

## Zool 567 Annotated Bibliography

**Topic:** Captive snake rectilinear behaviours and stress.

**Article organization:** The articles are organized into a few categories starting with broad reviews covering environmental enrichment, enclosure size, and how they affect captive animal behaviour. The following articles are separated into studies looking into the effects of enclosure size on snake behaviour and studies looking into the effects of enrichment on captive snake behaviour.

**Effects of enclosure size and enrichment on captive animal behaviour**

Mason, G., Clubb, R., Latham, N., & Vickery, S. (2007). Why and how should we use environmental enrichment to tackle stereotypic behaviour? *Applied Animal Behaviour Science*, 102(3), 163–188. <https://doi.org/10.1016/j.applanim.2006.05.041>

**Summary:** This article reviews stereotypic behaviours and abnormal repetitive behaviours (ARBs) in captive animals, their possible causes, and potential ways to reduce them. Previous research shows that many captive animals are kept in enclosures that induce ARBs and stereotypic behaviours. Stereotypic behaviours are caused by deficits in the housing provided to captive animals that invoke frustration or discomfort. ARBs are behaviours that are repeated in attempts to cope with captivity, and some can be caused by issues in the brain. Most ARBs can be classified as stereotypic behaviours and both ARBs and stereotypic behaviours are indicators of poor welfare and of stress. Enclosures that are too small or do not provide appropriate enrichment often result in stereotypic behaviours stemming from frustration at being unable to perform natural behaviours. Repetitive behaviours have also been linked with other indicators of poor welfare. This suggests that environments which induce stereotypic behaviours are also likely to cause decreased welfare. In addition to decreased welfare, the presence of stereotypic behaviours raises other ethical issues. When seen in zoos, stereotypic behaviours reduce an animal's educational and conservational value as these behaviours are not seen in the wild. If the behaviours become a habit, they may even prevent animals from being reintroduced into the wild. This review suggests that there are a variety of possible ways to mitigate stereotypic behaviours including environmental enrichment, pharmaceuticals, and other methods such as punishment. While no single method has been shown to completely eliminate stereotypic behaviours, environmental enrichment was the most beneficial overall as it tackles the root of the problem: a captive habitat that lacks the resources to allow for natural behaviours. This article is significant as it demonstrates how important environmental conditions are for captive animal welfare and suggests that keeping animals in enclosures that cause stereotypic behaviours is unethical.

**Contribution:** This review article summarizes why stereotypic behaviours occur, and how they can be prevented. This article was chosen for the review as it provides a broad understanding of stereotypic behaviours and how they can be addressed. By showing that there are multiple reasons why stereotypic behaviours occur in captive animals and by describing possible solutions, this article is important for zoos, or any animal keepers. Furthermore, it demonstrates that environments that result in stereotypic behaviours cause a reduction in welfare. Therefore,

they should be avoided. Future research could include looking into if there are lasting detrimental effects of stereotypic behaviours.

Warwick, C., Arena, P., Lindley, S., Jessop, M., & Steedman, C. (2013). Assessing reptile welfare using behavioural criteria. *In Practice*, 35(3), 123–131. <https://doi.org/10.1136/inp.f1197>

