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Getting your feet wet: Responses of the endangered pygmy bluetongue lizard (*Tiliqua adelaidensis*) to rain induced burrow flooding

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Abstract. The pygmy bluetongue lizard, *Tiliqua adelaidensis*, is an endangered Australian skink. It refuges in narrow vertical burrows with single entrances, constructed by lycosid and mygalomorph spiders. Lizards spend most of their time associated with their burrows. Following heavy rainfall events we observed that some burrows failed to drain rapidly, but that lizards remained in those burrows immersed in water. The two impacts most likely to have negative effects on lizard populations were that at least one lizard was seen to become trapped in wet clay, and that some burrows, usually unoccupied ones, were degraded as debris and soil were washed into them. Burrow destruction was more prevalent in an area without grass cover, implying a detrimental impact of heavy grazing.

Keywords. Pygmy bluetongue lizard, flooding, burrow, rain, vegetation.

Introduction

Most species live in environments that are subjected to unpredictable catastrophic events, such as fires and storms. The immediate consequences of those events are often local population decline, although species with distributions that extend beyond the affected area can rapidly recover (Freeman et al., 2008; Lugo, 2008, Driscoll and Henderson, 2008). In many cases species have developed specific adaptations to resist some of the detrimental impacts of extreme weather events (Kanowski et al., 2008) or fires (Williams et al., 2012). However, fragmentation of the ranges of many species has increased the risk of local catastrophe induced declines, because normal dispersal based recovery of those populations is now blocked (Root, 1998).

One such species is the endangered pygmy bluetongue lizard, *Tiliqua adelaidensis*, whose once widespread native grassland habitat in South Australia is now fragmented into a few isolated patches where small lizard populations persist. For this species, and others like it, a local catastrophic event may have more severe implications than for species with broader and more connected distributions. This lizard occupies narrow vertical burrows with a single entrance, and in this paper we report observations that some of those burrow fill with water after heavy rain events. We were interested in how catastrophic that may be for a local population.

The pygmy bluetongue lizard is the smallest member of genus *Tiliqua* with an average adult snout-to-vent length of 95 mm (Armstrong and Reid, 1992). All known populations are found on small fragments of native grassland in the mid north of South Australia (Hutchinson et al., 1994). The lizards select narrow vertical burrows with single entrances that have been constructed by lycosid and mygalomorph spiders. They use these burrows as refuges, basking at the entrance, ambushing passing prey from them, and producing litters in them (Hutchinson et al., 1994; Milne et al., 2003). For *T. adelaidensis* the burrow is a central resource where they spend most of their time, and they even restrict their aggressive response to conspecific individuals to within a body length distance, so they do not need to be fully emerged (Fenner and Bull, 2011). Adult lizards prefer burrows with an entrance slightly wider than their head width (average 15.1 mm) and deeper than 30 cm. Juveniles usually leave the natal burrows after five weeks and initially select smaller burrows (Milne and Bull, 2000).

Pygmy bluetongue lizards are vulnerable to predation from several bird species and from the brown snake, *Pseudonaja textilis,* and are more vulnerable to those predators when exposed on the surface (Fenner et al., 2008a; Fenner et al., 2008b; Hutchinson et al., 1994). Thus any event that reduces the suitability of a burrow, forcing a resident lizard to seek new burrow opportunities,

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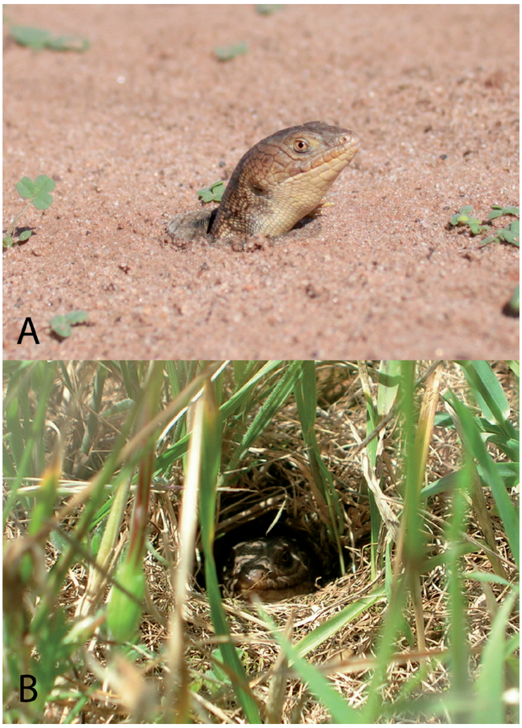

Figure 1. A. pygmy bluetongue lizard basking at entrance of artificial burrow; B. pygmy bluetongue lizard basking at entrance of natural burrow (photographer: Dr Aaron Fenner).

will be potentially detrimental to the fitness of the lizard. Heavy rain might be one such event if burrows become flooded or destroyed by water flow. Here we report some observations of the behaviour of lizards after rain, and their responses to burrow flooding.

