The western bearded dragon, *Pogona minor* (Squamata: Agamidae): An early lizard coloniser of rehabilitated areas

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(Manuscript received March 2002; accepted August 2002)

Abstract

We investigated why the western bearded dragon (*Pogona minor)* is an early coloniser of rehabilitated waste dumps in the mining area around Ora Banda, Western Australia. The daily distance travelled for 19 (14 female and 5 male) *P. minor,* measured using nylon thread spools attached to the lizard's tail, was 115 m. This corresponded to a mean linear distance moved of 68 m. Our data suggest that *P. minor* are one of the first species of reptiles to colonise mine site rehabilitation areas because they move appreciably greater daily distances than other agamid lizards, are spatially widely-foraging, frequently forage in or use saltbush (*Atriplex* spp) and bluebush (*Maireana* spp) as basking sites, regularly traverse open areas, readily move up and down steep slopes, and eat bull ants which are generally present on rehabilitated sites. *Pogona minor* also have a high reproductive potential and show no obvious aversion to mine sites as oviposition locations. *Pogona minor* eggs incubated at 27 °C took an average of 64 days to hatch, the mean snout-to-vent length was 36.1 mm and the mean mass was 1.74 g.

Keywords: Western bearded dragon, *Pogona minor*, daily distance travelled, recolonisation, rehabilitated mine site, reproduction

Introduction

Although western bearded dragons (*Pogona minor*) are a common and conspicuous agamid lizard, particularly in spring when they are often seen on country roads, little is known about their daily movements or their biology (Greer 1989). *Pogona minor* is one of three species of bearded dragons (*P. minor, P. microlepidota* and *P. nullarbor)* in Western Australia (Aplin & Smith, 2001). Bearded dragons are medium-sized and stout in shape, with a well-developed row of spines on the head and along the sides of the body (Storr *et al.* 1983). The lizards in this study all had white mouths; elsewhere in the state some have yellow mouths.

Pogona minor is found in most habitat types in the Western Australian goldfields and is thought to be a widely-foraging, generalist feeder (Pianka 1986). Anecdotal evidence indicates that *P. minor* is one of the early colonising reptiles in mine site rehabilitation areas. It is not known if this is because of their widely-foraging behaviour with no apparent home range, or because they move greater distances in a day compared to other agamids, prefer the disturbed type of habitat often present in rehabilitated areas, or their relative high fecundity (based on multiple clutches in a season; Bradshaw 1981; B Jennings, University of Texas at Austin, personal communication) and recruitment forces juveniles into new areas.

The presence of *P. minor* on rehabilitated mine sites and the proportion of total species richness were used to determine whether this species is an early coloniser in rehabilitated mining areas. If *P. minor* is present and represents a higher proportion of the species in rehabilitated areas compared with the adjacent undisturbed areas, then this is evidence that they are one of the first species to colonise an area. Evidence of successful reproduction by species in a rehabilitated area would also provide evidence of successful colonisation into the area. Rehabilitated sites that are developing into self-sustaining functional ecosystems generally have less species than the adjacent undisturbed areas (Read 1999). Presuming an appropriate rehabilitation program is in place on the mine site, species richness will increase as species progressively move from the adjacent areas into the rehabilitated area (Fox & McKay 1981; Fox & Fox 1984; Fox 1990).

The aim of this research was to investigate the daily movement patterns of *P. minor* in the mining area around Ora Banda, Western Australia, to ascertain if there was a pattern to their daily movements (*e.g.* confined within an activity area), how far they travel in a day, which micro-habitats they frequent, and whether these data can shed light on why this species is an early coloniser in rehabilitated mine areas.

