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Using student-centred research to evidence-base exhibition of reptiles and amphibians: three species-specific case studies

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Abstract

When zoo-housed animals have choice over aspects of their environment, and are able to exercise control over interactions with their surroundings, welfare can be improved and exhibits' value to the zoo increased. Reptiles and amphibians are not common subjects in enrichment studies yet their demanding captive requirements suggest a need for enclosure diversity and biologically sound enrichment programmes. As popular captive subjects, such animals are readily available for potential research projects that investigate behaviour, welfare and effects of enclosure design. Undergraduates on animal science courses that undertake a research-led dissertation or similar projects can collect data on such species that, if collected under a robust methodology, can be used to inform future husbandry decisions. This paper discusses three small-scale studies (on two reptile species and one amphibian species) that were designed to improve husbandry and welfare. The aim of the paper is to show that undergraduate projects, properly managed, can have a positive impact on overall day-to-day exhibition and management of these species. Results from these projects have shown that small changes to enclosure design can have a beneficial impact on activity patterns, and that overall enclosure design can help display the animals in a more interesting way to visitors. Potentially, the animal welfare benefits of enriched set-ups can be passed on to zoo visitors in the form of a more engaging, exciting and educationally relevant zoo experience.

Introduction

Reptiles and amphibians are some of the most commonly housed species in modern zoological collections and are kept by numerous private hobbyists globally. They also feature heavily in educational establishments teaching animal husbandry/management. Species-specific husbandry guidelines are lacking for many herptiles and recommendations for appropriate enrichment may be anecdotal. Our understanding of reptile and amphibian behaviour in captivity can also be limited, and enrichment projects that enhance the psychological welfare of reptiles and amphibians rarely appear in the peer-reviewed zoo literature. Improvements to the welfare of captive reptiles could be seen if behavioural repertoires are more closely examined and interpreted to enhance enclosures and support enrichment protocols. Students enrolled on degree programmes at establishments keeping such species are therefore an excellent resource that can be utilised to collect data to evidence-base husbandry regimes and enhance standards of care. Here we explain how such student-centred projects can have a positive impact on herptile exhibition and welfare, and are able to add to the scientific literature on reptile and amphibian husbandry requirements.

In many species it is known that provision of choice enables a higher welfare state to be reached (Bassett and Buchanan-Smith 2007; Nicol et al. 2009; Swaisgood 2007; Whitham and Wielebnowski 2013). Amphibians and reptiles both rely on environmental factors to regulate internal metabolism and hence require a thermally heterogeneous environment to move through daily to maintain homeostasis. When such heterogeneity is not provided, behavioural disturbances may result (Morgan and Tromborg 2007; Shah et al. 2003). As is the case in captive mammalian and avian species, reptiles have also been shown to develop stereotypic, abnormal behaviour patterns (Young 2003). Reduction and eventual eradication of such unwanted activities could be possible through increased stimulation from the environment in which the animal is housed. Both reptiles and amphibians have the capacity to benefit from well thought-out enrichment programmes that can be built in to their enclosures or be added to in a similar fashion to that done with mammals and birds (Blake et al. 1998; Hawkins and Willlemsen 2004; Hayes et al. 1998).

There has been a growing call for more reptile enrichment to be undertaken and evaluated (Burghardt et al. 1996; Hernandez-Divers 2001) to ascertain the effects of behavioural enrichment on reptile activity, health and welfare. Husbandry regimes and enclosure design based around natural behaviour, termed "ethologically-informed" practices, are described by Greenberg (1995), yet the term "evidence-based husbandry" (Melfi 2009), coined for all captive animals, probably better sums up what is needed to further improve management of reptiles and amphibians in zoos. This would then ultimately enhance the message (and value) that such exhibits have to visitors. The design of zoo animal enclosures ultimately affects the public's perception of the occupants. Likewise, zoos strive to recreate naturalistic environments that promote "normal" behaviour patterns and give a positive image of the zoo as a whole (Robinson 1998). A positive visitor experience, (see Fernandez et al. 2009), can effectively champion the key aims of the modern zoo (conservation, education, research, entertainment). Such aims are better promoted when animals are housed in enclosures that mimic natural environments and engage visitors, as per Conway (1973)'s highly relevant, if now dated, article on displaying bullfrogs (*Lithobates catesbeianus*) effectively.

