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Animal Welfare 2020, 29: 371-378
ISSN 0962-7286
doi: 10.7120/09627286.29.4.371

A persistent abnormal repetitive behaviour in a false water cobra (Hydrodynastes gigas)

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Abstract

*Stereotypies (a subset of Abnormal Repetitive Behaviour [ARB]) are characterised by an unchanging pattern of behaviour and in captive animals can be associated with poor welfare. Although well known in certain taxa, little is known about both welfare and ARBs in reptiles, especially snakes. We document an instance of an ARB in a captive snake species (*Hydrodynastes gigas*), set it in the context of husbandry in zoos, and assess efforts to reduce it. The stereotypy consisted of a fixed pattern of movement against the enclosure's viewing window. Ethographic data were used to focally sample the animal's behaviour over several months in the context of different enrichment interventions. Modified Spread of Participation Indices (mSPIs) were also calculated to quantify the evenness of enclosure use. The snake spent considerable portions of time (47% of observations) performing a behaviour that fulfils the criteria for stereotypy. mSPI data suggested a possible welfare impact of the behaviour on the snake. Zoos holding this species globally were surveyed about observations of similar behaviour and one other institution reported similar behaviour. Standard husbandry practice (A) was used alternately in an ABAC format with prey scent trails (B) and modified feeding schedules (C), representing enrichment types based on species' natural history. Neither stereotyping frequency nor mSPI was found to be significantly affected by any of the enrichments. Our results, interpretation of which is limited by the paucity of data on snakes, uncover stereotypies in snakes and suggest that, as with other taxa, ARBs may be resistant to strategies employed to reduce them.*

Keywords: *abnormal repetitive behaviour, animal welfare, enrichment, false water cobra snake, reptile, stereotypic behaviour*

Introduction

Globally, animals from a broad range of taxa are maintained in zoos and similar institutions for a variety of valid reasons; most importantly, for use in environmental education, *ex situ* conservation and scientific research. Despite widespread efforts to eliminate them, stereotypies are still relatively common in captive animals and can be associated with poor animal welfare (Swaisgood & Shepherdson 2005; Mason *et al* 2007). Some authors used the term 'stereotypical behaviour' to describe behaviours that are repeated, invariant and serve no obvious purpose (Mason 1991). Stereotypies are a subset of Abnormal Repetitive Behaviours (ARBs), characterised by an unchanging pattern of behaviour (such as pacing), rather than more generally an unchanging goal of behaviour (such as feather pecking, where the movements themselves may vary) (Garner 2005).

While there have been numerous reports of stereotypical behaviour in many taxa, these have largely focused on mammals and birds (Swaisgood & Shepherdson 2005). A small number of studies have reported stereotypies in reptiles, but only in the Order Chelonia (turtles and tortoises) (Burghard *et al* 1996; Therrien *et al* 2007). It is likely that ARBs do exist in other reptile taxa, but that taxonomic bias in this field has led to a failure to detect them (Burghardt 2013; Benn *et al* 2019). The detection of stereotypical behaviours can enable animal care staff to recognise and tackle welfare problems; these interventions tend to be focused on eliminating the stereotype. Enrichment is the most frequently used method (Mason & Latham 2004) and often results in a reduction in the proportion of time spent stereotyping. Therrien *et al* (2007) report a successful reduction of stereotyping in chelonians after object-based enrichment was provided. Yet reductions are not universal and, in mammals, enrichment has not always been successful in reducing stereotypical behaviours (Augustsson *et al* 2003; Marashi *et al* 2004). In order to address the lack of empirical data surrounding stereotypes in reptiles, and therefore provide evidence-based strategies for improving the welfare of captive reptiles, it is important to develop a better database of case studies, following the framework set out by Swaisgood and Shepherdson (2005). In this work, we report a stereotypical behaviour in a snake, a false water cobra (*Hydrodynastes gigas*), a large, active, opistoglyphous colubrid snake from South America. We characterise the stereotypical behaviour and investigate possible effects on enclosure use and activity budgets. We surveyed international institutions holding the species in order to better understand the prevalence of the stereotype in captive individuals of this species. Having identified the stereotypy in one snake, we report the attempts to reduce it using enrichment designed to replicate natural behaviours of the species in nature.

Materials and methods

Ethical statement

The work presented here was conducted within normal husbandry practice and had no deleterious effects on the animal in question as a result of experimental conditions. The work was reviewed internally by the Zoological Society of London (Zoological Projects Database reference number ZDZ95) and designated as not requiring full ethical review, or any form of licensing under the Animals (Scientific Procedures) Act (1986).

