The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

Animal Welfare 2011, 20: 377-384
ISSN 0962-7286

# Environmental enrichment for captive Eastern blue-tongue lizards (Tiliqua scincoides)

CJC Phillips*†, Z Jiang†‡, AJ Hatton‡, A Tribe†‡, M Le Bouar†§, M Guerlin†§ and PJ Murray†

† Centre for Animal Welfare and Ethics, School of Veterinary Science, University of Queensland, Gatton 4343, QLD, Australia
‡ School of Animal Studies, The University of Queensland, Australia
§ Ecole Nationale Veterinaire, Toulouse, France
* Contact for correspondence and requests for reprints: c.phillips@uq.edu.au

## Abstract

*Eastern blue-tongue lizards (*Tiliqua scincoides*) are kept in zoos and increasingly commonly as exotic pets, but little is known about improving their welfare by enrichment of their environment. Using nine animals kept individually in cages provided with a brick for basking and a pipe for hiding, we initially investigated enriching their environment with mealworms, either scattered on the floor or inserted into a foodball. The mealworms increased the time that the lizards spent feeding on both their ration and the mealworms and increased liveweight gain. Scattering the mealworms on the floor of their cages increased the time taken to eat them, compared with taking them from the foodball. Mealworms also reduced the time that the lizards spent hiding. Second, using eight individually housed lizards and replacing the pipe with a log which could be used both for basking and hiding, we investigated whether increasing the size of their enclosure and its temperature affected their behaviour, in a two-factor changeover design with two-week periods. When lizards were moved from small to large enclosures, they greatly increased the time that they spent walking on the first day, and they walked longer and further for the rest of the period. Lizards in big enclosures also spent more time hiding in the log and less time inactive on the log or the brick. Lizards in hot enclosures spent more time basking on the log and less time hiding in it, which would be valuable for display animals. The benefit of enriching the captive environment of Eastern blue-tongue lizards by scattering mealworms in their cage may depend on the effect on the lizards' weight and the cage's conditions, as captive lizards often become obese, and inactivity and weight loss are normal in their natural habitat during the dry season. Increasing the size of enclosures increases walking activity and reduces weight gain, which similarly will have variable effects on welfare depending on the impact on their bodyweight. Lizards in large enclosures have an increased propensity to hide so it is important that opportunities for this are provided.*

**Keywords**: *animal welfare, Eastern blue-tongue lizard, environmental enrichment, skink, space availability, temperature*

## Introduction

The majority of environmental enrichment research has focused on mammals and birds (Young 2003), and the enrichment of reptiles has been largely ignored (Hayes *et al* 1998). Two reasons have been suggested for this. Firstly, reptiles are not as commonly kept as either companion or production animals as mammals or birds, which has meant that there has been neither an emotional nor an economic motivation to develop their husbandry (Warwick *et al* 1995). Secondly, their main captive environment has traditionally been in zoos, where reptiles were believed to be torpid and highly tolerant and adaptive to novel environments, so that no enrichment was needed (Case *et al* 2005). However, it has been argued that reptiles, as social foragers that are deprived of social learning opportunities in isolation, may be less tolerant of, and adaptable to, their artificial captive environment (Warwick *et al* 1995).

Reptiles and other exotic pets represent a growing sector in the pet market, having first entered the mainstream trade in the 1990s (Altherr & Freyer 2001). A recent survey in the USA found that there were approximately one million lizards kept as pets, compared with 72 million dogs, 82 million cats and 11 million birds (AVMA 2007). In Germany, it was estimated in 1989 that there were about 1.5 million reptiles, and this number is believed to have increased substantially in the latter years of the 20th century (Altherr & Freyer 2001).

Few studies have investigated the welfare of reptiles in captivity. Enclosure design has been assessed for a few species, such as Round Island day geckos (*Phelsuma guentheri*) (Wheler & Fa 1995), blue-tongued lizards (*Tiliqua scincoides*) (Kreger 1993), and Nile soft-shelled turtles (*Trionyx triunguis*) (Burghardt *et al* 1996; Krause *et al* 1999), but its influence is inadequately understood (Hayes *et al* 1998). Reptile husbandry guides that have been published make little mention of environmental enrichment (McCarthy 1992; Pough 1992; Warwick *et al* 1995), and enrichment strategies that are used for reptiles are not generally based on an objective assessment of their effects on behaviour. Many keepers rear mealworms to enrich the diet of reptiles. Understanding the natural behaviour of reptiles is also important, as providing an environment that fosters natural behaviour is the main objective for enrichment of captive animals (Shepherdson 1998).

