Wildl. Res., 1993, **20**, 227–31

Daily Movement Patterns and Habitat Preferences of *Varanus caudolineatus* (Reptilia : Varanidae)

Graham Thompson

University of Western Australia, Stirling Highway, Nedlands, W.A. 6009, and
Edith Cowan University, 2 Bradford Street, Mt Lawley, W.A. 6050, Australia.

Abstract

Eleven *Varanus caudolineatus*, a small Western Australian varanid, were tracked for up to 18 days by means of a radioactive tracer (^{22}Na). The lizards foraged extensively on the ground and used trees as a safe refuge when resting. They were found most frequently in hollows of dead, standing trees, but they were also found in live trees, and in dead trees and stumps lying on the ground. Upon release after capture the lizards moved up to 159 m, remaining in one tree for 1–15 days (mean 2·93 days) before moving a mean distance of 33·9 m to another tree or a pit-trap. Most of the foraging activity occurred in late morning or early afternoon, when the ambient temperatures were near their peak. The movement of lizards from 'resident' trees was significantly positively correlated with daily maximum temperatures (30–45·5°C).

Introduction

Almost all that is known of the ecology of *Varanus caudolineatus* is derived from Pianka (1969, 1986). Storr and Harold (1980) and Schmida (1975) refer briefly to aspects of this lizard's ecology, Smith (1988) provides information on egg laying by one female, and Thompson *et al.* (1992) provide details on their combat ritual. Most other published literature on *V. caudolineatus* (Storr *et al.* 1983; Cogger 1986; Greer 1989) appears to be derived from Pianka (1969).

The little that is known about the ecology of *V. caudolineatus* suggests that these lizards are arboreal, living in mulga (*Acacia aneura*) country. They are found under the loose bark and in the hollows of *A. aneura*, and occasionally on eucalypts and in rock crevices of exfoliating granite outcrops (Pianka 1969). The stomach contents of specimens caught by Pianka (1969) and of those in the Western Australian Museum collection (G. Thompson and D. King, unpublished data) indicate that these lizards eat predominantly spiders, grasshoppers, roaches and lizards. Gut contents of *V. caudolineatus* caught at Atley Station, Western Australia, contained predominantly scorpions and a lesser but substantial number of ground spiders (G. Thompson and D. King, unpublished data). These findings suggest that *V. caudolineatus* forages on the ground, searching for prey by going down their holes.

Previous attempts to track *V. caudolineatus* with miniature radiotransmitters (mass <2 g) proved unsuccessful as the transmitters severely restricted the lizards' movements within tree hollows. This study reports on the daily movement patterns of 11 *V. caudolineatus* tracked for a period of up to 18 days by means of a radioactive tracer.

Materials and Methods

The study site has red loamy soils that support a vegetation consisting mainly of patches of spinifex (*Triodia* sp.) grasses and small trees. The trees are predominantly mulga (*Acacia aneura* and *Acacia craspedocarpa*) with a lower number of mallee eucalypts (*Eucalyptus* spp.)

1035-3712/93/020227$05.00

Nine of the 11 *V. caudolineatus* used in this study were captured by searching dead mulga and eucalypt tree hollows in the vicinity of the study site on Atley Station (28°25'S.,119°07'E.; 55 km south-west of Sandstone, Western Australia). The remaining *V. caudolineatus* were captured within the study site. The process of systematically searching for *V. caudolineatus* in hollows of dead trees in nearly all cases necessarily resulted in the destruction of the tree in which the lizard was originally found and of most of the other similar suitable habitats in the vicinity. It was considered more appropriate to release these lizards into a similar area in the vicinity where the dead trees remained intact rather than in the location in which they were captured where their habitat had been significantly altered.

The lizards were measured for snout–vent length and total length; any external marks (e.g. short tail, scars) likely to be useful in later identification were also noted. Before being released each lizard was injected with approximately 9 μCi of ^{22}Na (370 KBq) into its peritoneal cavity. A scintillation meter (Mini Instrument model 540) with a wide-face probe (model 44b) on the end of a 3·2-m extension was used to detect the presence of ^{22}Na. Prior to the fieldwork, it was determined in the laboratory that 10 μCi of ^{22}Na injected into a 15-g lizard was sufficient to detect a lizard shielded by 90 mm of wood with a slow pass of the probe, 500 mm away.