**Summary:** This article reviews how behaviour can be an indicator of welfare in captive reptiles by looking at abnormal behaviours and captivity stress. Unlike most mammals, reptiles have historically been kept in small enclosures that do not allow for the expression of normal behaviours. Normal behaviours are behaviours seen in the wild expressed in an appropriate context in captivity. Conversely, abnormal behaviours are typically not seen in the wild or are natural behaviours that are exhibited in an abnormal context. Additionally, captivity related stress behaviours can include decreased exploration, excessive hiding and may even result in physical injuries such as rostral lesions from interacting with enclosure boundaries. In this study two lists were compiled, one of behavioural signs of stress and one of behavioural signs of comfort, to assess their possible causes. Two major considerations were found to be common causes of behavioural issues and decreased welfare. The first issue concerned spatial accommodations. As reptiles are commonly kept in small enclosures, normal behaviours tend to be disrupted. When an animal is forced to remain in small spaces, they may be unable to be active and to explore. Furthermore, small enclosures prevent natural body positions, particularly rectilinear positions in snakes. Overcrowding is also a commonly seen issue resulting in behavioural indicators of stress. The second issue concerns thermoregulation. Reptiles require thermal gradients to properly thermoregulate, something that often is not accommodated for in small enclosures. This results in a decrease in welfare as the animal cannot regulate their own temperatures. This study is significant as it shows that there are multiple behavioural indicators of poor reptile welfare as a result of improper husbandry. Furthermore, this study can be used as a reference for reptile keepers in identifying abnormal behaviours, what may have caused them, and how to remedy the problem.

**Contribution:** This review article summarizes a growing field of research looking into how reptile welfare can be assessed via behaviours, and what causes those behaviours. This article was chosen for the review as it highlighted the impact of improper housing on reptile behaviour and welfare. The findings of this article are consistent with those of more recent studies showing that reptiles need more space than commonly provided for proper welfare. Furthermore, this research is important as it could be used to help push for stricter government regulations for reptiles. Future research could include how species-specific enrichment could improve welfare.

Warwick, C., Grant, R., Steedman, C., Howell, T. J., Arena, P. C., Lambiris, A. J. L., Nash, A.-E., Jessop, M., Pilny, A., Amarello, M., Gorzula, S., Spain, M., Walton, A., Nicholas, E., Mancera, K., Whitehead, M., Martínez-Silvestre, A., Cadenas, V., Whittaker, A., & Wilson, A. (2021). Getting it straight: Accommodating rectilinear behavior in captive snakes—A review of

recommendations and their evidence base. *Animals*, 11(5), 1459.

<https://doi.org/10.3390/ani11051459>

**Summary:** This article reviews research that analyzes the impact of enclosure size on captive snake welfare, and the ability to exhibit rectilinear behaviour (completely stretching out the body). Snakes have historically been housed in enclosures shorter than their length, thereby preventing rectilinear behaviours. Proponents of small enclosures cite rules of thumb and non-scientific or erroneous sources to support the claims that small enclosures are beneficial to the snakes. The most common claim is that snakes feel threatened by large spaces and thus will feed, breed, and thrive better in small enclosures. In this article, Warwick et al. (2021) reviewed 31 peer reviewed sources, 18 grey sources (report or scientific letter sourced from Google Scholar), and two opaque sources (source based on opinion and common practice). Of these categories, the majority of the peer reviewed, and grey sources supported enclosures that are greater than the length of the snake whereas the opaque sources argue for enclosures smaller than the snake. This article summarizes that keeping snakes in large enclosures allows for natural behaviours and improves the overall welfare of the snake based on primary research and an extensive network of literature assessing the natural environments and behaviours of snakes as well as the effects of enclosure size on snake welfare. Additionally, this article shows that there is no scientific consensus that snakes have better welfare in small enclosures, and that keeping snakes in small enclosures benefits only their keepers as more snakes can be held in smaller spaces. The sources that support the keeping of snakes in small enclosures rarely cite scientific studies and are rather based in opinion. This shows that large enclosures are scientifically agreed upon to be better for the overall welfare of captive snakes as it allows them to exhibit a variety of natural behaviours including rectilinear behaviours.

**Contribution:** This review article summarizes an evolving understanding of the environmental requirements for captive snakes by providing an in-depth look at past and current literature surrounding the snake keeping hobby and is why this article was included in the summary. By showing that snake welfare is improved by large enclosures, it may help push governments to mandate minimum enclosure sizes for snakes like they do for other captive animals. This article is also important for snake keepers as it highlights the importance of relying on data driven research as sources of information for proper snake enclosures.