Study subject, repetitive behaviour and husbandry

This study focused on a male false water cobra (*H gigas*) hatched at ZSL London Zoo in 2011. ARB has been anecdotally reported in this animal by staff since May 2017. The snake was frequently observed engaging in repetitive undulatory movements in contact with the glass at the front of the enclosure. The behaviour was highly invariant in both pattern and location within the enclosure: a slow lift of the front third of the body, followed by lateral undulations against the viewing pane, and then a shift to the opposite end of the glass, over a piece of wood. This would be repeated on the other side before returning to the original position.

For the duration of the study, the snake was housed in a display enclosure with a floor area measuring 133 × 143 cm (length × width). The enclosure was furnished with plants, logs, rocks and dry leaves, on a substrate of bark mulch and compost, which provided a useable height of up to 1.1 m within a total enclosure height of 1.9 m. It contained a centrally positioned pond of maximum dimensions 90 × 70 cm and up to 30 cm deep. A fan heater provided an ambient temperature gradient between 20–28°C during the day outside the basking area, while nocturnal temperature was 20–24°C. The bask zone expanse was 45 × 30 cm and heated to 31–33°C by one 160 W Arcadia mercury vapour lamp in a reflective dome. Along with the basking light, the enclosure was lit by two Prolight T5 lamps (Ritelite Systems Ltd, UK) and two 12% Arcadia T5 lamps (Arcadia Reptile, UK), giving Ultraviolet indices of 0–3.2 in the enclosure and 2.4–3.2 in the bask zone. Photoperiod was 10:14, including all public visiting hours. The enclosure shared one glass side (the shorter side of the square base) with the public gallery, giving zoo visitors visibility to most of the enclosure, with the exception of an area behind plants and leaves. The glass wall sloped slightly (approximately 10° from vertical) outwards towards the public, so the snake could rest part of its bodyweight against it while climbing vertically.

Outside of the enrichment phase (phase C; see below), the snake was fed weekly with a defrosted rodent, avian or fish prey meal weighing approximately 200 g.

Experimental conditions

Baseline and experimental conditions were presented in an ABAC design, beginning in February and ending July 2018. A baseline for the snake's behaviour (see below for behavioural sampling methods) was established (18th February–10th March 2018) by maintaining it in the standard conditions described above (Treatment A). Treatments B and C were enrichment regimens devised on the basis of natural history information available in the literature regarding this species (Strüssmann 1990; Lopez & Giraudo 2004). Following Treatment A, Treatment B was delivered (11th March–4th April 2018), which involved daily enrichment through the addition of prey scent formulated from one prey item from the normal dietary options (rotating rodent, avian and fish prey) blended to a homogenous liquid with 750 ml of water. Subsequently, the snake was again kept in standard conditions, without scent enrichment (return to A) (5th April–4th May 2018). Finally, a second intervention (Treatment C) was presented (21st May–17th June 2018) following a short period of normal husbandry without observations by modifying the feeding schedule to offer the same weekly total mass of food but spread out to three quasi-equally spaced feeds per week (for example, Monday, Wednesday and Friday). The original intention was to collect a final set of baseline data, to create an ABACA design. However, this was prevented by failure of a climate control system, which caused the environmental parameters to shift beyond the limits outlined above and would have distorted the data. This environmental perturbation did not overlap with any other treatment.

Behavioural observations

Data were collected in two formats (long-term and focused) in order to investigate the stereotypic behaviour at different temporal scales, while allowing data collection to be logistically possible with few resources at the disposal of investigators. Long-term data collection aimed to develop a picture of the snake's behaviour over a longer period (weeks). It was not feasible to intensively collect data for this length of time. In order to ensure that behavioural patterns that might be observed only through intensive data collection were not missed, a separate set of data were collected through a smaller number of intensive observation windows, which it was feasible to resource.

Long-term behaviour data were collected for a total of 12 weeks, spanning all experimental treatments. This was a lower resolution data set and broke the snake's behaviour down into simply 'stereotyping' and 'not stereotyping' categories, which was feasible to robustly collect via animal care staff as they completed routine duties. Behaviour was noted once per hour between 0900 and 1700h, with the observation always taken within the first 30 min of the hour, by animal care staff from the public viewing window. Observations were made from as great a distance as possible and as soon as the exhibit was in sight so there was not time for the animal to react to the presence of an observer. For each observation, a score of 1 was recorded if the snake was engaged in the pre-defined ARB. The score was 0 if the

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snake was performing any other behaviour or was out of sight. A mean value was calculated across the eight observations for each day, and these values were used for analysis; ie one mean value for each day was analysed. Data for days when the snake was in slough, determined by a dull colouration to the skin, followed by opaque spectacles and finally moulting, and therefore like most snakes inactive (Kauffeld 1953), were discarded. We did not control for time out of sight, as the animal only performed the ARB in one location, where it could be viewed from the observation position.