A dearth of research exists on the importance of such "good display" on the perception and educational or conservation relevance of reptiles and amphibians in zoos, as well as on the impact of such informed design on the occupants' behaviour. The common occurrence of popular "pet-style" species in educational facilities enables empirical research to be conducted in a situation that mirrors larger zoological collections, with the advantage of exhibits to be manipulated more quickly and set up in tandem to measure specific variables. Well managed undergraduate degree students that have access to these animals can be used to help increase the research output on such under-studied species.

This paper describes three experiments conducted by undergraduate students at Sparsholt College Hampshire (SCH), Winchester, UK. Students collected data on behaviour, visibility, activity levels and enclosure usage of two species of reptile (chuckwalla, *Sauromalus ater*, and corn snake, *Pantherophis guttatus*) and one species of amphibian (blue dart frog, *Dendrobates tinctorius azureus*) on display in the College's Animal Management Centre (AMC). The study species were chosen as they are representative of many such animals held in captivity and hence the results from these investigations would have far-reaching and relevant application to many other individuals. All students were registered on a BSc (honours) Animal Management degree and were working towards a dissertation project or involved in a personal development project to train and develop their research skills. Students were provided with standard ethograms and trained in the identification of specific behaviours and in the data collection procedures prior to each research project being implemented.

Case study 1: Chuckwalla enclosure design

Western chuckwallas are an arid-dwelling species that naturally occur in the deserts of south-western North America (Kwiatkowski and Sullivan 2002). Classified as "rock-dwelling" (saxicolous) lizards, chuckwallas actively avoid areas of habitat that are devoid of suitable rock structures for hiding and climbing (Goode et al. 2005). A chuckwalla's main defensive strategy is to expand lung capacity beyond normal volumes, thus inflating and wedging the lizard into a rock crevice or similar small space (Deban et al. 1994). This saxicolous lifestyle means that vivaria housing chuckwallas must enable the performance of an array of behaviours above the ground, on rockwork, in a similar manner to those documented in free-living animals.

Table 1. Ethogram of chuckwalla behaviour.

Behaviour	Description
Movement	The animal is walking, climbing, running around the exhibit and over furnishings.
Hidden	The animal is not fully on view and is using the furnishing of the enclosure to conceal itself.
Basking	The animal is flattened against a heat source or positioned under a radiant heat source. The animal is stationary.
General interaction	Social behaviour between the two chuckwallas of a non-threatening, non-aggressive nature.
Reproductive interaction	Head-bobbing, chasing, yawning and push-ups from male to female. Colour-flushing and orienting of body towards each other.
Other	Stereotypic movements against a glass barrier or stereotypic movement against a solid boundary.

Male chuckwallas are territorial (Alberts 1994), hence it is important to provide features of the vivarium that can be used as territorial markers. Familiarity with immediate environment is known to give a sense of security (Baumans and Van Loo 2013; Nikaido and Nakashima 2009) and hence is a means of decreasing stress in captive animals. The aims of this project were to provide two chuckwallas with the ability to improve overall behavioural repertoire by increasing spatial complexity of their enclosure (creating a micro-climate that would better resemble wild conditions) and to provide the chuckwallas with an outlet for key appetitive behaviours that may enhance reproductive potential.

Stress-related behaviours (in the form of repetitive interaction with a transparent boundary) have been noted in the past in the two subjects of this investigation. Re-evaluation and subsequent redesign of the enclosure has been undertaken to improve the likelihood of courtship display performance and to reduce the time spent stereotyping. By providing the two chuckwallas with a