### Effects of enclosure size

Warwick, C., Arena, P., & Steedman, C. (2019). Spatial considerations for captive snakes. *Journal of Veterinary Behavior*, 30, 37–48. <https://doi.org/10.1016/j.jveb.2018.12.006>

**Summary:** Many non-scientific and governmental recommendations for snake keeping argue that snakes do not need an enclosure that is longer than their total body length. Furthermore, they say that the provision of large enclosures will cause stress for the snake. Conversely, new behavioural studies have shown that small enclosures are detrimental to snake welfare. This article has two components; an observational component to determine how often snakes will stretch out completely and a review component to summarize natural snake habitats and

behaviours, as well as pervading myths about snake keeping. While thought to be sedentary animals, this article suggests that many species of snakes are frequently active and even species that are more sedentary will spend time engaged in active behaviours. Additionally, when active, snakes spend time in rectilinear, completely stretched out positions. Many keepers and care sheets will also claim that snakes fear large spaces and therefore, small enclosures are better for the snake. In the wild however, snakes have been shown to have large home ranges, indicating that small enclosures may restrict natural snake behaviours. For the observational component, 31 different species of snakes were observed in zoological facilities for a period of 60 minutes to determine how often rectilinear or near-rectilinear postures occurred. Of the 65 snakes observed, 24 (37%) adopted a rectilinear posture during the 60-minute observational period. Given the short observation time, and that all snakes were observed during the day, this is likely an underestimation of rectilinear prevalence. Additionally, rectilinear posture was seen in a wide variety of species, both while at rest and while mobile. These results are significant as they indicate that rectilinear behaviours are important natural behaviours. Furthermore, these results suggest that keeping snakes in small enclosures is detrimental to their welfare and that sources that recommend small enclosures are outdated.

**Contribution:** The research and review done in this article is important as it highlights how the natural habitat of snakes are large and allow for movement, activity, and rectilinear behaviours. Furthermore, when provided with enough space, these behaviours are also seen in captive snakes. This is why the article was included in the review. As government regulations in many countries do not require that snakes be kept in large enclosures, this article could be helpful in changing government regulations. Further research that could be done on this topic include a more comprehensive observational study on the frequency of rectilinear behaviours.

Hoehfurtner, T., Wilkinson, A., Walker, M., & Burman, O. (2021). Does enclosure size influence the behaviour & welfare of captive snakes (*Pantherophis guttatus*)? *Applied Animal Behaviour Science*, 243, 105435. <https://doi.org/10.1016/j.applanim.2021.105435>

**Summary:** Previous studies have shown that snakes are more active in large enclosures with enrichment. This study aims to look at the effect of the enclosure size on corn snake (*Pantherophis guttatus*) activity. To answer this question, Hoehfurtner et al. (2021) placed adult snakes into either a large or a small enclosure. The snakes' behaviour was observed, and they were weighed regularly during a period of 32 days after which they were exposed to four behavioural tests. After the tests, the snakes were put in the other size of enclosure and the process was repeated. The weight of the snakes did not differ significantly over the course of the experiment. When in small enclosures the snakes spent significantly more time with their body in contact with a novel object and spent significantly more time partially and tightly coiled while resting. In small enclosures, snakes also spent significantly more time visible on the substrate. Snakes in large enclosures were significantly more active and spent more time loosely coiled when resting. The snakes also spent around 19% of their time fully stretched out but was not analyzed as snakes in small enclosures could not exhibit this behaviour. The snakes in large enclosures also spent more time in hides. A preference test was conducted where snakes were

given the choice between the large and small enclosures. When resting there was no significant difference in the choice of enclosure size but when active, snakes showed a significant preference for the large enclosure. These results are significant as they show that the activity of snakes is limited in small enclosures and may even force the snake to remain in contact with novel objects. A large enclosure allows the snake to be more active and gives the snakes more choices on where to rest, improving overall welfare.