The Eastern blue-tongue lizard (*T. scincoides*) is the largest member of the Scindidae family in Australia, growing up to 400 mm in snout-vent length, and is diurnal, solitary and terrestrial (Wilson & Swan 2003). It is becoming a popular pet due to its ability to adapt well to captivity, lack of aggression, low cost and ease of feeding and maintenance (Turner 2001). In the wild, *T. scincoides* feeds on insects, snails, carrion, flowers, fruits, and berries of native vegetation in the many Australian habitats that it occupies, which include woodland, grassland, coastal heaths and forests, fallen logs and under leaf litter (Cogger 2000; Wilson & Swan 2003). Being poikilothermic, it is dependent on environmental heat resources to maintain an appropriate body temperature (Savage 2005) and has a low metabolic rate to avoid unnecessary heat loss (Hildebrand *et al* 2001). *T. scincoides* can manipulate its thermal environment by basking in sunshine in cold conditions (McFarland 1999) and sheltering when hot (Lissone 1999). Failure to maintain the appropriate body temperature in cold conditions results in *T. scincoides* becoming inactive and stopping feeding, with the result that its immune and digestive system become suppressed (Mader 2006). Confinement in unsuitable conditions can lead to abnormal behaviours being performed. Observations on lizards in captivity have found that the abnormal behaviours are mainly related to escape attempts: climbing up the boundary, focusing movement on the boundary and knocking behaviour on transparent boundaries (Altherr & Freyer 2001).

The aim of this study was to investigate the potential of enrichments to moderate the behaviour of captive Eastern blue-tongue lizards and hence elucidate the effects on their welfare in captivity.

## Materials and methods

This research was approved by the University of Queensland's Animal Ethics Committee (licence numbers SAS/189/08 and SAS/211/09) and the Queensland Government's Parks and Wildlife Services Scientific and Educational permits WISP05075208 and WIEP05076508 for the use of native fauna.

### Experiment 1 — The effects of feeding enrichment on behaviour and welfare

Nine captive-bred (four female and five male) Eastern blue-tongue lizards were purchased at age two months from a local retail outlet (Pet City, Brisbane, Australia) and transferred to the wildlife facility of The University of Queensland, Gatton campus. Each lizard was kept in an individual, transparent, plastic enclosure (60 × 40 × 40 cm; length × width × depth), which was furnished with two dishes for food and water (each 5 cm in diameter), a pipe (20 × 5 cm; length × diameter) for shelter, and a clay brick (12 × 18 cm; length × width) to facilitate basking and skin shedding. Newspaper was used as a lower layer of bedding and was overlaid with blank paper to prevent newsprint contamination of the lizards' torso. Cages received sunshine through windows, and additional UV light was supplied between 0800 to 1700h by two UVA/UVB fluorescent tubes. The temperature of the room was maintained at a constant 30°C. Each animal was fed their diet as a mash, which contained the following components (and the quantity in the mix): carrot (100 g), broccoli (100 g), apple (100 g), grapes (100 g), banana (100 g), mushrooms (100 g), raw eggs (1), mealworms (*Tenebrio* spp larvae) (20) and bran (40 g).

Animals were allocated at random to the three treatments of a Latin-Square design with three periods of 30 days each and a seven-day rest in-between periods. The three treatments were: SC, in which six live mealworms were scattered at random in the enclosure; FB, in which six live mealworms were inserted into a foodball (a table-tennis ball with two 4 mm holes opposite each other); and a Control treatment with no live mealworms. The mash was offered at 20% of their liveweight daily at 0900h, with refusals collected daily, and rations adjusted weekly after weighing each lizard using a precision industrial balance (GP-30k electronic scales, 5 g to 31 kg measured to 0.1 g, A&D Instruments Ltd, Cleveland, USA). Dry matter concentrations were determined by drying the diet at 60°C for 24 h.

Behaviour was individually recorded for 5 h daily after feeding using time-lapse cameras mounted in front of the cage. The following behaviours were recorded on a continuous basis: eating the ration; eating the mealworms; drinking; inactive under the paper; on the floor or on the brick; active above the paper; wall climbing (climbing or inactive when at least half of the body was against the wall); hiding in the pipe; walking; rubbing nose on the wall.

### Experiment 2 — The effects of space allowance and temperature on behaviour and welfare

Eight lizards, three females and five males from Experiment 1, were utilised for this experiment, which was conducted one year after Experiment 1. The remaining female lizard from Experiment 1 was kept in its original cage throughout. The eight lizards were allocated at random to four treatments in a two-factor, four-period Latin-Square design (Table 1). The treatments were: BH, big cage, hot temperature; BC, big cage, cold temperature; SH, small cage, hot temperature; and SC, small cage, cold temperature. Periods were of two-weeks duration with a one-day transition between periods, when the animals were allowed to bask under UV light in their original cages.