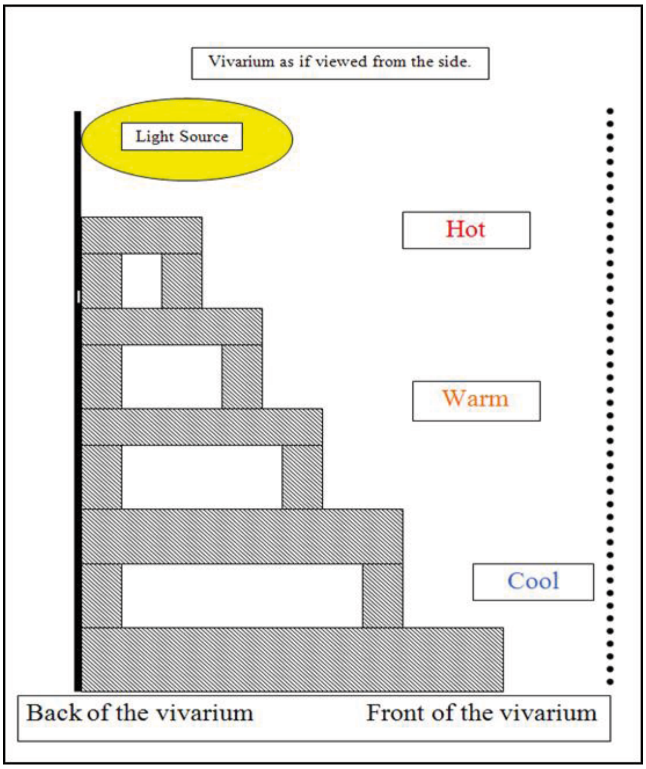

Figure 1. Schematic illustration of the "stack" built into the chuckwallas' enclosure.

Figure 2. Reduced number of hiding places (left) and new "stack" built for the chuckwallas to add spatial diversity, increased height and more hiding places into their exhibit (right).

range of basking areas as well as a gradual temperature gradient across the enclosure (via the construction of a basking stack out of blocks that enable the animals to move towards or away from heat; see Figure 1), it was hoped that an improved overall behavioural performance would be observed.

This project involved two adult western chuckwallas (one male, one female). To minimise the effect of extraneous variables, observations were conducted at the same time for each day of recording. An ethogram of chuckwalla behaviour was provided and explained to all data collectors (see Table 1). From October until December 2009, observations were conducted on the chuckwallas in their "normal" enclosure (as per College husbandry guidelines). A total of 1533 minutes of data were obtained and students worked in pairs to record state behaviours every minute for two (afternoon) 30-minute sessions, every Wednesday during term time using instantaneous scan sampling of focal individuals. The addition of new features to enrich the exhibit allowed for acclimatisation to environmental change before observations recommenced.

Comparison of before and after enrichment activity budgets, and use of the different features of the exhibit, was used to determine overall effects of enrichment (the increased "choice") on the activity levels, social expression and courtship displays of the two chuckwallas. During the entire experimental procedure,

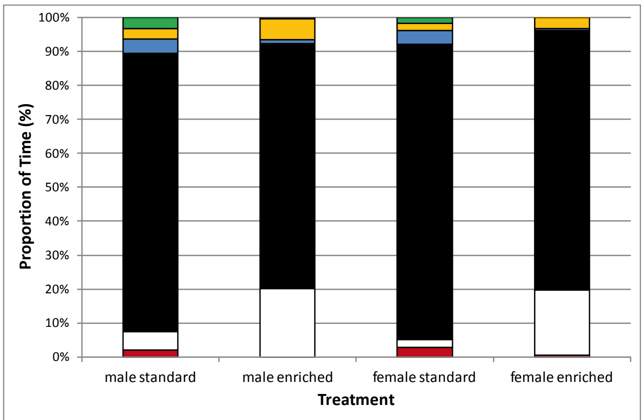

Figure 3. Activity budget for each chuckwalla (left two bars male; right two bars female) during the enriched and standard data collection periods. Behaviours shown are: red = movement; white = hidden; black = stationary/basking; blue = general interaction; orange = reproductive behaviour; green = other (e.g. stereotypy). Chuckwallas altered time spent hiding away and stationary when the basking stack was added in to the enclosure.

environmental conditions (lighting, heating and humidity) were maintained along the same parameters. At the time of the study, the chuckwallas' enclosure measured 1 m^3 in total volume. Figure 1 shows a schematic diagram of the alteration provided in the vivarium to encourage the chuckwallas to use a range of thermal conditions and hence display a more extensive range of behaviours. Figure 2 illustrates specific furnishings in the exhibits both before and after alteration of the enclosure. The "stack" was constructed of a brick and breeze block lattice, in a stepped formation across the back wall of the vivarium.

Data were analysed using Minitab 16 statistical software. As these data were non-parametric, one-factor and two-factor chi-squared tests were used to determine significant differences in behaviour patterns against enclosure style. Figure 3 outlines overall activity budgets for each chuckwalla.

