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## Home-range fidelity in the Australian sleepy lizard, *Tiliqua rugosa*

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### Abstract

A study was conducted at a semi-arid site near Mt Mary, South Australia. Fifty-eight adult sleepy lizards, *Tiliqua rugosa*, were radio-tagged and regularly located over the spring season, when they are most active, for 2–5 years. Home-range area did not differ between males and females. Changes in home-range position between years were assessed by the distance between home-range centres measured at intervals of one, two, three or four years. Mean distances for successive years were less than the span of the home range in one year. The distance did not differ between sexes, it was not related to lizard size, nor did it increase with increased time interval. This implies that for the resident adult population, lizards retain their home ranges for at least five years, and that the sexes do not differ in their fidelity to home range.

### Introduction

Home-range fidelity, when an individual maintains the same home range over consecutive seasons, has been recorded in a broad range of taxa. Home-range fidelity can enhance fitness because residents are familiar with food sources and refuges from predators within their home range (Greenwood and Harvey 1982). It is commonly observed in territorial birds (Newton and Marquis 1982; Beletsky and Orians 1987; Peterson and Best 1987) and mammals (Horsup 1994; Boellstorff and Owings 1995; Wauters *et al.* 1995). Usually, in those studies, successful breeders were more likely to retain home ranges, and unsuccessful breeders were more likely to shift. Home-range fidelity is far from universal. Many bird species disperse between breeding events (Greenwood and Harvey 1982) and many mammals regularly change home-range area (Ballance 1992; Norbury *et al.* 1994; Watts 1994). Similarly, fish can show strong (Hartney 1996) or weak (Vincent *et al.* 1995) home-range fidelity. Where dispersal occurs it can often be sex-biased, so that individuals of one sex disperse further than the other, perhaps to reduce the possibility of inbreeding (Greenwood 1980; Pusey 1987).

Among reptiles, snakes commonly use the same refuges over extended times (Webb and Shine 1997). Less is known about home-range fidelity in lizards. Several studies have shown short-term changes in the space used by lizards in response to environmental changes: *Lacerta vivipara* adjusted home-range area with changed population density (Lecomte *et al.* 1994), and *Psammodromus algirus* adjusted home-range area with changed predation risk (Salvador *et al.* 1995). Lizards can respond to changes in resource distribution; for instance *Cnemidophorus uniparens* shifted home-range centres towards sites where food was supplemented (Eifler 1996), and *Urosaurus ornatus* expanded home-range boundaries with increased availability of dead saguara cactus (M'Closkey 1997). Age and breeding behaviour can also influence space use in lizards: juveniles of *Lacerta vivipara* tended to disperse more than adults and yearlings (Clobert *et al.* 1994), juvenile males of *Lacerta agilis* dispersed more than females (Olsson *et al.* 1996), and adults of *Lacerta agilis* dispersed between breeding events, and dispersed further if their breeding success had been low (Olsson *et al.* 1997).

There are relatively few longer-term studies that have investigated the spatial stability of home-range use by lizards, but Kreckorian (1984) reported that 92% of individuals of *Dipsosaurus dorsalis* were recaptured within 40 m of their original capture point after almost three years.

The Australian sleepy lizard is a large skink with adult snout–vent length exceeding 28 cm (Bull 1995). It is largely herbivorous (Dubas and Bull 1991), and lives at least 9 years (Bull 1987) and probably 20–50 years (Bull 1995). At two study sites in South Australia, individuals have been reported to occupy stable home ranges within a year (Bull 1978; Satrawaha and Bull 1981; Bull and Baghurst 1998), and 91.7% of 759 recaptures within six years were within 100 m of the original capture point (Bull 1987). Freaake (1996) showed that individuals had a strong tendency to orient towards their home range when experimentally displaced. In the present study we investigated the fidelity of sleepy lizards to a home-range area across five years (1992–96) at a study site near Mt Mary in the mid-north of South Australia.

We considered whether males and females differed in the level of fidelity to home-range sites, and whether there was any chance of increased home-range shift with increasing time.

## Methods

The study was conducted in a 70-ha area of homogeneous chenopod scrubland around the Winters Homestead (33°55'S, 139°20'E) about 22 km north-west of Mt Mary, South Australia. The Mt Mary study area has been described by Petney and Bull (1984). It has an average rainfall of 250 mm, with cool winters and warm summers. We observed sleepy lizard home ranges from late August or early September until mid December (spring to early summer) in each of the five years 1992–96. Sleepy lizards were most active in that period. Earlier in the year, at the end of winter, ambient temperatures were too low for lizard activity, and later in the summer it was too hot and dry for extensive lizard activity (Bull *et al.* 1991; Bull 1995).