Two big and two small enclosures were constructed in each of two rooms (Figure 1), providing eight cages for individual housing of lizards. The small cages were 70 × 70 cm (length × width), as recommended for this species by Turner (2001), and the big cages were 140 × 140 cm, ie four times larger. The height of all cages was 60 cm, which was sufficient to prevent the lizards escaping and convenient for cleaning and handling. The cages were constructed from 4-



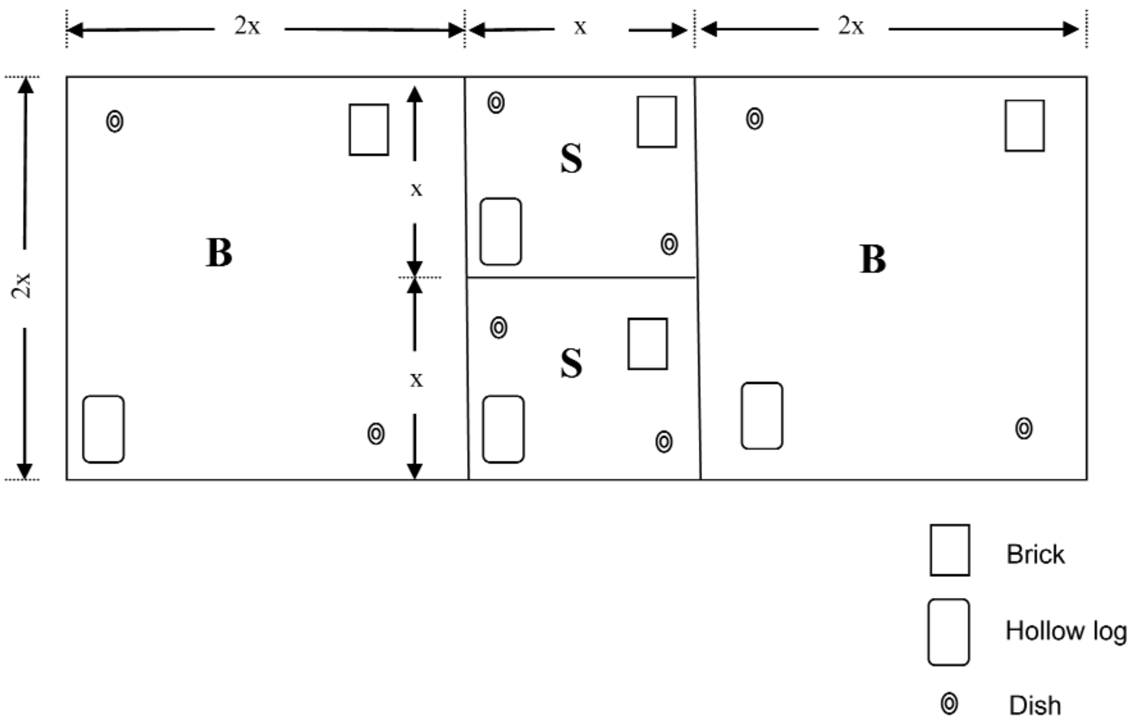
https://doi.org/10.1017/S0962728600002931 Published online by Cambridge University Press

**Table 1 The experimental allocation of four treatments in Experiment 2.**

| | Lizard number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Period** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | BH | SH | BC | SC | BH | SH | BC | SC |
| 2 | SC | BC | SH | BH | SH | BH | SC | BC |
| 3 | BC | SC | BH | SH | BC | SC | BH | SH |
| 4 | SH | BH | SC | BC | SC | BC | SH | BH |

BH: big cage, hot temperature; BC: big cage, cold temperature; SH: small cage, hot temperature; SC: small cage, cold temperature.

**Figure 1**




Cage structure within each room in Experiment 2, B = big enclosure; S = small enclosure, x = 0.7 m.

mm thick, rigid, black polyethylene, stapled at the corners for added strength. This material also covered the floor and was overlaid with a 1 cm layer of sand and furnished with dishes for food and water, a clay brick as in Experiment 1, and a hollow log for shelter. A camera (model K-32HCF, Kobi CCD, Ashmore, Australia) was suspended 120 cm above the centre of each cage and connected to a video recorder (Model Lite 900, LG, Yeouido, South Korea) and screen.

The two rooms were randomly allocated to be hot or cold, with the temperature of the hot room aimed to simulate the lizards' natural environment in northern Australia (34°C in the day time; 0600 to 1800h, and 29°C during the night; 1800 to 0600h), and that of the cold room set to the recommended standard for captive lizards (Turner 2001), 24°C by day and 19°C at night. Temperature was controlled through a central air-conditioning system and monitored daily at ground level.