**Contribution:** The research done in this article is important as it shows that enclosure size is an important factor in snake welfare and that snakes should be provided with an enclosure that is larger than they are long. This article was selected for this review as it adds more evidence to the argument that rectilinear behaviours in snakes are important. Furthermore, it indicates that an enclosure that does not allow for the snake to completely stretch out limits the animal's welfare. Future topics that could be researched next include the benefits of enrichment and what types are best benefit captive snakes.

Hollandt, T., Baur, M., & Wöhr, A.C. (2021). Animal-appropriate housing of ball pythons (*Python regius*)—Behavior-based evaluation of two types of housing systems. *PLOS One*, 16(5), e0247082. <https://doi.org/10.1371/journal.pone.0247082>

**Summary:** This article investigated the role of housing systems on ball python (*Python regius*) welfare and on the occurrence of natural behaviours. Previous outdated sources and many non-peer-reviewed sources advocate for small enclosures such a rack system. In the wild, ball pythons often use rodent burrows or old termite mounds as hides, which may be why people believe a small enclosure is suitable. Hollandt et al. (2021) aimed to observe the frequencies of a variety of natural and stereotypic behaviours exhibited by ball pythons based on the size of enclosure the snake was in. To explore this question, Hollandt et al. (2021) placed thirty-five ball pythons individually first in the rack system with minimal enrichment for a period of eight weeks. Then the ball pythons were placed terrariums with enrichment for another period of eight weeks. The snakes' behaviour was observed and an ethogram for ball pythons was created. Hollandt et al. (2021) show that there is a significant difference in the frequencies of eight of the tested behaviours depending on the housing the snake was in. Of these behaviours, comfort behaviours were seen more frequently in terrarium housing. Some of these behaviours, such as basking, burrowing, and climbing were only possible in the terrarium housing as the rack housing was too small. Stereotypic behaviours, including pushing the mouth against the edge of the enclosure, were seen significantly more in the rack housing. Feeding behaviour was not studied as feeding was a scheduled event beyond the snakes' control. This study is significant as it shows that enrichment is critical for the welfare of captive snakes and that not accommodating for a variety of behaviours is detrimental to them. Additionally, these results are significant because they show that old standards of care are not sufficient for snake welfare.

**Contribution:** The research done in this article highlights how environmental enrichment affects the behaviour of captive snakes particularly ball pythons (*Python regius*). These snakes are often kept in small, sparse enclosures for ease of feeding, breeding, and clean-up. This is why this

article is included in the summary. This article challenges the idea that keeping snakes in small enclosures is beneficial for the snake, instead claiming that the only benefit is for the keeper. The work in this article brings up potential follow-up questions regarding snake cognitive ability and how keepers can accommodate it.

### **Effects of environmental enrichment**

Almli, L. M., & Burghardt, G. M. (2006). Environmental enrichment alters the behavioral profile of ratsnakes (*Elaphe*). *Journal of Applied Animal Welfare Science*, 9(2), 85–109.

[https://doi.org/10.1207/s15327604jaws0902\\_1](https://doi.org/10.1207/s15327604jaws0902_1)

**Summary:** Previous studies in mammals show that environmental enrichment is beneficial to animal welfare and promotes more natural behaviours. No such studies, however, have been performed on reptiles. This study aimed to investigate the effect of environmental enrichment on the behavioural performance of rat snakes (*Elaphe obsoleta*). To answer this question, the authors placed 16 snakes in either a standard or enriched enclosure for a period of eight months. After eight months, the snakes were measured, weighed, and subjected to three behavioural tests. Over the course of the experiment, enriched snakes saw a significant increase in both weight and mass when compared to standard snakes. When presented with a problem-solving task, enriched snakes were significantly quicker at finding the goal than the standard snakes. In an open field test, where the snakes were allowed to explore a large novel environment, there was a significant difference in the number of tongue flicks between enriched and standard snakes. When combined with locomotor data, the trends indicate that enriched snakes may be quicker to habituate to novel environments however, there were no statistically significant differences between the two treatments. The results of the feeding test showed no significant differences between the two types of housing. These results show that housing conditions can have an effect on snake behaviour. When compared to enclosures with minimal enrichment, snakes kept in enclosures with ample enrichment showed that they were superior in problem-solving abilities and were quicker to become habituated in a new environment. This data is significant as it shows that snakes who are provided with enrichment are better adapted and experience better welfare than snakes in enclosures without enrichment. Additionally, the results showing that enriched snakes were larger than standard snakes directly disproves that snakes kept in rack systems will grow larger, and do so faster.