Focused observations were conducted for a total of 3 h a day for one day in each of three conditions: normal routine before any intervention was initiated (Treatment A); day when a scent trail was presented (Treatment B); and feed day (Treatment C). The same observer (BG) recorded behaviour using an ethogram (see Table 1) for six 30-min intervals at 1000, 1100, 1300, 1400, 1600 and 1700h. Simultaneously, the zone of the enclosure in which the head of the animal was located was recorded. No habituation period was used as all observations were conducted from the public viewing window, while wearing non-uniform clothing, and so the observer did not differ visually from members of the public routinely viewing the snake. Data were unfortunately unavailable for the repeated Treatment A condition.

Survey

A search on the Zoological Information Management Service (ZIMS) database revealed 18 institutions globally, in addition to ZSL London Zoo, where false water cobras are kept (Species360 2019). We contacted each institution via email in August 2018, using addresses that were either acquired from ZIMS or previous contact with the relevant keeper. We described the behaviour we observed and asked, regarding *H gigas*, "whether the animals in your collection (as per ZIMS holdings), or any previous animals, have ever been noticed exhibiting this behaviour or any sort of repetitive behaviour that would not serve any particular function, and if so provide a brief description of what it does and when it does it." We guaranteed anonymity in this publication to assuage concerns over public perception of animal welfare if responses were taken out of context.

Statistical analysis

Two datasets were subject to analysis. The first were data from hourly observations of the snake's behaviour, which were scored as stereotyping or not stereotyping each time, excluding days when the snake was in slough. A randomisation test with 10,000 iterations of cases assigned randomly to A, B or C categories in proportions reflecting the real dataset, and using the residual of baseline and treatment means as the test statistic, was used to analyse mean behaviour scores, performed in Microsoft Excel® for Windows 365® (following Dugard *et al* 2012; Tanious & Onhega 2019). Randomisation analyses are well suited to single case experimental designs, such as the present one.

The second dataset concerned enclosure use as measured during the focused observations on a baseline day, a day with enrichment, and a feed day. The enclosure was divided up into five zones based on the resources available. These were: the sloping glass front of the exhibit; the pond; a planted area offering dappled shade and branched structure; an area of open ground separate from the basking zone; and the basking zone. The proportion of the total enclosure that each zone represented was calculated using ImageJ (https://imagej.nih.gov/ij/) and a plan photo of the enclosure. The mean proportion of time spent in each zone of the enclosure was calculated from the six observations conducted on each of the days, and modified Spread of Participation Indices (mSPI) were calculated using the formula:

Table 1 **Ethogram used for observations of the false water cobra (*Hydrodynastes gigas*).**

Behaviour	Description
Stereotype	Side-to-side movement propped up against front glass or body draped over log at the front (see also text)
Exploration flat	Moving in the environment with body parallel to ground
Exploration vertical	Moving in the environment with head raised above ground
Motionless	Not moving any part of the body
Out of sight	Front half of the body obscured

$$mSPI = \frac{\Sigma|f_o - f_e|}{2(N - f_{e\,min})}$$

where f_o is the observed frequency of observations in a zone, f_e the expected frequency of observations in a zone, based on zone size assuming even use of the whole enclosure, $|f_o – f_e|$ the absolute value of the difference between f_o and f_e, summed for all zones, N the total number of observations in all zones, and $f_{e\ min}$ the expected frequency of observations in the smallest zone (Plowman 2003).