Artificial light was provided by a single fluorescent tube activated during the day, with no natural sunlight available. The lizards were allowed to bask under the UV light for one day at the end of every experiment period, ie every two weeks. They were fed thrice weekly on the same diet as in Experiment 1 on an *ad libitum* basis, with refusals removed before feeding at 1030h.



https://doi.org/10.1017/S0962728600002931 Published online by Cambridge University Press

Video recordings were made of each animal's behaviour on alternate hours from 0600 to 1800h. The hours recorded were changed by one on alternate days, ensuring the full 12-h period was recorded every two days. Five minutes in the middle of each hour were used for analysis, providing 30 min of video recordings per lizard per day. During replay, continuous records were made of the duration and frequency of the following behaviours: eating ration; drinking; inactive on the log, the floor or the brick; hiding in the log; wall climbing; walking; head by the wall (the head or at least half of the animal's total length in the grid squares immediately adjacent to the wall, see below); pacing (consecutively moving backwards and forwards along the same path at least twice); and circling (moving continuously in circles around the enclosures for at least two circles).

In order to quantify the walking activity, the monitor screen was divided by grids drawn onto a superimposed transparent plastic membrane. Since the big cages were four times larger than the small, there were 64 squares (8 × 8) in the big cages and 16 squares (4 × 4) in the small. The peripheral outer squares next to the wall were used to identify when the lizard was by the wall. The live weight of each lizard was recorded weekly as in Experiment 1.

### Statistical analysis

In Experiment 1, the differences between the treatments, for each behaviour, were examined by analysis of variance (ANOVA) using Minitab 15.1.1.0, including lizard and treatment as factors in the model.

In Experiment 2, the differences between the treatments for each behaviour were examined by ANOVA using the SAS® restricted maximum likelihood (REML) mixed model procedure (Version 8.2© 2001), including lizard, period, enclosure size and temperature treatments as factors and days as repeated measures. The initial analysis included all days but, because day 1 was different to other days for some behaviours, a subsequent analysis omitted day 1. Count data (behaviours recorded by times or grids) were logarithm-transformed prior to analysis to reach an approximately normal distribution of residuals. Due to the different sizes of big and small enclosures, the probabilities of a lizard being in the squares by the wall were 28/64 in the big enclosures and 12/16 in the small. To avoid a systematic error caused by this difference, the time that they spent by the wall was divided by the relevant probability value, and this corrected value analysed as for other data. The mean weekly liveweight gain for each lizard-period combination was calculated, then analysed as a simple crossover design using the Sign test.

## Results

### Experiment 1

The time spent eating the ration and ration dry matter consumption were increased by the provision of live mealworms, and lizards offered mealworms in the foodball ate them faster than if they were scattered on the floor (Table 2). The lizards gained little weight over the experiment, but it was increased by provision of mealworms, regardless of method of supply.

The provision of live mealworms did not affect the lizards' drinking time, but it reduced the time that lizards spent inactive under the paper, regardless of whether the mealworms were scattered or inserted into the foodball, and almost doubled the time spent active above the paper (Table 2). Live mealworms did not affect wall climbing or time spent hiding in the pipe, but they increased the time that the lizards spent rubbing their nose against the wall, and walking, especially if they were in the foodball.

### Experiment 2

The following behaviours exhibited significant variation over days: hiding in the log ($P = 0.04$), inactive on the floor ($P = 0.01$) and walking (across grids, $P = 0.03$ and as a proportion of time $P = 0.10$). For all except the time spent walking, day effects were similar across treatments. However, the day effect for walking time was different for the two enclosure size treatments. On day 1, walking time was much greater in the big than in the small enclosures (Figure 2). There was a smaller but still significant difference of the same order between the two treatments after this day. Over the remaining days, lizards in big enclosures also walked across nearly twice as many gridlines as those in small enclosures (Table 3).

Eating and drinking times were not affected by enclosure size or temperature. Lizards in big enclosures spent more time hiding in the log (Table 4), and they spent less time inactive on the log, particularly in the cold temperature room, and they tended to spend less time inactive on their brick. They also tended to spend less time with their head by the wall, but this difference was not evident when the data were corrected for the proportion of wall to total area. Lizards in hot enclosures spent less time inactive on their log and more time hiding in it than those in cold enclosures. Frequencies of climbing up the wall, onto the brick and head moving were not affected by enclosure size or temperature (Table 3). Neither pacing nor circling was observed in any treatment in sufficient frequency for statistical analysis. Liveweight gain of lizards in the small cages (mean: 9.9 g per week) was significantly greater than zero ($P = 0.03$), whereas for the lizards in the big cages it was not (mean: 0.7 g per week, $P = 0.82$). Temperature did not affect liveweight gain ($P = 0.44$).