In this investigation lizards were treated using procedures formally approved by the Flinders University Animal Welfare Committee, in compliance with the Australian Code of Practice for the Use of Animals for Scientific Purposes. Lizards were captured by random encounter while walking through the study area. They were classed as adults if they exceeded 28 cm in snout–vent length (Bull 1995), and given unique combinations of toe clips for permanent identification. We tagged 40–50 adult lizards each year with 25-g, 2-stage radio-transmitters (Titley Electronics), representing 2–4% of the lizard mass. Radio-transmitters were attached to the dorsal surface of the tail using surgical adhesive tape; they had to be re-attached in late December or January when the lizards shed their skins. Each year some lizards retained their radio-transmitters from the previous year, and others were radio-tagged as we located them from late August. We painted unique combinations of coloured bands around the body of each lizard to identify and determine the location of individuals from a distance with minimal disturbance. Because adult sleepy lizards have few predators in the study area (Bull 1995), we did not consider these visual marks would influence lizard survival.

We located radio-tagged lizards with a Titley Regal 2000 receiver and a 3-element Yagi antenna at least once per day on 4–7 days per week over about 15 weeks of the study period each year. We usually avoided more regular locations, or extended observations of an individual, because these interrupted normal activity and led to lizards retreating into refuges for very long periods (Bull *et al.* 1993). Some radio-tagged lizards were located on fewer days if they were first tagged late in the season, or if their transmitter was shed or stopped transmitting during the season. Other lizards without transmitters were identified and recorded when they were encountered incidentally during radio-location surveys. On each location, we recorded the position of the lizard relative to nearby tagged bushes with known coordinates in the study area. Minimum convex polygon estimates of the home range of each lizard for each year were derived from all its locations in that year using Ranges V software (Kenward and Hodder 1996). The same software produced a harmonic mean location for each lizard in each year, which is a robust estimate of the centre of activity in the home range (Dixon and Chapman 1980; Spencer and Barrett 1984).

In this paper we considered only those lizards that were recorded over more than one year. For each lizard we calculated the distance between home-range centres for each pair of years when it was recorded. If the position of the home range remained stable from year to year, we predicted that there would be no increase in this distance between centres with increased number of years. On the other hand, if home ranges shifted position between years, we predicted that the distance between home range-centres would increase with elapsed time.

To distinguish between these two predictions we derived average distances for each time interval for each lizard. For instance, a lizard observed in all five years would yield four values for the distance between home-range centres over one year, three values for distances over two years, and so on. Only the single average value for each time interval for each lizard was used in a repeated-measures ANOVA with individual lizards as the replicates, and distances at one, two, three and four years being the repeated measures within each lizard.

An alternative indicator of home-range stability, which we did not use, is the percentage overlap between home ranges of a lizard in different years. We detected differences in home-range size among years. These may have been real or may have resulted from different sampling procedures by different field workers each year. For instance, more intense sampling or sampling later in the day, when lizards were more active, was more likely to detect occasional long forays by lizards beyond their normal home-range boundaries. These added substantially to the minimum convex polygon estimates of home-range area.

Variations in home-range size among years made analysis of home-range overlap between pairs of years difficult to interpret. A small overlap value could either reflect a substantial shift in home range by that lizard, or fidelity to the same area but a small measured home range in one year overlapping a small part of a larger measured home range in the next year.

## Results

Thirty adult male lizards and 28 adult females were observed in two or more years in the survey. Seven males and 8 females were observed in all five years (1992–96). Table 1 shows the mean home-range area of males and females in each year among the 58 lizards involved in this study. Home-range data were included only where there were more than 20 locations of an individual lizard in a year. No significant differences (evaluated by *t*-test) were found in mean home-range area between the sexes in any year.