Methods

Pit-traps (alternating lines of 20 L PVC buckets and 600 x 150 mm PVC pipes, 5–6 m apart and joined by 300 mm high fly-wire drift fences) were used at rehabilitated mine sites and the adjacent undisturbed areas in the vicinity of Ora Banda (30° 22' S, 121° 03' E) to capture small vertebrates. Seventy two pit-traps (12 arrays of 6 lines) were placed on each of five rehabilitated waste dumps and 48 pit-traps (8 arrays of 6 lines) in the adjacent undisturbed areas. The pit trap arrays adjacent to the waste dumps are between 50 and 200 m away from the base of the waste dump. Pit traps were positioned in an additional six undisturbed areas (48 pit-traps each) during this period. Different habitats based on vegetation types were selected for each of the undisturbed areas. Although the undisturbed habitats varied in composition they can generally be characterised as Eucalypt-Casuarina-Mulga woodlands interspersed with *Acacia acuminata* shrublands. The rehabilitated waste dumps are less vegetated, generally with a sparse covering of chenopod shrubs (*i.e.* bluebush and saltbush) and large areas of bare ground. The waste dumps were rehabilitated in 1993, 1994, 1997 and 1998, and the fifth waste dump had a staged rehabilitation in 1992 and 1996.

Daily movements of adult *P. minor* were monitored between 13 and 29 September, 1 to 15 December 2001, and 11 to 23 January 2002, a total of 43 days. These lizards were caught by hand or in pit-traps and released at or near their place of capture within 10 minutes of capture. Lizards were weighed, snout-to-vent (SVL) and tail length measured, and individually numbered by toe clipping. Sex was confirmed by the eversion of hemipenes (for males) or the presence of eggs (for females).

A spool of white, double-stranded nylon thread (Penguin Thread Co, Victoria) was attached to the dorsal surface of the base of each lizard's tail with 35 mm grey, polyvinylchloride (PVC) electrical insulation tape. The attachment of the spool to the dorsal surface of the base of the tail was intended to minimise the possibility of the spool impeding movement. The free end of the thread was tied to a fixed object at the point of release. As the lizard moved away from this point the thread pulled away from the centre of the bobbin, leaving a white nylon thread on the ground indicating the path the animal had taken. Each nylon spool contained over 225 m of thread. If the nylon spool ran out, either the lizard was recaptured (and the spool replaced) or the insulation tape came off after a further 2–3 days, leaving the lizard unencumbered.

The daily movement patterns of 19 *P. minor* were recorded from the day after their release, by retrieving the nylon thread by hand, noting where the lizard had moved, and measuring the length of the nylon-thread trail. The lizards were handled and disturbed as little as possible, and there was no evidence to suggest that their distance travelled or their behaviour was affected by handling. A Universal Transverse Mercator (UTM) location for each *P. minor*, each day, provided a measurement of the linear distance moved for the previous day. UTM's were accurate to ± 4 m (Garmin GPSII Plus). The daily distance travelled, as measured by the length of the nylon thread, is referred to as the 'foraging distance', and the distance between UTM positions is referred to as the 'linear distance' travelled. The habitat traversed (*e.g.* number of bushes, log piles, ant mounds visited, *etc*) by each lizard was recorded when retrieving the nylon thread.

Most rehabilitated mining waste dumps around Ora Banda have steep sides with a flat or concave top. Vegetation on waste dumps generally consists of a high proportion of *Atriplex* spp and *Maireana* spp, often with little leaf litter, and many sites have large areas where the vegetation is sparse. Most have an apron of bare ground around the perimeter that colonising reptiles must cross to get onto the top of the waste dump. For most sites, the topsoil had been deeply ripped on the top and sides to stop water run-off, formation of gullies and erosion. Deep ripping creates a very uneven surface of linear mounds and furrows.

Three gravid females from the site were removed in early October and laid eggs that were incubated at 27.5 (± 1.0) °C in a mixture of vermiculite and water (1:1 by mass) to determine incubation period and neonate size at a known temperature.

Results

Pogona minor always represented a higher proportion of the reptile species richness in the five rehabilitated mining sites than in the adjacent undisturbed areas (1/14 species *vs* 1/33 species; 1/9 *vs* 1/25; 1/9 *vs* 1/17; 1/20 *vs* 1/25 and 1/17 *vs* 1/25). Because *P. minor* was present on all rehabilitated sites, even when the species richness was less than for the adjacent areas, we conclude that *P. minor* is one of the early reptile species to colonise rehabilitated mines sites in the Ora Banda area.