## Discussion

### Mealworm provision

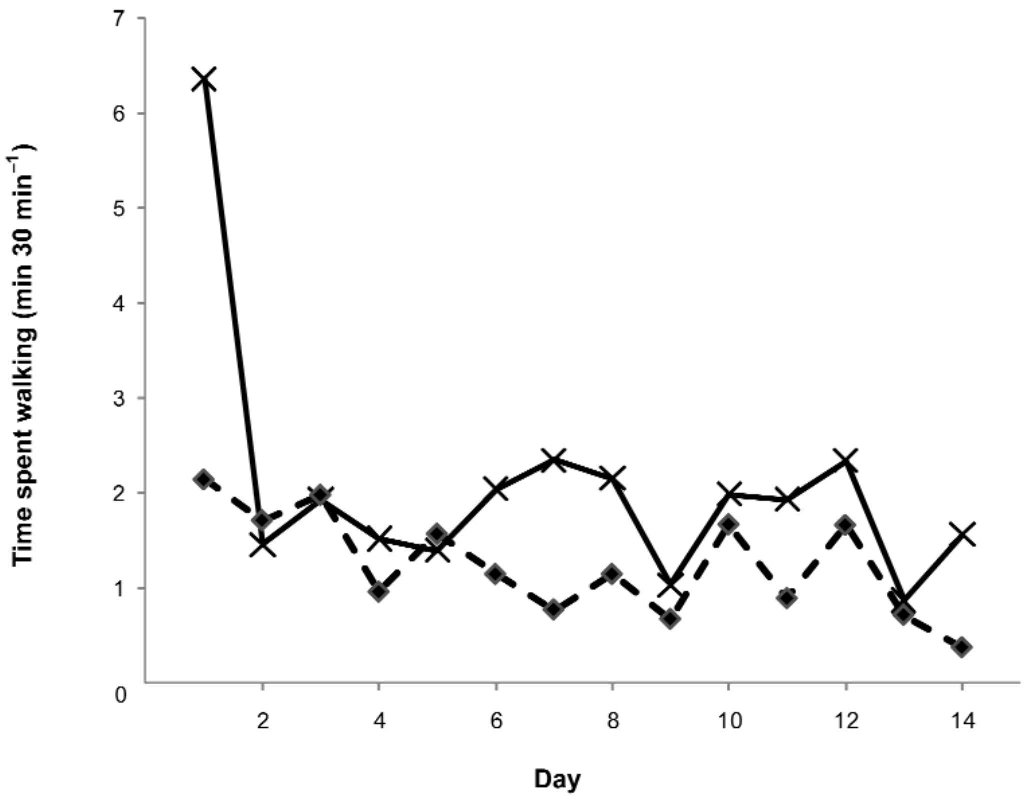
The increase in time spent eating the ration, ration consumption and liveweight gain when live mealworms were provided suggests that they stimulated lizards' appetite and nutrient absorption. Faster mealworm consumption when they were provided in the foodball was probably because the lizards could locate them more easily. This may have given the lizards greater time for walking. The impact of mealworm provision on welfare is hard to assess. Reduced time spent hiding under the paper and increased activity when live mealworms were provided are contrary to the natural behavioural tendencies of *T. scincoides* in the dry season, when they spend much time in their burrows, conserving water and

**Table 2 The effect of live mealworm provision, either scattered in the enclosure (treatment SC) or inserted into a foodball (FB) on the least square means, standard errors of the difference between two means and significance of the treatment differences for behaviours recorded as a percentage of time, and feed intake and liveweight gain, in Experiment 1.**

| | Treatment | | | | |
|---|---|---|---|---|---|
| | **Control** | **SC** | **FB** | **SED*** | ***P*-value** |
| Eating ration (% time) | $0.7^{b}$ | $1.1^{a}$ | $1.3^{a}$ | 0.229 | 0.04 |
| Dry matter consumption (g $day^{-1}$) | $1.7^{b}$ | $2.2^{a}$ | $2.0^{a}$ | 0.113 | < 0.001 |
| Liveweight gain (g $day^{-1}$) | $0.1^{b}$ | $0.5^{a}$ | $0.5^{a}$ | 0.16 | 0.04 |
| Eating live mealworms (% time) | – | 0.8 | 0.5 | 0.096 | < 0.001 |
| Drinking (% time) | 0.2 | 0.2 | 0.2 | 0.48 | 0.90 |
| *Inactive (% time)* | | | | | |
| Under paper | $80.5^{a}$ | $73.2^{b}$ | $73.0^{b}$ | 0.31 | 0.006 |
| On floor | 3.1 | 6.7 | 6.3 | 1.98 | 0.20 |
| On brick | 1.1 | 1.1 | 0.87 | 0.407 | 0.80 |
| Active above paper (% time) | $8.7^{b}$ | $16.0^{a}$ | $16.1^{a}$ | 0.36 | 0.002 |
| Wall climbing (% time) | 2.0 | 2.0 | 1.9 | 0.43 | 0.90 |
| Hide in pipe (% time) | 0.23 | 0.23 | 0.20 | 0.146 | 0.90 |
| Walking (% time) | $0.9^{c}$ | $1.8^{b}$ | $2.5^{a}$ | 0.41 | 0.006 |
| Rubbing nose on wall (% time) | $0.11^{b}$ | $0.30^{a}$ | $0.41^{a}$ | 0.101 | 0.03 |