**Table 1. Mean (s.e.) values of the Minimum Convex Polygon estimates of home-range area for each year for adult male and female lizards captured in two or more years in the study**

Only lizards with more than 20 locations in a year were included. The mean (s.e.) number of locations per lizard is shown

Year	Sex	No. of lizards	Mean (s.e.) home range (ha)	Mean (s.e.) no. of locations
1992	M	11	3.90 (0.51)	145.4 (18.3)
	F	6	4.11 (1.05)	154.5 (20.0)
1993	M	14	3.95 (0.86)	90.1 (4.0)
	F	9	2.72 (0.48)	78.4 (9.4)
1994	M	21	5.09 (0.92)	54.9 (3.8)
	F	13	4.72 (1.50)	56.9 (4.0)
1995	M	16	9.06 (1.66)	72.2 (3.1)
	F	22	7.26 (0.99)	65.7 (4.4)
1996	M	17	3.88 (0.40)	105.2 (6.5)
	F	22	3.49 (0.32)	96.6 (5.5)

Table 2 shows the mean distance between home-range centres for males and for females captured in successive years, and captured two, three, or four years apart. Note that three of the 30 males in the study were not included in the analysis for successive years (but were included in the analyses of greater time intervals) because they were only located two years apart. Because some (but not all) lizards were included in data from more than one time interval an overall analysis was not attempted on these data. However, there was no statistical difference (by *t*-test) between males and females in the distance between home-range centres over any individual time interval. That is, the two sexes shifted home-range centres by equivalent distances over each time interval examined.

Lizards in the study varied in snout–vent length from 22.5 to 32 cm when first captured, and in mass from 325 to 850 g. There was no correlation between either measure of size at first capture and distance between home-range centres for any time interval (Table 3). Specifically, larger lizards did not show any greater home-range fidelity than smaller lizards.

Five lizards were located more than 20 times in each of the five years of the study. For those five lizards a repeated-measures ANOVA showed no significant effect on distance between

home-range centres of sex ( $F_{1,3} = 3.97$ ;  $P = 0.14$ ) or of time interval ( $F_{3,9} = 0.08$ ;  $P = 0.97$ ). Nor was there any significant interaction effect between sex and time interval ( $F_{3,9} = 0.58$ ;  $P = 0.65$ ). The mean distance between home-range centres for those five lizards for each of four time intervals is shown in Table 4.

**Table 2. The mean (s.e.) distance between home-range centres for male and female lizards over different time intervals**

Where there was more than one value for an individual (for instance, a lizard observed in three years had two values for distance between successive years), the average value for that individual was used in deriving this table. Also shown are the results of *t*-tests comparing the mean distance of male and of female lizards for each time interval

Time interval (years)	Sex	No. of lizards	Mean (s.e.) distance (m)	<i>t</i>	d.f.	<i>P</i>
1	M	27	88.5 (16.6)	0.73	53	0.47
	F	28	74.3 (10.6)			
2	M	22	93.1 (12.7)	0.48	34	0.64
	F	14	109.7 (38.9)			
3	M	16	91.5 (20.4)	0.45	26	0.66
	F	12	112.7 (47.4)			
4	M	12	132.5 (38.6)	0.94	19	0.36
	F	9	88.0 (17.2)			

**Table 3. Correlation coefficients for the lizard size at first capture (measured as snout-vent length, SVL, and as body mass) and distance between home-range centres over different time intervals**

Time interval (years)	<i>n</i>	Snout-vent length		Mass	
		<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
1	55	-0.19	0.17	-0.20	0.14
2	36	-0.08	0.96	-0.11	0.52
3	28	0.03	0.86	-0.11	0.58
4	21	0.16	0.50	0.14	0.54

**Table 4. Mean (s.e.) distance between home-range centres for each time interval**

Results are based on more than 20 locations for each lizard in each year of the study

Time interval (years)	Distance between home-range centres (m)	
	'5-year' lizards ( <i>n</i> = 5)	'4-year' lizards ( <i>n</i> = 18)
1	67.0 (19.4)	60.9 (9.6)
2	63.9 (12.1)	70.5 (9.2)
3	68.9 (21.4)	65.7 (13.3)
4	67.0 (20.9)	

Eighteen lizards were located more than 20 times in each of four successive years of the study. These included the five lizards located in five years. Again repeated-measures ANOVA showed no significant effect on distance between home-range centres of sex ( $F_{1,16} = 0.02$ ;  $P = 0.88$ ) or of time interval ( $F_{2,32} = 0.13$ ;  $P = 0.87$ ). Nor was there a significant interaction effect between sex and time interval ( $F_{2,32} = 1.20$ ;  $P = 0.32$ ). The mean distance between home-range centres for these lizards for each of the three time intervals is also shown in Table 4.