Results showed that chuckwallas in the enriched environment significantly reduced the number of "general" interactions, i.e. those not associated with reproduction, ($\chi^2 = 7.58$; df = 1; p = 0.006) but performed an increased frequency of reproductively-associated behaviours (from 9.5% to 17.5% of an average time budget) although this was not significant (see Figure 3). Whilst performance of stereotypical behaviours (interaction with a boundary) was low overall (only three minutes of "pacing" around a glass boundary), under enriched conditions no stereotypy was recorded. This suggests that the provision of the "stack" was important in altering the chuckwallas' ability to feel secure in their environment; this is perhaps supported by the result that both chuckwallas were hiding significantly more of the time when the "stack" was provided ($\chi^2 = 44.1$; df = 1; $p < 0.001$). Whilst this may not make the animals a "better" exhibit from a display point-of-view, it highlights the fact that choice of escape area is important to psychological welfare. Careful positioning of hide spots would therefore enable chuckwallas to feel secure in their enclosure and be on view.

Figure 4 shows that under enriched conditions chuckwallas did use the extra height they were provided with and spent more time off the ground; this seems highly apparent in the male individual and provides scope for further investigation. It is possible that gender differences in resource use mean that male animals are more inclined to use height more frequently than female animals. A Pearson's chi-squared test for comparing the effect of enrichment on each individual's use of height shows a significant difference for both animals' behaviour between enriched and standard conditions ($\chi^2 = 389.9$; df = 2; $p < 0.001$). Prieto and Ryan (1978) state that chuckwallas are normally found in multi-sex groups so it may be that a pair is an unnatural social structure to

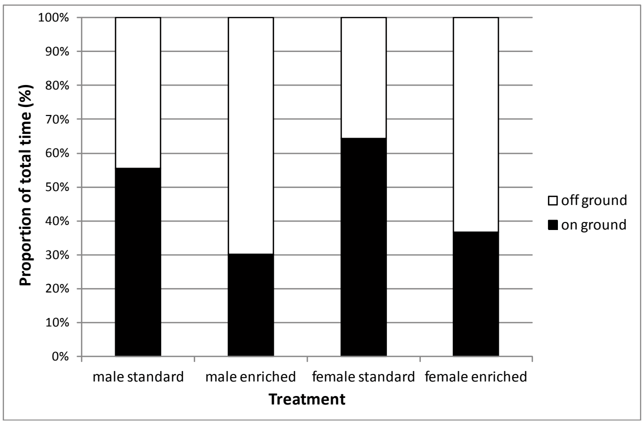

Figure 4. Differences in time spent on and off the ground under the two different enclosure treatments for each chuckwalla (male, left two bars; female, right two bars).

Table 2. Ethogram of corn snake behaviour.

Behaviour	Description
Hiding (terrestrial)	Majority of body concealed in substrate or furnishing on the ground.
Hiding (arboreal)	Majority of body concealed in vegetation.
Exposed(terrestrial)	Majority of body visible but stationary and respiring.
Exposed (arboreal)	Majority of body visible but stationary off the ground and respiring.
General locomotion and climbing	Movement: actively moving from one location to another. Actively climbing on furnishings of enclosure.

live in. Differences were noted in amount of time spent basking; this could be attributed to inconsistencies between observations whereby animals that were simply "exposed" or sat out in the open were deemed to be basking. Nevertheless, this is a particular aspect of the chuckwalla's behaviour that could be investigated further. Some arid-dwelling lizards are known to gather heat from rocks (thigmothermy) as well as radiant heat from the sun (heliothermy) (Belliure and Carrascal 2002); thus it is possible that differences in time basking/exposed could be attributed to use of the new rockwork as a means of regulating body temperature.

Case study 2: Behavioural enrichment of corn snakes

Corn snakes are often kept in flat, rather barren exhibits and numerous "pet literature" articles are available advising owners to maintain snakes in little more than plastic storage boxes (Jones 2000). Corn snakes are classed as rat snakes (Bartlett and Bartlett 2006), a group of snakes known to be highly exploratory (Almli and Burghardt 2006; Mullin and Cooper 1998), preferring a heterogeneous habitat of natural and man-made environments. These exploratory traits should be encouraged in captive enclosures. Casual observation of adult corn snakes at Sparsholt College indicated a preference for resting above ground, providing the foundation for this investigation. Research has shown that young corn snakes have a keen ability to learn from their surroundings (Holtzman et al. 1999), suggesting that behavioural patterns are modified via experience and indicating the importance of a stimulating environment to cognitive development. Almli and Burghardt (2006) noted that a related species, the black rat snake (*Elaphe obsoleta*), reacted in ways similar to those seen in mammalian species provided with enrichment, and that snakes in enriched exhibits are more behaviourally competent, further emphasising the importance of biologically relevant exhibits for captive reptiles and overall assessment of environmental enrichment.