Methods and Results

We made two sets of observations of the response of pygmy bluetongue lizards to significant rainfall events. One was from a captive population held at Monarto Zoological Park (35°06′S 139°09′ E), approximately 70 km SE of Adelaide, the other was from a natural population near Burra (33°68′S 138°94′E), both in South Australia.

Captive population

Eight male and eight female *T. adelaidensis* from two populations near Burra, South Australia (site one: 33°36′S 138°59′E; site two: 33°37′S 138°59′E) were moved to four 15 m diameter circular cages at Monarto Zoo (35°06′S 139°09′ E) in October 2009. Each cage had a galvanized iron wall, 1 m high and a bird wire roof. We released two male and two female lizards into each cage.

The cages had no natural spider burrows for the lizards to use, and 71 artificial burrows, 30 cm lengths of wooden dowling, drilled out with a central tube of 2 cm internal diameter, were hammered vertically into the ground in each cage. The burrows were open at each end, and the ground substrate was a sandy soil that we expected would allow water to drain rapidly. Pygmy bluetongue lizards readily accepted these artificial burrows (Ebrahimi et al., 2012a) (Fig 1 A) and other artificial burrows of similar design (Milne et al., 2003b; Souter et al., 2004).

Lizards in these cages were used in a series of experiments and observations of lizard behaviour and responses to environmental variation (Ebrahimi and Bull, 2012a; Ebrahimi and Bull, 2012b; Ebrahimi et al., 2012b) during spring and summer (October-March) of two seasons 2009/2010 and 2010/2011. During these studies we recorded lizard behaviour in the daylight hours 0700 – 1800h on each day of the experiment, with four surveillance cameras (Longse: LICS23Hf, 3.5 mm lens) mounted above each cage, and a 16 channel h.264 Digital Video Recorder (ESW26), powered by four 12 V batteries. Lizard location and status were checked by inspecting each burrow with a 14 LED torch twice a day, once in the early morning and once late in the afternoon. We also checked the status of each lizard after extreme weather events such as heavy rain.

On 21-22 Nov 2009, a total of 21.7 mm of rain fell at Monarto with the rain stopping in the morning of 22 Nov. During inspection at 1000 h on that day, 10 mins after the rain had stopped, 19 of the 284 burrows were found to contain free standing water, with an average water depth of 124.5 ± 0.4 mm (range 80 – 190 mm). Three male lizards and one female were found occupying these water filled burrows, submerged in the water up to their necks during burrow inspection. In one additional burrow, although not waterlogged at the time of inspection, the rain had washed soil and debris into the burrow entrance, so that the entrance was blocked. The resident lizard had become trapped inside the burrow, as its feet were stuck in wet clay that had washed into the burrow. This lizard was rescued and transferred to a dry burrow in the same cage. The 19 waterlogged burrows took 7-10 days to dry out.

At the time of the rainfall we were conducting an experiment on the impact of the density of grass tussocks on lizard behaviour. In two cages we had a density of

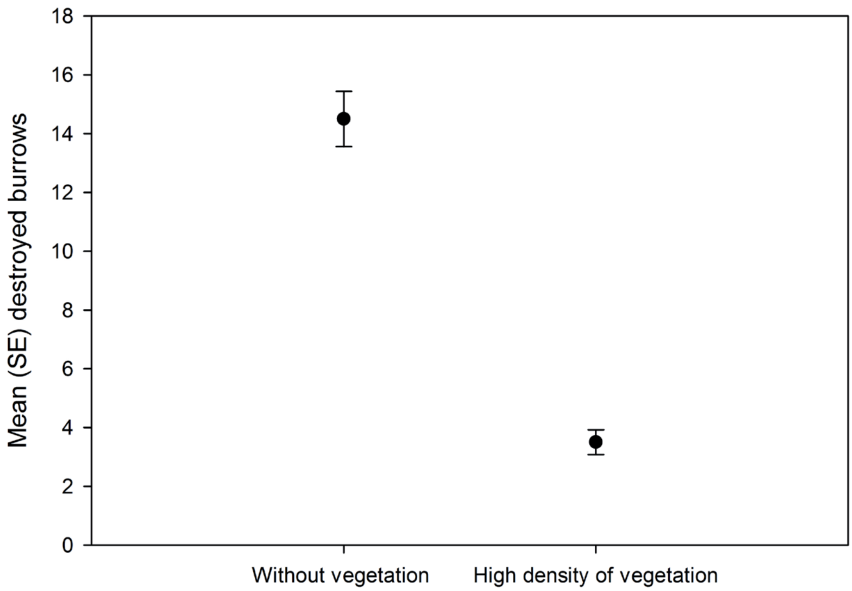

Figure 2. Mean number of burrows were destroyed by rain in cages with high density of vegetation and without vegetation.