* Standard error of the difference between two means. Means within rows with different superscripts are statistically different ($P < 0.05$).

**Figure 2**




The least square mean time spent walking in the big (straight line) and small (dashed line) cages (min 30 $min^{-1}$) during the 14 days of each period by all the lizards in Experiment 2.

**Table 3 The effect of size of enclosure (B = big and S = small) and temperature (C = cold and H = hot) on the least square means, standard errors and significance of the differences for behaviours recorded as a percentage of time between days 2 and 14 in Experiment 2.**

| | Treatment | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| | BC | BH | SC | SH | SED* | Space | Temperature | Space × Temperature |
| Eating | 0.2 | 0.2 | 0.1 | 0.3 | 0.32 | 0.88 | 0.22 | 0.31 |
| Drinking | 0.1 | 0.1 | 0.03 | 0.1 | 0.20 | 0.34 | 0.65 | 0.61 |
| *Inactive* | | | | | | | | |
| On log | 13.3 | 5.7 | 35.0 | 8.0 | 4.31 | 0.006 | < 0.001 | 0.02 |
| On floor | 12.0 | 9.0 | 13.7 | 14.0 | 3.82 | 0.41 | 0.75 | 0.67 |
| On brick | 1.7 | 1.7 | 3.3 | 2.7 | 1.73 | 0.10 | 0.52 | 0.65 |
| Wall climbing | 1.7 | 0.7 | 1.7 | 1.3 | 0.71 | 0.62 | 0.36 | 0.57 |
| Hide in log | 63.7 | 76.0 | 42.7 | 69.3 | 5.12 | 0.009 | 0.001 | 0.16 |
| Walking | 5.3 | 6.3 | 3.3 | 4.3 | 1.95 | 0.03 | 0.28 | 0.78 |
| Burrowing | 0.1 | 0.1 | 0.2 | 0.1 | 0.24 | 0.53 | 0.89 | 0.39 |
| Head by wall | 8.7 | 4.3 | 13.4 | 13.7 | 3.62 | 0.06 | 0.57 | 0.52 |
| Corrected | 19.8 | 9.8 | 17.9 | 18.2 | 6.48 | 0.55 | 0.38 | 0.35 |

* Standard error of the difference between two means for the space × temperature interactions.

**Table 4 The effect of size of enclosure (B = big and S = small) and temperature (C = cold and H = hot) in Experiment 2 on behaviours recorded as frequencies between days 2 and 14 and presented as least square logarithm adjusted and unadjusted mean values.**

| | Treatment | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| | BC | BH | SC | SH | SED* | Space | Temperature | Space × Temperature |
| *Walking distance* | | | | | | | | |
| $Log_{10}$ number of lines crossed per 30 min | 1.83 | 1.97 | 1.31 | 1.60 | 1.43 | 0.05 | 0.33 | 0.73 |
| Unadjusted number per 30 min | 5.2 | 6.2 | 2.7 | 3.9 | | | | |
| *Wall climbing* | | | | | | | | |
| $Log_{10}$ number of times per 30 min | 0.50 | 0.47 | 0.34 | 0.43 | 0.64 | 0.40 | 0.77 | 0.61 |
| Unadjusted number per 30 mins | 0.65 | 0.60 | 0.40 | 0.54 | | | | |
| *Head movements* | | | | | | | | |
| $Log_{10}$ number of times per 30 min | 1.97 | 1.82 | 1.84 | 1.91 | 1.32 | 0.93 | 0.84 | 0.59 |
| Unadjusted number of times per 30 min | 6.2 | 5.2 | 5.3 | 5.8 | | | | |
| *Brick climbing* | | | | | | | | |
| $Log_{10}$ number of times per 30 min | 0.39 | 0.46 | 0.59 | 0.54 | 0.67 | 0.11 | 0.84 | 0.45 |
| Unadjusted number of times per 30 min | 0.48 | 0.59 | 0.80 | 0.72 | | | | |

* Standard error of the difference between two means for the space × temperature interactions.

energy due to the poor availability of food and water and high temperatures during this period (Christian *et al* 2003). However, during the wet season they are much more active and restore their bodyweight. To simulate natural behaviour, it would be important to take account of the temperature and humidity conditions that the lizards are kept in before providing supplementary food in this way. In addition, lizards in small enclosures easily become overweight (Altherr & Freyer 2001), and it would be important to monitor lizard weight if mealworms are being offered.