A spool was attached to five adult males (mass = 59.2 ± se 2.63 g; SVL = 125.8 ± se 3.15 mm) and 14 adult female *P. minor* (mass = 67.3 ± se 7.95 g; SVL = 128.9 ± se 2.42 mm). Nine lizards were recorded for six or more consecutive days, and we have 103 lizard-days of movement data. One lizard was found immobilised in a bush, caught by the nylon thread, on three occasions. Data for this lizard on the days for which its movement was impeded were not used in the analysis and are additional to the 103 days of data. There were no mortalities.

On some days, lizards did not move, and on some days the thread broke or ran out. Consequently we have three possible measurements of daily distance moved; a) distance travelled when the total distance moved was known (including when the lizard did not move and the thread did not break or run out) was 79.0 ± se 7.40 m (n = 79); b) distance travelled when the total distance moved was known but excluding those days when the lizards did not move away from their overnight position (and excluding days when the thread broke or ran out) was 114.6 ± 14.77 m (n = 90); and c) distance travelled on all days, including data where the thread broke, ran out or was dislodged, which was 111.7 ± 15.53 m (n = 103). The corresponding 'linear distances' are 41.2 ± 3.69 m, 68.3 ± 11.83 m and 66.8 ± 12.12 m. The length of thread when it broke or ran-out was greater than the mean for the known daily distance travelled ('foraging distance' = 186.4 ± 14.43 m and 'linear distance' = 123.4 ± 16.44 m, n = 11) so it can be assumed that the 114.9 m 'foraging distance' or 41.2 m 'linear distance' is an underestimate of the actual mean daily distance travelled by *P. minor*. The ratio of 'foraging distance' to 'linear distance' travelled was 1.68:1 for days when lizards moved and the total distance moved was known (*i.e.* moved with unbroken nylon thread).

Habitats traversed

Pogona minor regularly climbed into and over bushes and piles of logs (often created when earth-moving equipment had cleared vegetation for a road or track) during their daily movements. They often moved into the canopy of shrubs that were between 40 and 150 cm high, and the thread trail indicated in some instances that these lizards moved around (perhaps foraged) in these bushes. The mean number of bushes and log piles climbed over or foraged in each day when the lizard moved from its overnight retreat was 4.5 ± 0.61 (n = 317). This equates to one bush or log pile visited per 28.04 m of foraging distance travelled. Thread trails indicated that *P. minor* regularly crossed unvegetated areas or bare ground.