The lizards were released and tracked between 26 November and 15 December 1991. Daily minimum and maximum temperatures were recorded to the nearest 0·5°C in the shade, 750 mm above the ground in a sheltered area with a Zecol B.S. 2840 thermometer.

The lizards were released in the late afternoon into a suitable tree hollow in an area approximately 200 by 600 m that was chosen because its soil and vegetation were typical of that of the area in which the lizards were caught. Sixty 20-L pit-traps with 10-m fly-wire drift fences had been placed in this area 10 weeks earlier. The pit-traps were arranged in 10 rows of 6 with approximately 65 m between rows and 40 m between pit-traps in each row. One of the two *V. caudolineatus* caught in the study site was released in the tree on which it was caught, the other was released onto the closest suitable tree adjacent to the pit-trap in which it was caught.

Each morning (between 0700 and 0900 hours), commencing at its last known position, a search was carried out for each lizard with the scintillation meter. Lizards were located by a significant increase in the counts on the meter. The location of the trees and the position of the lizards in the trees were recorded. The lizards were not otherwise disturbed.

The pit-traps were inspected every morning (0700–0900 hours) and every afternoon (1500–1700 hours). Any *V. caudolineatus* caught in a pit-trap was removed, and its identity checked before it was released in the nearest suitable tree hollow later that afternoon.

The analysis of movement patterns excluded data from the day of release and movement from that tree if it occurred on the following day.

Results

The snout–vent lengths of the 11 *V. caudolineatus* ranged from 80 to 120 mm, with a mean of 106 mm (s.e. = 5·44 mm), and total lengths from 169 to 267 mm, with a mean of 225 mm (s.e. = 10·8 mm) (Table 1). Eight of the *V. caudolineatus* injected with ^{22}Na were caught on a total of 10 occasions in pit-traps during the study period. Five were captured at the end of the study. In all cases the lizard captured was the one that would have been expected at that location.

There was a significant positive correlation ($r = 0{\cdot}61$, $P < 0{\cdot}004$) between maximum daily temperature and the percentage of lizards recorded as having travelled a significant distance (i.e. moved from their known 'resident' tree to another tree, or caught in a pit-trap). *V. caudolineatus* were caught only in the afternoon pit-trap inspections (1500–1700 hours), suggesting that they were active on the ground late in the morning and early afternoon when the ambient temperature was near its highest. No *V. caudolineatus* were caught in pit-traps in the morning even though late-afternoon and evening ambient temperatures were often in the mid 30s to low 40s (°C).

When a lizard was located in a standing tree, it was invariably in the highest hollow into which it could just squeeze. If a lizard was not found in such a tree, then a systematic search of all available trees and shrubs within a 75-m radius was carried out. Lizard No. 1's location was known for 18 days, the maximum period following release. The locations of lizards No. 5 and No. 8 were known for only 5 of the possible 18 days.

Table 1. Size and movement of *Varanus caudolineatus*

Lizard No.	Snout–vent length (mm)	Total length (mm)	Number of days whereabouts known	Distance travelled from release tree (m)	Maximum days recorded in one tree	Number of trees known to have been occupied	Maximum distance known to have travelled in one day (mm)
1	118	240	17	27	13	2	27
2	120	230	15	0	15	1	0
3	118	267	15	79	13	3	67
4	80	169	13	18	6	2	18
5	88	185	5	24	3	2	14
6	85	192	11	159	2	8	156
7	81	185	13	28	6	4	38
8	119	236	5	81	3	2	80
9	119	247	7	0	5	1	22
10	120	261	13	49	3	5	40
11	119	265	9	64	3	4	53
Mean	106·1	225	11·2	48·1	6·5	3·1	46·8
s.e.	5·44	10·8	1·25	14·0	1·44	0·62	13·0

Localities of other lizards were known for 6–18 days (Table 1). The locations of five lizards were not known for varying periods (1–9 days) but these animals were subsequently found, mostly within the previously searched area. On two occasions when a lizard was not found in its 'resident' tree in the first search of the morning it was subsequently found to have returned to that tree in a later mid-morning search.

