contact if they can tell that another lizard has recently been near. Although these are

speculative ideas, our data from this study provide a foundation for future research to address these questions, and to gain new understanding of this well-studied social system.

Our third question was about the transmission of naturally occurring gut parasites. Our data suggest broad opportunity for transmission to neighboring lizards that inspect deposited scats. Again our study provides a foundation for more investigations of the duration of infectivity of any parasitic stages in the scats, and of the frequency of scat inspections. In order to further investigate the links between scat piling, social complexity and resource availability, possible additional experiments could be conducted that manipulate the available shelter sites or the numbers of individuals competing for those shelter sites, and examine whether or not scatting patterns change with resource availability for a range of species within the *Egernia* group. Another possible experiment could be to investigate how individuals respond to scats of different times since defecation, and the effectiveness of the scat as a social marker over time. This would also have implications for parasite transmission. Understanding scat deposition is another part of the broader picture of natural history and behaviour of sleepy lizards, which can allow further insights into patterns of social organization and host-parasite interactions.

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Table 1. Summary of ANCOVA of lizard sex and home range size on the mean distance between scats and the mean distance between scats and the previous overnight refuge. Significant results $P < 0.05$ are in bold.

Effect	Shelter site to scat distance			Scat to scat distance	
	<i>d.f</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>

Sex	1,6	2.661	0.154	0.981	0.360
Home range	1,6	0.699	0.435	0.313	0.596
Sex x Home range	1,6	2.834	0.143	1.186	0.318

1

2 **Table 2.** The number of scats each lizard deposited in each of the four direction segments and Chi-square values for each lizard. Significant
3 values are in bold font.

Lizard Number	Sex	North - East	South - East	South - West	North- West	χ^2	<i>d.f</i>	P
Lizard 1	Female	6	3	4	5	1.11	3	0.775
Lizard 2	Male	3	3	3	4	0.25	3	0.969
Lizard 3	Male	3	0	7	6	7.50	3	0.057
Lizard 4	Male	3	4	0	2	3.89	3	0.273
Lizard 5	Female	0	1	9	2	16.66	3	<0.001
Lizard 6	Female	3	7	5	3	2.44	3	0.486
Lizard 7	Male	6	4	5	8	1.52	3	0.678
Lizard 8	Female	3	8	2	8	5.85	3	0.119
Lizard 9	Female	7	3	2	9	6.23	3	0.101
Lizard 10	Male	2	2	4	5	2.07	3	0.558

4 **Figure Legends**

5 **Figure 1.** A core home range polygon showing the location of shelter sites used (grey
6 triangles) and the locations where scats were deposited (black circles), by a single female
7 lizard over the entire study period.

8 **Figure 2.** Mean core home range area (m^2) of male and female sleepy lizards.

9 **Figure 3.** Mean distance (metres) between the previous overnight refuge and scat deposition
10 sites for male and female sleepy lizards.

11 **Figure 4.** The number of scats deposited by all lizards and their distance from the previous
12 overnight refuge.