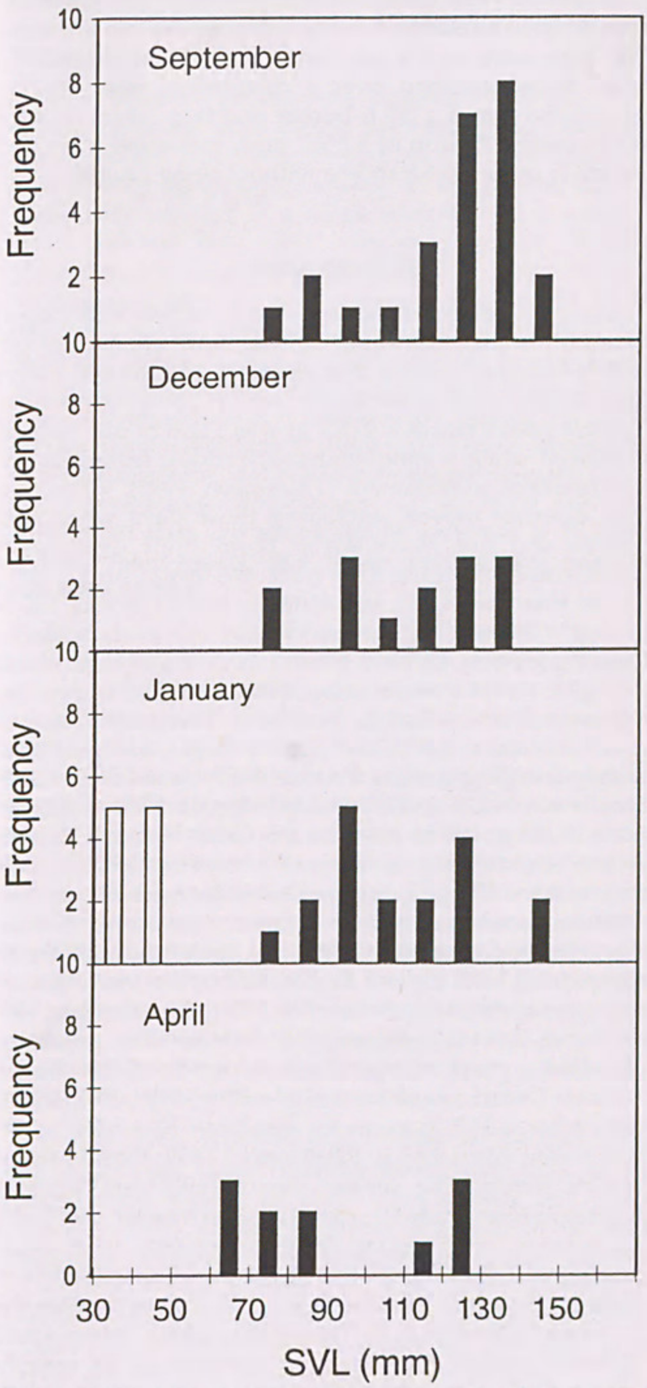

Figure 1. Snout-to-vent lengths of *P. minor* captured in pit-traps in the Ora Banda area during September, December, January and April showing the month which hatchlings (open bars) entered the population.

Reproduction

Three female *P. minor* were recorded as laying eggs in the field. One female dug two 'test' holes about 100 mm deep, one on 4 December and another on 6 December, and subsequently laid eggs later on 6 December. This female dug its burrow into the side of a mound so that the burrow was approximately horizontal. After laying her eggs she dug a vertical exit hole. The burrow entrance was ⌓ shaped and approximately 110 x 80 mm. The thread retrieved from the hole indicated that it was about 200 mm deep. A second *P. minor* dug its burrow on 9 December into flat ground and backfilled the hole so the disturbance was barely detectable. Again the thread left in the hole indicated the burrow was about 200 mm deep. Both of these egg chambers were excavated in April 2002 and seven hatched egg-shells were present in each burrow. Another female *P. minor* was recorded laying eggs in the field on 17 January. All egg burrows and 'test' holes were in open unvegetated areas, in full sunlight. Pit-trap data indicated that hatchlings were not present in early to mid December and first appeared in January (Fig 1). In January, hatchlings had a SVL in the range 35–50 mm; by April hatchlings had a 60–90 mm SVL. Two hatchling *P. minor* were caught in pit-traps on two waste dumps, suggesting that the colonising adults may be successfully reproducing in rehabilitated areas or very near by. No nesting burrows were actually observed on waste dumps.

Mean pre-oviposition body mass for three gravid females removed from the study site was 67.7 g. Oviposition occurred on 14, 16 and 19 October. Eggs incubated at 27.5 ± 1.0 °C took a mean of 64 days to hatch (Table 1). Neonates had a body mass of 1.74 ± 0.10 g, SVL of 36.1 ± 0.61 mm and tail length of 50.5 ± 2.10 mm (n =8). These captive-bred *P. minor* grew at the rate of 0.17 mm day^{-1} and 0.02 g day^{-1} for the first three months.

Table 1

Clutch mass, incubation period and neonate size for three clutches of *P. minor*. Measurements are mean (± se where applicable).