Varanus caudolineatus appear to have a preference for residing overnight in dead standing trees, probably because these trees contain many small hollows, although they were also found in live trees and dead trees lying on the ground, and one (No. 10) was located in a large stump of a mulga tree, 0·2 m above the ground for three days. On only one occasion was *V. caudolineatus* found under the bark of a tree; it was located close to the ground (about 0·1 m) and had probably been disturbed and had taken temporary refuge at this location as it was found the next day at another location.

The mean maximum distance covered in one day from one 'resident' tree to another or to a pit-trap was 33·9 m (s.e. = 6·11, $n = 10$) and ranged from 14 to 156 m (Table 1). The known distance that *V. caudolineatus* travelled from their release tree ranged from 0 to 159 m. The maximum number of days *V. caudolineatus* remained 'resident' in one tree ranged from 2 to 15 days (Table 1) with a mean number of 2·93 days (s.e. = 0·52) spent in one tree before moving. Two lizards were recorded as returning to a tree that they had previously occupied.

Discussion

Although *V. caudolineatus* is commonly referred to as an arboreal lizard (Pianka 1969; Storr and Harold 1980; Storr *et al.* 1983; Cogger 1986; Greer 1989), it clearly forages on the ground (G. Thompson and D. King, unpublished data) and uses trees as a safe resting refuge. Given its wary nature, it is likely to retreat, when disturbed, to the nearest tree hollow or, if none is available, to a high position on the far side of a tree. It is this behaviour that probably results in the most *V. caudolineatus* being located in trees.

Attempts to observe the daily movement behaviour of *V. caudolineatus* from a hidden position met with very limited success because these lizards are very wary. A number were observed to locate themselves in a hollow of a tree, often 3–5 m above the ground, so that

their head and neck protruded from a hole. They would remain almost motionless in this position, often for longer than 60 min. This position, together with their cryptic skin colour and pattern, provided them with a vantage point from which they could see potential predators and retreat into their hollow without being readily detected.

Of those *V. caudolineatus* whose whereabouts were known for 10 or more days, the greatest recorded distance moved from the point of release was 154 m while the mean maximum distance moved from the point of release was 58·7 m (s.e. = 15·2, $n = 8$). One particular *V. caudolineatus* was caught on 27 September 1991 and again 35 m away on 12 December 1991, a period of 74 days. The distances travelled by these varanids are short when compared with other small or small-to-medium-sized goannas [e.g. *Varanus eremius*, 'I have often followed a fresh track for distances up to half a mile', Pianka (1968: 42); *Varanus tristis*, 'cover distances nearly one mile', Pianka (1971)].

Most of the ground foraging was done in the late morning or early afternoon when ambient temperatures (T_a) were near their peak (mean maximum $T_a = 39{\cdot}67$°C, s.e. = 0·92, $n = 18$) and when most other lizard species had retreated to their holes. No *V. caudolineatus* was caught in a pit-trap cleared after 1700 hours yet the ambient temperature on many of the days would have exceeded 35°C at this time. It was noted also that the larger *Varanus gouldii* in the area often emerged from their burrows on these hot days at around 1700 hours. When *V. caudolineatus* were not found in the first search of the morning but were later located in the tree that they had occupied on the previous day, or were not found for a couple of days then located in the area that had previously been searched, it was presumed that they were on the ground foraging and had hidden in the spinifex, leaf litter or a hole in the ground.

Relocation of Lizards

Four of the varanids were caught approximately 1 km from the study site in an area approximately 50 by 100 m, and five were caught approximately 5 km from the study site in an area approximately 100 by 150 m. The relocation of nine of the 11 *V. caudolineatus* used in this study could have altered their movement behaviour. However, there was no evidence to suggest that the movements of the two lizards caught in the study area differed from that of the other nine, nor was there a discernible change in movement behaviour over time as the relocated lizards adapted to their new environment.