This project involved behavioural observation of two populations of juvenile corn snakes housed in the Animal Management Centre at Sparsholt College Hampshire. The enriched population (two snakes) lived in a simulated planted enclosure, whereas the control group (two snakes) lived in a more basic style of accommodation (see Figure 5). Both populations were subject to similar environmental conditions (lighting, heating and humidity) and these variables were recorded throughout the study. Students worked in pairs and observed the snakes for two 30-minute periods every Wednesday in term-time from October 2008 until March 2009. Overall 540 minutes of behavioural data were recorded for each snake, using instantaneous scan sampling. The same

Figure 5. Furnishing of the enriched enclosure (left) and the pet-style, non-enriched, enclosure (right) for corn snakes used during the course of the study.

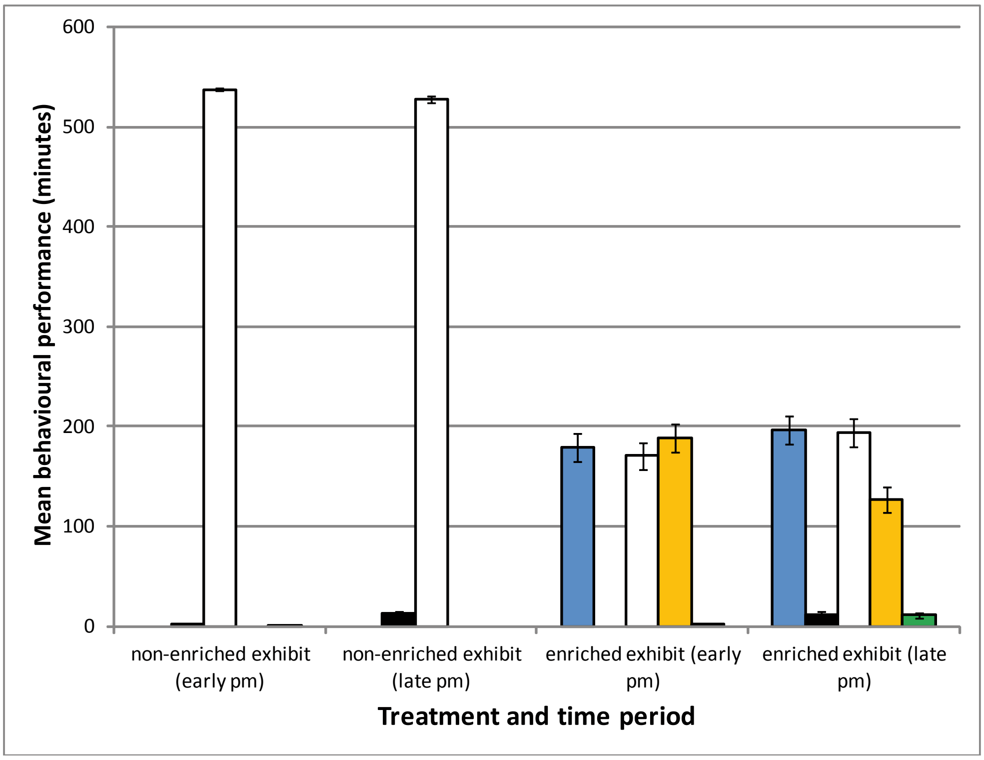

Figure 6. Mean activity budget (minutes) for each population of corn snakes within the two exhibits. Blue = exposed (arboreal); black = exposed (terrestrial); white = hiding (terrestrial); orange = hiding (arboreal); green = general movement (climbing, slithering).

time periods for observation were adhered to for each day of the project (1245 until 1315 and then 1515 until 1545). An ethogram (see Table 2) was produced to describe specific behaviours and activity patterns of note.

Data were analysed using Minitab 16 statistical software. All data were non-parametric and differences in behaviour, location and exhibit usage were evaluated using one- and two-factor chi-squared tests.

Snakes were provided with a complex environment, containing numerous branches for climbing and areas for off-ground resting increase the amount of time they are on view and are active (Figure 6). Comparison of the two populations highlighted the effect that extra furnishings have on the location of snakes in their enclosure; those in an enriched exhibit spent 31.7% of their time exposed and on view, whereas limited furnishings caused the snakes to be hidden for 98.6% of the total time observed. Snakes in the non-enriched exhibit, whilst provided with limited climbing opportunities, still did not use this element of their environment; yet an increase in availability of climbing "material" (as seen in the enriched enclosure) showed that the snakes spent 64.3% off the ground.