### Discussion

Home-range areas of about 4 ha measured for the lizards in this study coincide with estimates previously reported for sleepy lizards in the Mt Mary region (Bull 1988; Bull and Baghurst 1998). The estimated position of the centre of the home range for each lizard would be influenced both by the overall position of the home-range boundaries, and by the locations within the home range where there was most activity. Home-range centres may have shifted as a result of changes in boundary locations following a genuine change in home-range position. They may also have shifted if the sites where a lizard was most active changed within stable home-range boundaries. The sites of most activity could have changed among years if the best feeding sites, or the most suitable refuges are in different places in the home range in different years.

If home ranges were perfectly circular the diameter across a 4-ha home range would be more than 200 m. Home ranges are not circular (Bull 1994) and the mean span across home ranges can exceed 280 m (Bull and Baghurst 1998). The average shifts in home-range centres between successive years, and over longer intervals of up to four years, were always much lower than the home-range span. Home-range centres were unlikely to shift beyond their own boundaries of previous years.

There were two significant results from the study that provide new insights into the social organization of sleepy lizards. First, the home-range shifts of adult males and females, reflecting the pattern of dispersal of the two sexes over years, were no different, at least among adult lizards. This contrasts with the pattern commonly found in birds and mammals where adults of one sex are commonly more dispersive than the other (Greenwood 1980). Second, there was no trend for increased distance between home-range centres of individual lizards with increasing time. This clearly supports the view that home ranges of adult lizards were stable in position for at least five years.

The data also showed an apparent trend for home-range shifts to be smaller among lizards with over 20 observations per year for four or five consecutive years (Table 4), than for all lizards found in more than one year (Table 2). This could be because Table 2 included data from lizards with fewer than 20 observations in a year. In those years the estimates of position of home-range centre may have been less accurate, and biased the estimates of distance between years for those lizards. Alternatively, the data in Table 2 may have included some lizards only present in the study area for a few years, whereas the data in Table 4 included only long-term residents. Bull (1995) suggested that the population in any year consists of a stable component and a transient group of lizards. Transients, or newly established lizards, may adjust their home-range position each year if they stay for more than a year. While Table 4 represented a long-term stable component of the population that retained a high site fidelity among years, it was not necessarily representative of all lizards in the population. Lizard body size was not a good indicator of home-range fidelity. There was no significant decline in the distance between home-range centres in successive years comparing with increased lizard size, as might have been expected if residents were larger.

The results show that some long-term resident lizards retained home-range areas over many years. It is still unclear how they recognise home-range boundaries. Sleepy lizards are active for only about four months each year (Bull *et al.* 1991), when they probably use chemical trails to mark and recognise areas they occupy, as well as recognising the paths of other lizards (Bull *et al.* 1993). But when they start to become active in early spring, any trails and chemical signals

from the previous year would have been washed away by winter rains. Olfactory cues from plants would also have altered with spring growth.

Sleepy lizards could use visual cues to recognise their home-range area. Freaake (1966) showed that they oriented homewards when displaced from their home ranges, but less successfully if they were denied visual cues during displacement. The local visual environment would also change substantially from one year to the next, and to maintain a home range over several years they must recognise prominent stable landmarks. However, with their eyes only 3–4 cm above ground level, their perceived horizon would be very short, and landmarks may not always be visible. Zollner and Lima (1997) found that white-footed mice, with similar stature problems, were unable to orient towards their favoured forest habitat from distances greater than 30 m, even in an open field.

Additionally, the flat topography and the relatively uniform chenopod shrub vegetation would provide relatively few landmarks. However, lizards could use roads and other mammal (sheep or kangaroos) paths, fence lines and dams, larger trees, and rabbit or wombat warrens. Some other cues, such as magnetic fields (Walker *et al.* 1997), could also be used to recognise home ranges.

The fidelity to their home range indicates two remarkable aspects of sleepy lizard behaviour. First, being relatively low to the ground, yet maintaining large home ranges, the lizards must never be able to perceive more than a small fraction of their total home range at one time. The maintenance of relatively large home ranges implies the spatial integration by the lizards of a large number of small perceptual fields. Second, the long period of inactivity, up to eight months each year, means that the lizards do not have the opportunity to reinforce their perception of home range as it changes seasonally. They need to retain a long-term memory of the spatial configuration of the non-changing elements of their home range over the inactive period. It may be that they remember only a small central core of the home-range area, and each year make exploratory expansions around that core. Whatever the mechanism, the fidelity to home range over many years is impressive.

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