Omnivorous diet of the endangered Pygmy Bluetongue Lizard, *Tiliqua adelaidensis*

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**Abstract.** We used scats from 71 individuals to determine the diet of the endangered Pygmy Bluetongue Lizard, *Tiliqua adelaidensis*, from South Australia. As predicted both from its previously reported behaviour as an ambush forager, and from its relatively small size, this scincid lizard feeds largely on arthropod prey, and the prey in the diet change opportunistically over the spring and summer. As expected, the species is less herbivorous than larger species in the same or related genera. However plant material is included in the diet to a greater extent as the summer progresses. Conservation of this species may rely on maintaining a high abundance of arthropod prey, and a habitat where efficient prey capture is possible, and on retaining appropriate plants in the species’ habitat.

**Keywords: lizards, Tiliqua, herbivory, diet, South Australia.**

Herbivory, where the majority of the diet is plant material, is relatively rare among squamate reptiles (less than 2% of all species; Espinoza et al., 2004), but omnivory is more common. Some plant material has been found in the diets of about half of the lizard species that have been surveyed (Cooper and Vitt, 2002). Various hypotheses have been explored to explain the incidence and proportion of plant material in lizard diets, starting with the idea that physiological constraints allowed species with larger body size to exploit herbivorous diets more than smaller species (Pough, 1973). Other studies have suggested that lineages of lizards with active foraging species are more likely to have evolved to include plants in their diet, than those with a sit and wait foraging strategy (Cooper and Vitt, 2002), or that island forms of lizards are more likely to include plants in their diet (Van Damme, 1999). To digest the plant material lizards need a specialised gut biota (Mackie et al., 2004) and some species ingest small stones to help break up the plant food (Valido and Nogales, 2003). They also need warmer temperatures to sustain digestion of food (Tracy et al., 2005) although some lineages of cool climate small bodied lizards include plant material in their diet (Espinoza et al., 2004). Omnivorous lizard species have some morphological (Herrel et al., 2004) and chemosensory (Cooper et al., 2002) adaptations for detecting and ingesting plant material, that are not present in insectivores.

Brown (1991) reported that the diets of Australian skinks were largely influenced by the food types available, by the habitat the lizard species occupied and by the lizard species size. Greer (1989) concluded that Australian skinks were generalist predators, but that larger species tended towards omnivory. Duffield and Bull (1998) reported that for one Australian skink, *Egernia stokesii*, there was an ontogenetic change towards more herbivory with increasing age. The Australian scincid genus, *Tiliqua* has mostly large species such as *Tiliqua rugosa* which are omnivores with a predominantly herbivorous diet (Dubas and Bull, 1991).

*Tiliqua adelaidensis*, the Pygmy Bluetongue Lizard, is the smallest member of the genus, with a mean adult SVL of 90 mm for males and 95 mm for females (Milne, 1999). It is now restricted to a few fragments of once more exten-
sive native grasslands near Burra in South Australia, and is classed as endangered under the Australian Environment Protection and Biodiversity Conservation Act, 1999. It occupies narrow vertical burrows, apparently constructed by lygosid and mygalomorph spiders (Hutchinson et al., 1994). The burrows are used for shelter, and as sites to ambush passing invertebrate prey (Milne et al., 2003). For informed conservation management of this species, we require information about the resource requirements, including the types of food consumed in natural populations.

Three previous studies have reported on the diet of T. adelaidensis from relatively small samples. Before 1992 there were only 20 known specimens of T. adelaidensis (Shea, 1992). Ehmann (1982) described the diet from stomach contents of the 9 specimens located in Australian museums. He identified a range of arthropods, plus some plant material which he considered to be seeds of Dianella (Liliaceae) plus some chenopod material. A population was rediscovered near Burra in 1992, and Hutchinson et al. (1994) reported the stomach contents of three individuals that had been killed by predators. They included arthropods plus the leaves and flowers of the introduced plant Medicago sp. (Fabaceae). Milne et al. (2003) observed from video cameras located above lizard burrows, 32 feeding events when the lizard left its burrow and returned with food in its mouth. On 23 occasions lizards returned with invertebrates (mainly grasshoppers) and on nine occasions they returned with plant parts, mainly leaves of Medicago minima. Thus previous studies have indicated an omnivorous diet for the species.

In this paper we describe the diet of T. adelaidensis from the scat contents of a much larger sample of live caught animals over a complete spring and summer season. The study had two aims. One was to set the feeding behaviour of this species in a comparative context of other related lizards, and supply more data for the ongoing debate about the use of plant material in lizard diets. Because it is smaller than other Tiliqua species, and because it has been reported to adopt an ambush foraging strategy (Milne et al., 2003) we predicted T. adelaidensis would include less plant material in its diet than other Tiliqua species. Our second aim was to provide information relevant to the conservation of this endangered species. An understanding of the food resources normally used may contribute to maintaining viable populations, and recommending appropriate habitat management.