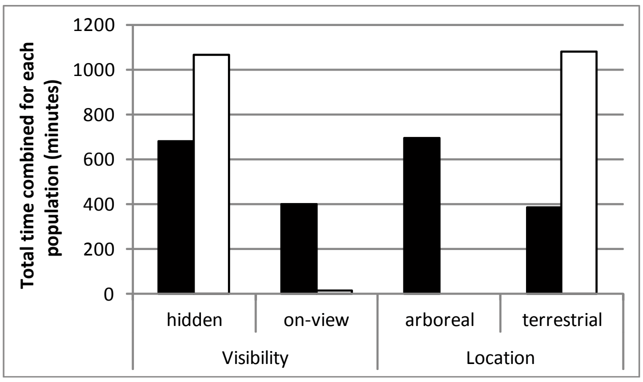

Figure 7. Relationships between style of the enclosure, location of the corn snakes and visibility to the observer. Black = enriched tank; white = non-enriched exhibit. Total time combined for both populations. Snakes were more likely to be on view and off the ground in an enriched environment.

Using a one-factor chi-squared test, it was found that corn snakes spend significantly more of their time off the ground when given the opportunity ($\chi^2 = 88.4$; df = 1; $p < 0.001$) and using a Pearson's two-factor chi-squared test there is a strong significant relationship between enclosure type and whether the snake is on view or hidden ($\chi^2 = 443.6$; df = 1; $p < 0.001$). These trends are illustrated in Figure 7. Such results highlight the importance of a sound knowledge of natural activity patterns when designing reptile exhibits.

Snakes may feel more secure when provided with a planted, naturalistic environment and hence are on show more often, adding to their role as a zoological exhibit. Corn snake exhibits should, therefore, incorporate height as well as floor space and provide the snakes with useable space above ground level, giving opportunities for elevated locomotion, basking, resting and interaction. Hernandez-Divers (2001) calls for more behavioural enrichment to be performed with captive reptiles and in spite of the limited sample size and time available for study, these results clearly state that corn snake behaviour patterns are affected by the type of enclosure they are maintained in.

Case study 3: Effect of exhibit design on poison dart frog activity

Amphibians are at risk of global extinction, and the importance of *ex situ* breeding programmes is a high profile topic (Griffiths and Pavajeau 2008; McGregor Reid and Zippel 2008). In order to promote zoo conservation the importance of public appreciation of species has been researched; findings show that "natural" or "unnatural" enclosure design can affect public perception of species within zoological collections. Zoos strongly promote their educational importance (Moss and Esson 2013), yet exhibits within zoos may not capture a visitor's interest and hence their message can be lost. Marcellini and Jenssen (1988) discuss the behaviour of visitors to a zoo reptile house and note that the public engage less with lizard and amphibian exhibits compared

Table 3. Ethogram of dart frog behaviour.

Behaviour	Description
Moving	A frog is hopping or crawling around its exhibit. Can include courtship wrestling.
Hunting	A frog is actively seeking out and searching for prey. Or pouncing and consuming prey.
Resting	A frog is stationary but completely visible.
Refuge use	A frog is partly visible or attempting to be fully concealed within foliage, furnishings or substrates in the enclosure.

to other species. The housing of many species of amphibian in relatively barren, "clinically sterile" exhibits because of heightened biosecurity could potentially detract from the exhibition potential of the frogs themselves. This study therefore explored the effects that enclosure design may have on the behavioural repertoire of amphibians held in the exhibit, and whether or not a clinical-style set-up altered the behaviour and activity level of the dart frogs in any way.

Two contrasting enclosures were created; one exhibit was representative of a naturalistic enclosure often seen at a larger zoo, and the exhibit was based upon a "clinical" style with non-natural furnishings and a bare substrate (see Figure 8). Due to constraints on the number of available animals, a sample of the same population of five frogs was used, first in one exhibit style and then in the other. Sixty hours of behavioural observation also took place on each frog population using a group scan sampling techniques every 5 minutes for 8 hours a day for 8 days in autumn 2011. An ethogram of behaviour (Table 3) was developed. Behavioural data were analysed using a one-factor chi-squared test (all using Minitab 16 statistical software).