### Enclosure size and temperature effects

Increased walking at high space availability, but not at high temperatures, reflects increased space to explore and has also been found with Round Island geckos (Wheler & Fa 1995). Exploration is probably the reason for the large increase in walking on the first day in the new enclosures, or it could be a rebound behaviour demonstrating thwarted walking motivation in small enclosures. However, there was no evidence of stereotyped pacing or circling, nor was there any evidence that escape behaviours (wall climbing and head by wall) were increased in small enclosures, both of which might indicate frustration. The increased time spent walking in the large enclosures may have been the reason for the reduced liveweight gain of these lizards, consistent with increased energy requirements. Lizards may become overweight in small enclosures, in which case increasing activity would be positive for animal welfare. According to Kirmair (1994), climbing up the wall and moving along the boundary are the most common abnormal behaviours in lizards, but there was no evidence from our study that they increased in small enclosures.

The precise distances walked are not possible to determine accurately from the observations of the number of gridlines crossed because the lizards may move sideways as well as forwards to cross gridlines. However, estimating an approximate distance per crossing of a gridline of 100 cm, compared with the distance between two gridlines of 175 cm, and using the mean values of number of gridlines crossed per 30 min gives total distances walked of 19 and 11 cm $min^{-1}$ for the big and small enclosures, respectively. Christian *et al* (2003) reported that the *T. scincoides* species is a particularly active lizard, requiring to respond to the wide variation in climatic conditions between the wet and dry seasons in their normal habitat in the north of Australia. In the wet season they feed daily, requiring regular scanning of the ground and vegetation for invertebrates and suitable foliage to eat, but they spend long periods burrowing in the dry season because of the food and water shortage.

The increase in hiding time in big enclosures observed in Experiment 2 has also been observed in space availability studies with Round Island geckos (Wheler & Fa 1995). This suggests a degree of agoraphobia which is probably because, in the wild, they spend much of their time hiding in bush litters, hollows or soil cracks to avoid potential predators, such as snakes and raptors (Cogger 2000). An alternative explanation is that the increased activity in large enclosures necessitated increased resting, which usually occurs in the logs and hollows. High temperatures also stimulated increased hiding behaviour, which may be a reflection of the shade-seeking that is normal in this species in higher temperatures.

Increased time spent inactive on the log in cold temperatures probably reflects an instinctive basking behaviour to capture the sun's radiant heat at low temperatures, even though this was not possible in this environment. Behavioural thermoregulation in lizards involves using a combination of basking in the sun (heliothermy) and absorbing heat from objects in the environment (thigmothermy) (Gillingham 1995). Altherr and Freyer (2001) recommend that a range of temperatures should be provided to reptiles, so that they can thermoregulate by moving between areas. Optimum temperatures vary with time of day, humidity, wind speed and physiological state of the animal (Altherr & Freyer 2001), and this study only quantifies their responses at two different temperatures. Providing more space by allowing *T. scincoides* freedom to range within a house often conflicts with provision of an adequate range of temperatures. However, in Experiment 2, there was only one interaction between space and temperature, time spent inactive on the log, suggesting that the behaviour and welfare responses to the two treatment factors were largely independent.

### Animal welfare implications

The provision of live mealworms increased activity, reduced hiding and increased weight gain. The effect on welfare may vary with captive husbandry conditions. There is little evidence that *T. scincoides* showed stereotypic activity indicative of frustration with their environment, hence the extra activity cannot be expected to be beneficial in occupying the lizards and reducing the time spent in abnormal behaviour. In relation to the lizards' ability to perform normal behaviours, in hot, dry conditions, providing mealworms may reduce welfare as the lizards would naturally hide for long periods, but in wet conditions it may stimulate a more natural pattern of behaviour.

A large enclosure had a similar effect on the welfare of *T. scincoides*, with an increase in activity, the benefit of which may depend on husbandry conditions and their relation to the natural environment. In this case, the propensity to hide was also increased, necessitating provision of a suitable place for this activity. Increasing cage temperature from 19/24 to 29/34°C did not have a major impact on behaviour or welfare of *T. scincoides*.