The study was conducted near Burra in the mid north of South Australia (33°42′S; 138°56′E), in semi-arid native grassland. The area has hot, dry summers (mean maximum temperature in February = 28.8°C) and cool moist winters (mean maximum temperature in July = 13.1°C), with an average rainfall between 400-500 mm (Milne, 1999). Six populations within a 60 kilometre radius of Burra were sampled over the period Oct 2005-March 2006. All were in paddocks on privately owned farms that had been extensively modified by sheep grazing and by the introduction of exotic weeds such as Avena barbata, Marrubium vulgare and Salvia verbenaca (Milne, 1999).

At each population site, T. adelaidensis individuals were located by looking into spider burrows using an Olympus IF8D4X2-10L optic fibroscope with an Olympus KLS-131 portable light source. Adult and sub-adult lizards were lured from their burrows with tethered mealworms and captured by hand (Milne, 1999). Upon capture, they often defecated, allowing fresh scats to be collected directly from known animals. Scats were placed individually into 10ml plastic tubes and preserved in sodium acetate formalin (SAF) for later analyses. A total of 71 scats (one from each of 71 individual lizards) was collected over the six month study period from the six sites (table 1).

Individual scats were soaked in water and identifiable contents were separated into plant and animal matter. The number of animal items and plant items were recorded and identified to order when possible, as well as the number of small stones >1mm diameter within the scats. The percentage of scats (by number) that contained each of the classes of ingested items was calculated. Then, for each scat, and only from the material that could be identified, the relative percentage by volume of animal and plant material was estimated to the nearest 10%.

Each of the 71 scats contained recognisable invertebrate material. The taxonomic identity of the prey could not always be determined when there were only small fragments of exoskeleton. Five invertebrate taxa were recorded from the scats (table 2). The most commonly detected were grasshoppers (in 63.4% of the scats), and all grasshopper remains appeared to come from the same acridid species, the plague locust...
Table 1. The number of scats collected from each site in each month over the study. Each scat was collected from a different individual lizard.

<table>
<thead>
<tr>
<th>Site/month</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>Total scats per site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>2</td>
<td>13</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total scats per month</td>
<td>12</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 2. The number and the percentage (by number) of scats collected each month that contained each of the identified categories of animal and plant based food items.

<table>
<thead>
<tr>
<th>Dietary item</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Orthoptera</td>
<td>7</td>
<td>58.3</td>
<td>8</td>
<td>80.0</td>
<td>14</td>
<td>93.3</td>
</tr>
<tr>
<td>Araneae</td>
<td>6</td>
<td>50.0</td>
<td>2</td>
<td>20.0</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>1</td>
<td>8.3</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>3</td>
<td>25.0</td>
<td>1</td>
<td>10.0</td>
<td>4</td>
<td>26.7</td>
</tr>
<tr>
<td>Blattodea</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>Seed</td>
<td>1</td>
<td>8.3</td>
<td>1</td>
<td>10.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Leaf</td>
<td>2</td>
<td>16.7</td>
<td>1</td>
<td>10.0</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>Stem</td>
<td>2</td>
<td>16.7</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>13.3</td>
</tr>
<tr>
<td>Shed skin</td>
<td>1</td>
<td>8.3</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Rock</td>
<td>3</td>
<td>25.0</td>
<td>5</td>
<td>50.0</td>
<td>6</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Chortoicetes terminifera. Ants were found in 26.8% of the scats, and were normally only represented by parts of the head. They were probably species of Rhytidoponera and Iridomyrmex that are common in the study area. Lycosid spiders were found in 14.1% of the scats. Beetles (order Coleoptera) were found in three scats and a cockroach (order Blattodea) in one. One scat contained the remains of at least 18 winged ants suggesting that this lizard had fed on emerging alates in a dispersal event. Eight lizards (11.3%) had scats that contained shed reptile skin. These skin fragments had scale sizes and shapes that suggested they were probably from the lizards’ own moultings.

The overall mean percent by volume of animal material in each scat was 92.1% (SE 2.2; range 10-100%; n = 71). There was no significant variation in the proportion of animal material in the scats either among the three most sampled sites (one-way ANOVA on arcsin transformed percent animal material per scat: $F_{2,65} = 1.09; P = 0.34$) or among the six sampling months ($F_{5,70} = 1.05; P = 0.40$).

However there were some seasonal trends for individual prey taxa. Significantly more scats contained grasshoppers when sampled early in the season (Oct-Dec) (78.4% of 37 scats) than later in the season (Jan-Mar) (47.1% of 34 scats) ($\chi^2 = 7.49; df = 1; P = 0.006$). Similarly more scats contained spiders early (24.3%) than late (2.9%) in the season ($\chi^2 = 6.70; df = 1; P = 0.009$). There was no seasonal trend for ants in scats (early 21.6%; late 32.4%) ($\chi^2 = 1.04; df = 1; P = 0.31$).