	Female A	Female B	Female C
Date of egg laying	14/10	16/10	19/10
Pre-oviposition body mass (g)	72.5	72.5	58.2
Post-oviposition body mass (g)	46.0	47.3	40
Clutch mass (g)	26.5	25.2	18.2
Relative clutch mass (%)	36.6	34.8	31.3
Clutch size	9	8	10
Mean egg mass (g)	2.9	3.2	1.8
Hatch dates	24/12	24 & 25/12	28-30/12; 1/1
Incubation period (days)	61	59, 60	70, 72, 74
Number of hatchlings	1	4	3
Mass of hatchling (g)	1.3	1.9 ± 0.03	1.7 ±0.21
SVL of hatchling (mm)	35	36 ± 0.82	37 ± 1.33
Tail of hatchling (mm)	49	49 ± 2.95	53 ± 4.48

General observations

Pogona minor appeared to have two patterns of movement based on information gleaned from the trail of nylon thread. They either moved about in what appeared to be a random pattern, foraging in logs, bushes or leaf litter that they encountered, or moved 'purposefully' in a particular direction. When the lizards were moving in a particular direction they would often go around or under bushes and logs in preference to through or over them. When these lizards were foraging the nylon thread was tangled and woven through the bushes, logs and leaf litter as they presumably searched the micro-habitat for prey. There were no obvious differences in the patterns of movement between males and females.

Pogona minor were often located early in the morning before they were active. They were normally found asleep under a bush in a shallow depression in the organic litter, on top of a saltbush (*Atriplex* spp) or bluebush (*Maireana* spp), or lying along a branch or twig in the canopy of larger shrubs (mostly *Acacia* spp). If the lizard was located during the warmer part of the day, it was frequently found on bare ground away from vegetation. In all cases when located during the day, *P. minor* made no attempt to run, and simply remained motionless. Lizards only moved away when disturbed (*i.e.* when recapture was attempted).

One individual lizard, on two occasions, systematically moved between bull-ant mounds (*Myrmecia* spp). On the first occasion, eight bull-ant mounds were visited in 112 m, and on the second occasion three bull-ant mounds were visited in 220 m. On both occasions the nylon thread indicated the lizard was passing through an area with little vegetation. Another captured lizard was found with a mouth full of chewed ants, confirming that *P. minor* eats these bull ants.

Pogona minor often returned to the same location multiple times, sometimes days apart. For example, lizard #2.16 returned 3 times to the same log pile 2 days apart (19/9–21/9 and 23/9–26/9). Another lizard (#3.11) was pit-trapped and released on 22 September and moved 132 m during the day before breaking the nylon thread (linear distance 70.5 m). This lizard was recaptured in a pit-trap, three days later (25/9) 25 m from its original location. The next day it moved 147 m in a similar direction to that which it had done on the 22/9 (linear distance of 74 m); and on the following day the lizard travelled 225m before running out of nylon thread within one metre of the previous day's release point. This lizard was not seen again. Another female lizard (#3.17) moved in a north-westerly direction for a period of three days with an accumulated 'foraging distance' of 303.9 m to a point where it laid her eggs. The following day she returned along the same route (within one metre most of the way), a 'foraging distance' of 239.2 m, before the thread ran out. Another *P. minor* (#4.8) crossed the same gap in a drift fence where there was a pit-trap three days in a row. This lizard also returned to the same bushes two days apart.

Pogona minor often moved over the deep rip lines and up and down the steep sides of rehabilitated waste dumps. Three different individuals (#2.6, #3.12, #3.15) moved between the sides of a waste dump and the top. Individual #2.6 was captured (17/9) on the top of the waste dump and moved down slope on the 19/9. It spent the next 14 days of observation moving around on the steep side of the waste dump. This lizard was previously caught on 7/4, 50m from the 17/9 capture location, indicating that it was still in the same vicinity after 5 months. *Pogona minor* #3.15 was first caught on top of a waste dump (30/11), moved down the slope and off the waste dump onto a top-soil storage pile (4/11), where two days later it laid eggs (6/11), then it moved into the adjacent undisturbed area (7/11) where it remained for two days until it returned (9/11) to the top-soil storage pile.

No lizards were observed to have walked along a drift fence or to have climbed out of a 20 L bucket or 150 mm PVC pipe used as the pit-traps. Three *P. minor* (#2.17, #3.12, #4.16) climbed over a drift-fence, one (#3.12) crossed the top of a 20 L bucket and two others (# 4.8, #3.15) crossed the top of a PVC pipe, indicating *P. minor* can easily cross a pit-trap line without being caught.