38 tussocks/ m2 around the artificial burrows, in the other two cages there was no grass, just a bare soil substrate. A number of the unoccupied burrows in each cage were destroyed as the heavy rain washed surface clay and debris into them. Significantly more of the burrows in the bare soil cages were destroyed than in the cages with grass tussocks (X2 = 17.2, d.f. = 1, P < 0.001) (Fig 2).

We left the four lizards in their water filled burrows and continued to film their behaviour over the next few days. The following day, Nov 23, was warm and sunny with a maximum temperature at the site of 23°C. One lizard moved from its water filled burrow to another dry burrow on that day. The other three lizards continued to act normally in their water filled burrows, and did not vacate those burrows even though there were many dry burrows available close by. They partially emerged to bask at the burrow entrance, but when disturbed retreated to the bottom of the burrow so that they were fully immersed, and then rested in the burrow with only their nose out of the water.

Natural population

Further observations were derived from regular monitoring, over the same period of three 1 ha square quadrats in a natural population of *T. adelaidensis* located 9 kms from Burra (Schofield et al., 2012). We used an Olympus IF8D4X2-10L optic fiberscope to inspect for resident lizards inside over 80 natural burrows that were located within each quadrat, on monthly surveys between September and March 2009/2010 and between January and March 2011 (Fig 1 B).

On two occasions thunderstorms resulted in heavy rain over the study site, with 24 mm of rainfall on13 Jan 2010, and 39.4 mm of rainfall on 5 Feb 2011. Inspection of all previously occupied burrows on the day after the rain found one water filled burrow on each occasion, with the resident lizard still present in each, up to its neck in water in the burrow. At the time of inspection, most of the water had drained from all of the other occupied burrows.

Discussion

These anecdotal observations show two impacts of heavy rain on lizards living in vertical burrows. One is that the burrows that have been selected by lizards can sometimes fill with water and take several days to drain. This included both natural burrows in field populations, and artificial burrows in our experimental enclosures. For artificial burrows the open ended tube inserted in sandy soil allowed water to drain rapidly from most burrows, but water persisted in a few. Perhaps some previously accumulated debris at the burrow base reduced drainage rates of the water in those cases. A similar explanation might account for the relatively rare cases of water filling burrows in the field population. In this study, lizards appeared to tolerate immersion in water within their burrows, at least for a few days while the burrows gradually drained, although one lizard became physically stuck in the wet clay. It is unlikely that a lizard would survive in similar circumstances in the natural population.

The study period was during the warmer spring and summer months when lizards had opportunities to emerge, bask, and dry out, but in the enclosures, only one of four lizards responded to these temporary aquatic conditions by changing to a drier burrow. Because of the increased exposure risks to potential predators from leaving an established burrow, lizards may prefer to tolerate wet conditions for short periods of time. All four lizards from the water filled burrows retained body condition and continued to participate in behavioural trials for the next 18 months without any apparent adverse impact from their brief aquatic experience.

Similarly, our less detailed observations of the field population indicated that lizards will remain immersed in water when their burrows become flooded after rain, although the duration of that tolerance was not determined. This conforms with previous observations of long term tenure of burrows by lizards. Suitable burrows are in relative short supply (Fellows et al., 2009) and resident lizards move infrequently from their burrows (Milne et al., 2003).The area that holds natural pygmy bluetongue lizard populations has a Mediterranean climate with normally warm dry summers and cold wet winters. Our observations were during the summer, but the consequences of immersion in water may be more detrimental in winter, when colder temperatures might limit the ability of this ectothermic species to respond appropriately, and to extract themselves if they become stuck. Thus poor burrow drainage may be more of a disadvantage in the winter season when burrows are more likely to become water filled.

The second impact was on the burrows themselves. We gathered no specific information about the impact on burrows of the two rain events in the natural population, but in the Monarto enclosures burrow structures were compromised by flooding events that washed soils and debris into their entrances. This suggests that there will be a continual loss of burrows, perhaps more pronounced in winter when the rainfall is normally heavier. Souter (2003) showed that unattended burrows deteriorated and collapsed over time, and Fellows et al. (2009) reported changes in the numbers of burrows during monthly surveys within a 1 ha survey plot close to the study site of this paper". Fellows et al. (2009) also reported limited availability of suitable burrows during the activity seasons in a natural population. Presumably, rain damage to burrows as documented in the current study is one factor leading to burrow loss. There have been no observations of lizards digging new burrows, and it has been assumed that lycosid and mygalomorph spiders maintain the supply by digging new burrows over winter when the soils are softer (Milne, 1999). This study has demonstrated that rainfall events can destroy burrows, and indicates the vital role these hole digging spiders play in maintaining a supply of refuge sites for these endangered lizards.

The study also found, although without any replication, that rain damage was more severe when grass was absent, and this may be a previously unconsidered impact of grazing on pygmy bluetongue populations (Pettigrew and Bull, 2011).

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