**Contribution:** The research done in this article is important as it shows that snakes, like mammals, benefit in multiple ways from the presence of environmental enrichment. This article was selected for the review as snakes and other reptiles are often not considered as high needs or in possession of high cognitive abilities that require environmental stimulation. Despite this, this study shows that enriched snakes may have increased problem-solving ability. Therefore, it is in the animals' best interest to provide them with enrichment to allow for a variety of behaviours. Future areas of research include further studies on snake cognition and learning.

Spain, M., Fuller, G., & Allard, S. (2020). Effects of habitat modifications on behavioral indicators of welfare for Madagascar giant hognose snakes (*Leioheterodon madagascariensis*). *Animal Behavior and Cognition*, 7(1), 70–81.

<https://doi.org/10.26451/abc.07.01.06.2020>

**Summary:** Previous studies have shown that animals kept in stimulating environments exhibit more species-typical behaviours and therefore, show increased welfare over those kept in simple enclosures. Hognose snakes use their upturned snouts to forage in the wild. Therefore, providing them with an environment which allows for digging behaviours should result in better welfare. The purpose of this study was to determine the effect of habitat enrichment on hognose behaviour. To answer this question, five Madagascar giant hognose snakes (*Leioheterodon madagascariensis*) were individually housed in small baseline enclosures with newspaper substrate for four weeks. The snakes were then moved to larger, modified enclosures with a deep sand and mulch substrate for four weeks. During these periods, the snakes' behaviour was observed. When in modified enclosures, the snakes showed a significantly increased behavioural diversity. Snakes in modified enclosures showed an increase in activity, exploration which is described as tongue flicks, and an increase in locomotion when compared to snakes in baseline enclosures. Additionally, all snakes engaged in digging behaviours in the modified enclosure, a behaviour not possible in the baseline enclosure. While not significant, there was a trend towards increased exposure in the modified enclosure. These observed differences in behaviours indicate that habitat modifications result in an increased welfare for hognose snakes. The results of this study are significant as they show that the baseline enclosure does not satisfy a behavioural need for hognose snakes as it did not allow them to dig. Digging is a behaviour that is seen in wild specimen. Additionally, this study shows that providing snakes with choice in their environment is beneficial to their welfare. Therefore, snakes should not only be provided with an enclosure large enough to allow for locomotion, and rectilinear behaviours, but also with species specific enrichment to allow for natural behaviours.

**Contribution:** The research done in this article is important as it shows that providing snakes with a large enclosure and enrichment that allows for species-typical behaviours is important for their welfare. This is why the article was selected for the review. It also shows that keeping snakes, particularly hognoses on newspaper substrate does not allow them to perform natural behaviours. These results contradict with common practice as many snakes are kept on newspaper. Future research could include non-behavioural measures of welfare depending on enrichment such as analysis of glucocorticoids and metabolites in fecal samples, an experiment done in mammals.

Hoehfurtner, T., Wilkinson, A., Nagabaskaran, G., & Burman, O. H. P. (2021). Does the provision of environmental enrichment affect the behaviour and welfare of captive snakes? *Applied Animal Behaviour Science*, 239, 105324.