Discussion

Daily distances travelled by *P. minor* are large compared with most other lizards, and are typical of widely-foraging lizards. For example, the known daily distance travelled by the larger, widely-foraging goanna *Varanus gouldii* (mass = 478.7 g) was 111.6 m day^{-1} when measured using a spool-and-line tracking technique in a semi-urban environment (Thompson, 1992); when the total distance moved, excluding those days when the lizards did not move away from their overnight position and including data when the thread broke, ran-out or was dislodged, the distance travelled was 180.5 m day^{-1}. Sweet (1999) reported the arboreal, widely-foraging goanna *Varanus glauerti* (SVL = 213 mm, mass = 92 g) to move a mean linear distance of 33.7 m day^{-1} in western Arnhem Land, Northern Territory. This is much less than that of the slightly larger, arboreal and widely-foraging goanna *Varanus tristis* (male SVL = 255 mm, mass = 228 g, 187 m day^{-1}; female SVL = 255 m, mass = 249 g, 100 m day^{-1}) in the Great Victoria Desert, or the slightly longer, *Varanus glebopalma* (SVL = 265 mm, mass = 179 g) living on the escarpment of western Arnhem Land that moved a linear distance of 70.1 m day^{-1}. So, *Pogona minor* travelled a linear daily distance comparable with that of *V. glauerti* but less than that of the appreciably larger varanids. The slow-moving, sit-and-wait, ant-eating agamid *Moloch horridus* generally travelled a greater linear distance per day in the Great Victoria Desert (mean for males = 67 m day^{-1}, SVL = 78.7 mm, mass = 31.2 g; mean for females = 32 m day^{-1}, SVL = 91.0 mm, mass 45.5 g; Pianka *et al.* 1998) than *P. minor* at Ora Banda. The similar size, sit-and-wait, agamid *Lophognathus gilberti*, on the perimeter of Lake Kununurra, confines its daily movements to a much smaller area than *P. minor* with the result that the linear distance travelled in a day is much less than that for the *P. minor* (Thompson & Thompson, 2001). Some small agamids confine their daily movements to an activity area around a couple of burrows or retreats that they use on a regular basis (*e.g. Ctenophorus ornatus*, *C. inermis*, *C. maculosus*, Bradshaw, 1965; Mitchell, 1973). The 'linear distance' moved by these lizards is much smaller than that of *P. minor*. It can therefore be concluded that the daily distance moved by *P. minor* is generally greater than that moved for other lizards of a similar size.

The return of *P. minor* to previously used retreats and foraging sites suggests that they have a good spatial knowledge of their area, and their movement patterns are not random. Some *P. minor* foraged in confined areas, others moved in varying directions across the terrain, and others moved in a consistent direction for a number of consecutive days. Movement in a consistent direction despite walking around obstacles (shrubs, logs, *etc*) for one or more days suggested there was some 'purpose' or destination for the direction of movement. This 'purposeful' movement was not related to capture and processing.

Our intensive pit-trapping program at 11 sites for a period of seven days during September and December 2000; January, April, July, September and December 2001; and January 2002 (approximately 45 000 pit-trap days in total) only resulted in a single recapture of an adult *P. minor* between field trips, suggesting low site fidelity. However, we caught a single female *P. minor* (#2.6) in September within 50 m of where it was caught in the previous April, suggesting that this individual had remained in the vicinity. It might not have moved if these lizards have an activity area in which they forage over an extended period, or if it was inactive during the cooler winter months. Perhaps *P. minor* restrict their movements to an activity area, and our low recapture rates are due to their avoidance of pit-traps, as spooling showed. Additional data are necessary to ascertain if *P. minor* confine their movements to an activity area over an extended period.

Studies of the spatial ecology of reptiles often use radio-transmitters to locate animals each day. As a consequence, linear distance moved rather than the actual distance travelled is recorded, as it is not possible to determine accurately how far an animal actually travelled during the intervening period. Knowledge of the ratio of 'foraging distance' to 'linear distance' moved for *P. minor* enables an estimate to be made of daily foraging distances from linear displacement data collected using radio-transmitters. The ratio of 'foraging distance' to 'linear distance' for *P. minor* was about 1.68:1 for known distances travelled (excluding days when the lizards did not move from their overnight retreat) although the range varied markedly as some *P. minor* returned to their point of departure in the morning (ratio $\rightarrow \infty$), while others moved in almost a straight line for most of the day (ratio $\cong 1$).