Recognisable plant material made up 10% or more by volume (range 10-90%) of the contents of 19 scats (26.8%). Seeds were found in 10 scats, leaves in 8, and stem material in 11. We could not identify the plant species for any of
this material. There were significantly fewer scats with plant material early (16.2%) than late (38.2%) in the season ($\chi^2 = 4.38; df = 1; P = 0.036$).

Small stones were found in the scat samples from 35 (49.3%) of the sampled lizards, with a mean of 6.3 (SE 0.93; range 1-20) stones in each stone-containing scat.

This study confirms that *Tiliqua adelaidensis* is omnivorous. Scat samples will not necessarily include all of the items ingested, and will be biased towards those items that have some less digestible parts, but in our study both animal and plant material was detected in the lizard scats so we can deduce that both forms were ingested as part of the lizard diet.

It is difficult from scat samples to compare quantities ingested among categories of diet that differ in digestibility. However, for an endangered species like *T. adelaidensis*, with few field-collected, preserved specimens, scats provide one of the best ways to accumulate data on diet. We assumed there was a constant level of digestive activity, and used data from scats to describe seasonal trends in diet. For *T. adelaidensis* we found there was a decline from spring to summer in consumption of grasshoppers and spiders, no change in consumption of ants, and an increase in the consumption of plant material. These results must be treated with caution given the low sample sizes for most prey taxa other than grasshoppers.

Our conclusion that this lizard is omnivorous confirms and extends the three previous reports on its diet (Ehmann, 1982; Hutchinson et al., 1994; Milne et al., 2003). The finding that plant material becomes more important in the diet later in the season confirms the video-recorded observations of Milne et al. (2003). This result is somewhat surprising, because much of the grassland vegetation has dried out by the summer (although seeds would still be available), but it may reflect reduced invertebrate activity on hot dry days. The presence of small stones in the scats may simply result from lizards ingesting some surface material along with the food items. Other researchers have interpreted this as an adaptation in omnivorous lizards to help break up plant material in the stomach (Valido and Nogales, 2003).

In an equivalent study of the scats of three larger *Tiliqua* species at Cape Jaffa in South Australia, Yeatman (1988) reported 80-100% of scats from *T. rugosa* (mean adult SVL 267 mm), *T. scincoides* (mean adult SVL 285 mm) and *T. nigrolutea* (mean adult SVL 289 mm) contained plant material. In the related skink genus *Egernia*, 94-97% of scats from adult *E. stokesii* (mean SVL 180 mm) contained plant material (Duffield and Bull, 1998), although other smaller *Egernia* species feed predominantly on arthropods (Bustard, 1970; Brown, 1991). Brown (1991) suggested that, among the Australian skinks, larger species were more likely to include plant material in their diets. Thus, although significant amounts of plant material in the diet of this relatively small *Tiliqua* species (*T. adelaidensis*: mean adult SVL 90-95 mm) were not expected, plant eating was only detected from 27% of the scats examined, a much smaller incidence than in the larger related species.

Similarly, plant feeding might not be expected for a lizard reported to forage largely by sitting at burrow entrances and waiting for passing prey (Milne et al., 2003). However, the increased use of plant material later in the summer may simply be a response of the lizards to a diminishing supply of active invertebrates moving past the burrow entrances in the hot dry summers of the semi-arid habitat they live in. Thus it will be important to investigate in more detail the plant species that are used by these endangered lizards and ensure that those plants are available around populations that we are trying to conserve.

It is possible that some of the plant material that was detected in the scats was not deliberately ingested by the lizards, but was accidentally included while capturing mobile prey, or was part of the gut contents of ingested herbivores, such as grasshoppers. Two pieces of ev-
idence suggest this was unlikely. The first was the increase in plant material at the time when animal content in the diet decreased. The second was the previous observations from video recordings of lizards returning to their burrows with just plant material in their mouths (Milne et al., 2003).

Although plant material was encountered in some of the scats, all scats contained remains of invertebrate prey. These were generally large mobile insects or arachnids that could have been captured by the sit and wait strategy that has been described for this species. This suggests that viable populations of prey species, and a habitat where they can be easily seen and captured will be essential components to sustain viable populations of this endangered species.

One potential threat to the ongoing persistence of the few remaining populations of this species may be the insecticide spraying that is commonly used within the species range, during times when grasshopper plagues develop. Even if insecticides are used that have a minimum direct effect on vertebrates, the impact on their food supply may be detrimental, particularly if the population relies on occasional years of abundant food for recruitment pulses. A second issue that will be important for the lizards is their ability to see and to capture prey successfully from their ambush positions at their burrow entrances. This may be influenced by the density of vegetation in the grassland habitats that they occupy, which in turn may be influenced by the grazing regimes of introduced sheep, and whether they are equivalent to the macropod grazers that once occupied these grasslands. The detailed dietary information from the current study can be used to explore the significance of these factors in future research into the conservation management of this species.

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References


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