<https://doi.org/10.1016/j.applanim.2021.105324>

**Summary:** Previous studies have shown that snakes are more active in large enclosures with enrichment and that enrichment improves welfare in non-reptilians. This study aims to look at the effect of the habitat enrichment on corn snake (*Pantherophis guttatus*) welfare. To answer this question, 15 adult snakes were placed into either a standard or enriched enclosure. The snakes' behaviour was observed, and they were weighed regularly during a period of 32 days after which they were exposed to two behavioural tests. After the tests, the snakes were put in the other type of enclosure and the process was repeated. After being tested in each type of enclosure, a one-time preference test was conducted where the snakes were given the choice between the enriched or standard enclosure. There was no effect of enrichment on the snakes' weight over the course of the experiment. Snakes in enriched enclosures spent significantly more time at the top portion of their enclosures. They also made fuller use of the entire enclosure, something snakes in standard enclosures were unable to do. Enriched snakes spent significantly more time in hides and also spent significantly more time visible and loosely coiled in their enclosure. In the behavioural tests, enriched snakes entered the quadrant with the novel object significantly more than the snakes in the standard enclosure. Otherwise however, the presence of enrichment made little difference in the behavioural tests. The preference test showed that snakes have a strong preference for the enriched enclosure. The results of the preference test and the behavioural observations are significant as they show that snakes will interact with enrichment if it is provided and therefore, neglecting to provide environmental enrichment is detrimental to snake welfare. Additionally, this study shows that enrichment allows snakes to utilize the entire space of their enclosure more fully.

**Contribution:** The research done in this article is important because it shows that snakes will chose to use enrichment when it is present and therefore, captive snakes should be provided with enrichment to allow for a variety of behaviours. This article was selected for this review as it shows that snakes require more than just a hide in their enclosure to have good welfare. This contradicts the beliefs of some snake keepers who claim that snakes can thrive in sparse enclosures. Future topics that could be studied include what types of enrichment is best suited for specific species of snakes.

Nagabaskaran, G., Burman, O. H. P., Hoehfurtner, T., & Wilkinson, A. (2021). Environmental enrichment impacts discrimination between familiar and unfamiliar human odours in snakes (*Pantherophis guttata*). *Applied Animal Behaviour Science*, 237, 105278.

<https://doi.org/10.1016/j.applanim.2021.105278>

**Summary:** Previous studies in birds and mammals show that enrichment improves welfare and reduces stress in novel environments. These studies, however, have not been conducted for reptiles. Additionally, it is known that interactions with humans can be stressful to captive animals. This article investigated how environmental enrichment impacted the reaction of corn snakes (*Pantherophis guttata*) to familiar and novel human odours. To study this, eleven corn snakes were individually placed into either a standard or an enriched enclosure. After four weeks, the snakes were given a series of behavioural tests. After the tests, the snakes were moved to the other type of enclosure and the process was repeated. The test consisted of an

empty enclosure with the novel and familiar scents placed in separate quadrants. The snakes were placed in the enclosure and time spent with each scent was recorded. While enrichment made no difference on the snakes' willingness to approach either stimulus, enriched snakes spent significantly more time investigating the novel human odour. After being switched from enriched to standard enclosures, the snakes no longer acted like they did when they were enriched. Therefore, this shows that enriched snakes were able to discriminate between two human odours based on familiarity. The effect, however, does not persist if enrichment is removed. This study is significant as it shows that enrichment can be effective in reducing potentially stressful situations such as being handled by humans. By providing enrichment, the snakes are given learning opportunities. These learning opportunities help reduce the stress of novel situations and may promote investigatory behaviour as seen in this experiment. Additionally, this study is significant as it shows that for the welfare benefits of enrichment to persist, the snake must always be provided an enriched enclosure. These conditions are not seen in racks, a common housing system.

**Contribution:** The research done in this article is important as it shows that snakes are capable of recognizing familiar scents and therefore, may experience reduced stress during handling. The minimization of stress can lead to an improved welfare. These beneficial effects, however, are only seen when enrichment is provided to the snakes. This article was selected for the review as it shows that enrichment may help reduce stressful situations by allowing snakes to be less fearful of novelty. Possible future studies include an analysis of stress hormones in snakes after being handled when in an enriched environment compared to a standard one.