Pianka (1986) reported that *P. minor* in the semi-arid, red sand-ridge, Great Victoria Desert eats ants, along with a wide variety of other invertebrates and plant material. One of the *P. minor* we monitored was frequently recorded on ant mounds, presumably feeding on ants (although it may have used these mounds as perches or basking sites) and another was caught with a mouth full of black bull-ants indicating that ants form part of the diet of *P. minor* in the Ora Banda area.

P. minor as an early coloniser

The conditions found on rehabilitated waste dumps (*e.g.* steep sides, lack of cover and leaf litter) would be a hostile environment for many small reptiles. The movement of *P. minor* from the top of the waste dumps and up and down the steep sides, across deep rip lines, and into the adjacent undisturbed area indicates that they will move across a variety of terrains to forage. This, together with their extensive daily movements, their willingness to move across unvegetated areas and climb steep slopes, and their propensity to forage widely and feed in dense low shrubs (*Atriplex* spp and *Maireana* spp) are likely reasons why it is an early colonising species in rehabilitated waste dumps. Interestingly, ants are also early colonisers of many rehabilitated mine sites (Majer 1989) and are a food source for *P. minor*.

Reproduction

Pianka (1986) reported *P. minor* to have a mean clutch size of 7.6 eggs and commit 19.5% of their body mass to a clutch. Greer (1989), in summarizing the available literature, reported clutch sizes for *P. minor* from 3–19, but mostly 5–8. The higher clutch sizes in Greer's data came from Bradshaw (1981) who reported a mean of 8.2 and a clutch size range of 5–19 eggs. More recently, Harlow *et al.* (2002) reported clutch sizes of 7, 8 and 9 for three *P. minor*, which are similar to the five (7, 7, 8, 9 and 10) that we recorded. Our measure of relative clutch mass (34.4%) is considerably higher than that reported by Pianka (1986; 19.5%) but similar to that reported by Harlow *et al.* (2002; 30.0%). We observed that the egg mass increases in the few days prior to parturition and there was a noticeable reduction in body tissue volume, particularly at the base of the tail. We presume that the shelled egg mass is increased by the uptake of water just prior to laying and this would account for the difference between the relative clutch mass values reported for oviducal and laid eggs. Given that some *P. minor* will double and triple clutch in a single summer (Bradshaw 1981; B Jennings, University of Texas at Austin, personal communication), these medium-sized lizards make a considerable energetic contribution to reproduction. The mean egg mass reported by Harlow *et al.* (2002) was smaller (2.02 g) than our eggs, although their neonates were generally heavier (mean 1.94 g) and longer (SVL = 38.3 mm). Harlow *et al.* (2002) reported the incubation period at 29 °C as 60.4 days (58–64), which is similar to those we incubated at 27.5 °C, and at 25 °C Harlow *et al.* (2002) reported they took a mean of 105.2 days (range 100–109) to hatch.

Field data and captive breeding records indicate the first hatchlings for the season appear either late in December or in early January. They have a SVL of 35–37 mm, body mass of 1.3–2.0 g when they hatch, and by April have increased their SVL to 65–85 mm with a corresponding body mass of 7–11.5g. The presence of hatchlings on waste dumps provides additional evidence this species can establish itself in rehabilitated areas.

Acknowledgements: The authors would like to thank Jessica Oates, Patrick Cullen, Rebecca Ince, Elizabeth McGuire, Joanna Coleman, Ryan Phillips, Chris Clemente and Craig Douglas for the field assistance. All lizards were caught under a licence issued by the Department of Conservation and Land Management (GGT). Financial support for this research was provided by OMG Cawse Nickel Pty Ltd, Placer Dome Asia Pacific West Operations, Kalgoorlie, and the School of Natural Sciences and the Centre for Ecosystem Management at Edith Cowan University.

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