The study found that enclosure design significantly affected the behavioural repertoire of blue poison dart frogs, with the naturalistic enclosure creating a more diverse activity range in the frogs (see Figure 9). The results of statistical analyses showed that the proportion of time spent active in the natural enclosure was significantly more than the time spent active in the non-natural enclosure ($\chi^2 = 147.91$; df = 1; $p < 0.01$). Likewise, frogs spent significantly more time resting in the clinical style set-up when compared to the naturalistic enclosure ($\chi^2 = 91.82$; df = 1; $p < 0.01$). Aspects of the three-dimensional, naturalistic enclosure were more likely to increase activity levels when compared to the unnatural enclosure, which was smaller and two-dimensional in design. This research can be used to understand how to increase the relevance of such exhibits (to visitors, to breeding potential, to positive animal welfare) in the zoo, as well as to highlight the importance of enclosure design in increasing the behavioural repertoire of poison dart frogs held in captivity.

Frogs still like to use refugia even if not provided in vast quantities; it is important to consider layout and planting of such exhibits so that poison dart frogs can feel secure enough to venture around the exhibit more often and use more of the available space. Potentially, frogs in the less natural set-up may have felt less inclined to move around their enclosure as they had less opportunity for retreating into refuge areas should they have felt the need to. Multiple refugia may also increase the range of microhabitats available to the frogs, thus providing increased environmental variables as well as hiding places, and hence enabling greater frog activity. The increased environmental diversity that the natural set-up provides enhances the activity patterns of the frogs themselves, suggesting they are more likely to be observed by visitors, and further increasing visitor engagement with the enclosure (and this species) in the zoo.

Discussion

All three case studies highlight that small-scale undergraduate projects can allow for evidence-based changes to enclosure design to be implemented that ultimately benefit the animals within the exhibit. Likewise, these studies highlight the positive responses that reptiles and amphibians give to an enriched set-up. Significant and beneficial differences in activity, space usage and, in some cases, visibility were noted in all three projects, demonstrating the importance of enriched housing for reptiles and amphibians. Building artificial cliff-faces for chuckwallas to choose where to thermoregulate, increasing the height that corn snakes can access, and recreating a small piece of rainforest to enhance a frog's chances of being more active are all small ways of improving the relevance of such animals within a captive setting. Developing an environment with added complexity can promote behaviours that make the animals more observable to zoo visitors and potentially, therefore, provide a better attraction overall.

Enrichment in the zoo can take many forms and does not necessarily have to be something added to the enclosure as a "toy" (Carlstead and Shepherdson 2000). Here, we have shown that the whole environment and overall layout of the enclosure can be enriching if this promotes a specific activity with a strong internal motivation (i.e. one that the animal is driven to perform). It is potentially easier to factor in an enriched enclosure

Figure 8. Furnishing of the naturalistic enclosure (left) and the clinical-style, non-naturalistic, enclosure (right) for blue poison dart frogs during the course of the study.

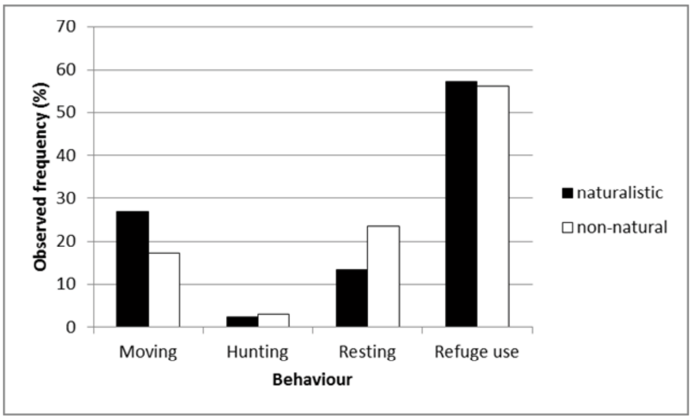

Figure 9. Activity pattern of the frogs when housed with a naturalistic (black bars) and non-natural, more clinical, enclosure (white bars).

layout, going back to the old principles of Greenberg (1995) and ethologically-informed schemes, from the inception of the exhibit rather than design a schedule that attempts to add enrichment in piecemeal afterwards. Lighting, heating, substrate composition and availability, water and planting are all key aspects of an enriched environment for reptiles and amphibians (Hawkins and Willlemsen 2004), and this research shows that provision of such factors in a manner akin to natural history enhances the behaviour and activity of a vivarium's inhabitants. Indeed, such a holistic approach to enrichment is championed by Mellen and Sevenich MacPhee (2001).