## References

**Altherr S and Freyer D** 2001 Morbidity and mortality in private husbandry of reptiles. *Pro Wildflife Report to RSPCA.* RSPCA: Horsham, UK

**AVMA** 2007 *US Pet Ownership & Demographics Sourcebook 2007.* American Veterinary Medical Association: Schaumberg, IL, USA

**Burghardt GM, Ward B and Rosscoe R** 1996 Problem of reptile play: environmental enrichment and play behavior in a captive Nile soft-shelled turtle, *Trionyx triunguis*. *Zoo Biology 15*: 223-238

**Case BC, Lewbart GA and Doerr PD** 2005 The physiological and behavioural impacts of and preference for an enriched environment in the eastern box turtle (*Terrapene carolina carolina*). *Applied Animal Behaviour Science 92*: 353-365

**Christian KA, Webb JK and Schultz TJ** 2003 Energetics of blue-tongue lizards (*Tiliqua scincoides*) in a seasonal tropical environment. *Oecologia 136*: 513-523

**Cogger HG** 2000 *Reptiles and Amphibians of Australia.* Reed New Holland: Sydney, Australia

**Gillingham JC** 1995 Normal behaviour. In: Warwick C, Frye FL and Murphy JB (eds) *Health and Welfare of Captive Reptiles.* Chapman & Hall: London, UK

**Hayes MP, Jennings MR and Mellen JD** 1998 Beyond mammals: environmental enrichment for amphibians and reptiles. In: Shepherdson DJ, Mellen JD and Hutchins M (eds) *Second Nature: Environmental Enrichment for Captive Animals* pp 205-235. Smithsonian Institution Press: Washington, USA

**Hildebrand M, Goslow GE and Hildebrand V** 2001 *Analysis of Vertebrate Structure.* Wiley: New York, USA

**Kirmair R** 1994 *Untersuchungen zur Terrarienhaltung von Reptilien unter besonderer Berucksichtung des Artenschutzes.* Munchen, Ludwig Maximulians-Universitat: Munich, Germany. [Title translation: Studies on the captivity of reptiles with special attention to animal welfare and conservation]

**Krause MA, Burghardt GM and Lentini A** 1999 Object provisioning for Nile soft-shelled turtles (*Trionyx triunguis*). *Laboratory Animal 28*: 38-41

**Kreger MD** 1993 The psychological well-being of reptiles. *Humane Innovation Altern 7*: 519-523

**Lissone L** 1999 Tiliqua scincoides. http://www.jcu.edu.au/school/tbiol/zoology/herp/ Tiliquascincoides.pdf.

**Mader DR** 2006 *Reptile Medicine and Surgery.* Saunders Elsevier: Philadelphia, USA

**McCarthy CR** 1992 Regulation and guidelines: the national institutes of health. In: Schaeffer DO, Kleinow KM and Krulisch L (eds) *The Care and Use of Amphibians, Reptiles and Fish in Research* pp 5-6. Scientists Center for Animal Welfare: Bethesda, MD, USA

**McFarland D** 1999 *Animal Behaviour: Psychobiology, Ethology, and Evolution.* Longman: Harlow, USA

**Pough FH** 1992 Setting guidelines for the case of reptiles, amphibians and fishes. In: Schaeffer DO, Kleinow KM and Krulisch L (eds) *The Care and Use of Amphibians, Reptiles and Fish in Research* pp 7-14. Scientists Center for Animal Welfare: Bethesda, MD, USA

**Savage JM** 2005 *The Amphibians and Reptiles of Costa Rica: a Herpetofauna Between Two Continents, Between Two Seas.* University of Chicago Press: Chicago, USA

**Shepherdson DJ** 1998 Tracing the path of environmental enrichment. In: Shepherdson DJ, Mellen JD and Hutchins M (eds) *Second Nature: Environmental Enrichment in Captive Animals* pp 1-14. Smithsonian Institution Press: Washington, DC, USA

**Turner G** 2001 *Keeping Blue-Tongue Lizards.* Australian Reptile Keeper Publications: Bendigo, Australia

**Warwick C, Frye FL and Murphy JB** 1995 *Health and Welfare of Captive Reptiles.* Chapman and Hall: New York, USA

**Wheeler CL and Fa JE** 1995 Enclosure utilization and activity of Round Island geckos (*Phelsuma guentheri*). *Zoo Biology 14*: 361-369

**Wilson S and Swan G** 2003 *A Complete Guide to Reptiles of Australia.* Reed New Holland: Sydney, Australia

**Young RJ** 2003 *Environmental Enrichment for Captive Animals.* Blackwell Science: Oxford, UK



https://doi.org/10.1017/S0962728600002931 Published online by Cambridge University Press