Capturing *V. caudolineatus* by using techniques that do not destroy their trees (e.g. pit-traps), in the author's experience, yields an impractically low catch rate; during September 1991 the study site was pit-trapped for nine days (444 pit-trap days) and only two *V. caudolineatus* were caught. It is probable, however, that other *V. caudolineatus* were on the site but not seen; on three occasions, four *V. caudolineatus* have been caught within an area approximately 50 by 100 m, suggesting that they live in close proximity, or in groups. It is probable that the density of *V. caudolineatus* on the study site was not significantly higher than would normally occur in other areas of Atley Station and it appeared to have been similar to that from which they had been caught. It was not possible to know the density of *V. caudolineatus* on the capture or release sites without destroying all of the trees, which was not desirable.

Radioactive ^{22}Na Tags

The regular location of *V. caudolineatus* injected with ^{22}Na proved to be an effective method of tracking these small arboreal varanids. There are two potential problems associated with this technique. Firstly, the time it takes to search and locate lizards that have moved from a 'resident' tree results in a human presence in the area that would otherwise not be there. This may have an unknown effect on altering the animal's behaviour (Sugerman 1990). The second problem is the possibility of detecting the presence of a radioactive *V. caudolineatus* scat in a tree and mistaking this for the lizard. *V. caudolineatus*

were found to ingest large prey items relative to their body size (G. Thompson and D. King, unpublished data) and the resulting scats were correspondingly large and often carried a significant amount of radioactive ^{22}Na. Considerable care was taken in this study to avoid mistaking a scat for the lizard by monitoring the counts from the scintillation meter.

Acknowledgments

This research was made possible by the financial assistance of Edith Cowan University and the University of Western Australia.

The field assistance of P. Hately, S. Thompson and W. Thompson was very much appreciated. Approval from Mr and Mrs Broadhurst to use Atley Station was appreciated. The manuscript was significantly improved by the comments of P. C. Withers and two anonymous referees.

All lizards were caught under a licence issued by the Department of Conservation and Land Management. Animal experimentation on live specimens was carried out with the approval of the Animal Welfare Committee of the University of Western Australia. Approval to use radioactive substances was approved by the Radiological Council of Western Australia.

References

Cogger, H. (1986). 'Reptiles and Amphibians of Australia.' (Reed: N.S.W.)

Greer, A. E. (1989). 'The Biology and Evolution of Australian Lizards.' (Surrey Beatty: N.S.W.)

Pianka, E. R. (1968). Notes on the biology of *Varanus eremius*. *Western Australian Naturalist* **11**, 39–44.

Pianka, E. R. (1969). Notes on the biology of *Varanus caudolineatus* and *Varanus gilleni*. *Western Australian Naturalist* **11**, 76–82.

Pianka, E. R. (1971). Notes on the biology of *Varanus tristis*. *Western Australian Naturalist* **11**, 180–3.

Pianka, E. R. (1986). 'Ecology and Natural History of Desert Lizards. Analyses of the ecological niche and community structure.' (Princeton University Press: Princeton, N.J.)

Schmida, G. E. (1975). Daumlinge aus der Familie der Riesen. *Aquarien Magazine* **9**, 8–11.

Smith, L. A. (1988). Notes on a clutch of monitor (*Varanus caudolineatus*) eggs. *Western Australian Naturalist* **17**(4), 96.

Storr, G. M., and Harold, G. (1980). Herpetofauna of the Zuytdorp coast and hinterland, Western Australia. *Records of the Western Australian Museum* **8**, 359–75.

Storr, G. M., Smith, L. A., and Johnstone, R. E. (1983). 'Lizards of Western Australia II: Dragons and Monitors.' (W.A. Museum: Perth.)

Sugerman, R. A. (1990). Observer effects in *Anolis sagrei*. *Journal of Herpetology* **24**, 316–17.

Thompson, G. G., Withers, P. C., and Thompson, S. A. (1992). The combat ritual of *Varanus caudolineatus* and *Varanus gouldii* (Reptilia: Varanidae). *Western Australian Naturalist* **19**, 21–5.

Manuscript received 31 January 1992; revised 3 April 1992; revised and accepted 23 July 1992