Ectotherms in general can be tricky subjects for which to gain public support and visitor interest. Reade and Waran (1996) noted that naturalness of zoo exhibits is the most important standard of husbandry noticed by zoo visitors, and that animals within "naturalistic" enclosures are more interesting, active and educational. Appropriate exhibition that engages the visitor's attention and provides the animals with a secure, relevant environment appears to be the best way to meet the needs of both stakeholders in this scenario. Current research suggests that evaluating the impact of species displayed in zoos on the education of visitors is multi-layered and that some taxa are viewed more favourably than others (Moss and Esson 2010). Zoos therefore need to be creative when integrating the exhibition of reptiles and amphibians into their long-term plans to ensure that such species are displayed in a fashion that engages the visitor and encourages natural behaviour.

Reptiles can be unappealing to zoo visitors, due to poor public image and ignorance of their natural history. Consequently, the provision of a spatially complex environment not only benefits the welfare of the animal, but can also further engage the viewing public, thus enhancing the zoo experience. The importance of this research to the development of reptile/amphibian-centred enrichment programmes is underpinned by Manrod et al. (2008), who state that whilst the welfare benefits of biologically relevant enrichment protocols for mammals and birds are well known, the benefits seen in reptiles post-enrichment suggest that this should become a standard procedure for husbandry practices in these species too. Results from the chuckwalla case study showed that animals budgeted their time differently when provided with an enclosure of increased temporal and spatial complexity. The stack provided for the lizards increased variation in thermal and lighting conditions, and it could be reasonable to assume that given the opportunity to regulate homeostatic mechanisms more precisely, the chuckwallas would then expend time (= energy) on diversifying specific behavioural displays. Dominance hierarchies, social flexibility and breeding success appear to be interlinked (Alberts 1994), and resource distribution can affect social stability. Consequently, spatially and temporally complex environments may help improve the behavioural repertoires of captive herptiles and lead to successful propagation. Provision of new spatial levels within enclosures may promote specific methods of social communication to enhance breeding success. Use of height by the corn snakes clearly shows that reptiles will utilise a range of three-dimensional spaces when given the opportunity to do so.

The research presented here was designed to show how these small manipulations to enclosure style can alter both animal behaviour and enclosure usage quickly and easily. Undergraduate projects can be beneficial to zoos and help advance the evidence basis of animal management. Directed research that is planned and explained to students, and thesis students under the supervision of a professional with expertise in the field, are useful ways that zoo research output can increase. The two groups of students (chuckwalla and snake projects) had all undertaken a second year-generic animal behaviour unit and had been trained in interobserver reliability (IOR), ethogram design and behavioural recording techniques. Data collection was practised with each group and behaviour of the animals observed *in situ* and explained to these students. Whilst a specific IOR was not generated for each cohort, we are confident in the credibility and validity of the results due to the extensive pre-experiment training that the students received.

Basic results from these case studies were presented, individually, at regional and international environmental enrichment conferences as well as at a British and Irish Association of Zoos and Aquariums (BIAZA) Research Symposium to demonstrate the efficacy of undergraduate research and the benefits of enrichment programmes for uncommonly chosen subjects (i.e. reptiles and amphibians). Increased collaboration between zoological collections and university departments, as described by Fernandez and Timberlake (2008), can provide more opportunities for the assessment and analysis of animal behaviour and visitor experiences if zoos are to move forward in their goal of adding science to all aspects of animal management, exhibit design and visitor education (Lawson, Ogden and Snyder 2008).

Conclusions

Overall, it can be concluded from these case studies that:

1. Small-scale undergraduate student projects can be used to alter husbandry for specific-species and evidence base management protocols for reptiles/amphibians housed in captivity.
2. Evidence from natural history can be implemented into enclosure layout in order to enrich the lives of the inhabitants within.
3. Spatially complex enclosures can enable a wider range of activities for reptiles and amphibians to perform.
4. Sociality between individuals that may be important for breeding activity can be promoted in an environment that provides for a fully-developed behavioural repertoire.
5. The style of the enclosure that reptiles and amphibians are displayed in increases activity and/or visibility and therefore may engage the observer for longer, thus increasing visitor engagement.

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