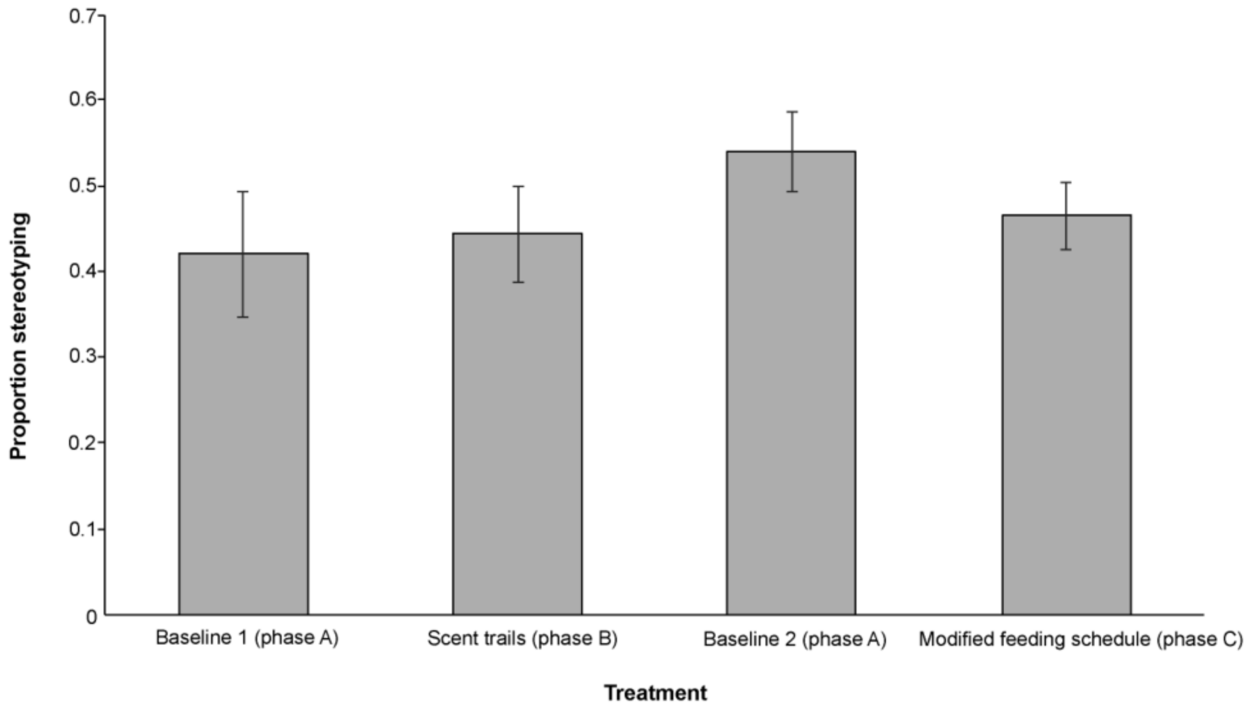
A single mSPI was calculated for each day and hence for each treatment, as each observation period within each day was non-independent and so precluded calculating multiple mSPIs per day. As only one mSPI was available per treatment, no statistical analyses were possible and simple comparison was used.

Results

Modified Spread of Participation Index values

Estimates of resource area with records of zone use from the focused observation data sets were combined to calculate a modified Spread of Participation Index (Plowman 2003). On the phase A/baseline focused observation, the average mSPI value over six observations was 0.50. An mSPI of 0.61 was calculated on the day when enrichment was provided. On the feed day, the mSPI index was considerably lower, at 0.28. Statistical comparisons of mSPI values were not appropriate due to small sample size (n = 1 per treatment); multiple mSPIs could not be collected from the focused data collection, as they would be non-independent.

Figure 1



The proportion of hourly observations from long-term data collection in which the snake was observed stereotyping in each treatment period. Bars indicate the mean (± SEM) proportion over three weeks (excluding slough days). Differences are not significant ($P > 0.05$).

Factors associated with stereotyping

We found no significant effect of scent trail ($P = 0.304$) or modified feeding schedule ($P = 0.435$) on the daily mean behavioural score calculated from the long-term observation dataset (Figure 1). On average, the snake was stereotyping in 47% of observations. Focused behavioural observations (Figure 2) showed a similar pattern, albeit with reduced stereotyping in favour of motionlessness on the feed day; these data were not suitable for statistical analysis.

In addition, the observation on the scent trail day indicated that the animal only engaged with the scent for 2.3 min.

Survey results

Out of 18 institutions we contacted, nine replied (50%). Replies came from the regions, as defined by Species360 (2019), of Africa, Europe and North America. We were unable to acquire responses from any South American institutions and unable to control for the length of time a specimen had been at its respective institution. In total, the institutions that provided responses hold between them 13 false water cobras, ten of which are over a year old. Only one institution reported a similar issue in a false water cobra, the only specimen of the species in their care at the time; the institution is not named here as anonymity was guaranteed as part of the survey. Staff at this institution reported seeing similar undulating behaviour on a daily basis, irrespective of the time of day or year and of husbandry procedures. In their case (though not ours) the behaviour often persisted even as the snake was consuming a prey item. Including the four animals held at ZSL London Zoo, two of which have been reported stereotyping in the past including the focal animal, a total of 17 snakes were included in the survey sample, three of which were reported to behave stereotypically. The non-focal individuals at ZSL London Zoo were not subject to data collection due to limited available resources, and the export of these animals from the collection.

Discussion

It is important to determine that the behaviour reported here is indeed a stereotypy, as such dysfunctional behaviour has not, to the knowledge of the authors, been previously reported in snakes. There is no universally accepted definition of a stereotype (Swaisgood & Shepherdson 2005). Mason (1991) and Mason *et al* (2007) have provided some definitions, but these are relatively ambiguous and require identification of frustration and understanding of brain activity, which is beyond the scope of this work. Garner (2005) proposes a definition involving a set of five inclusion criteria (in italics), against which we tested the behaviour presented here:

(i) Wild individuals do not engage in this behaviour: The behaviour described herein was in relation to a transparent glass barrier, which does not exist in nature, so comparison with wild behaviour is problematic. However, there are no reports of repetitive behaviour resembling the movements

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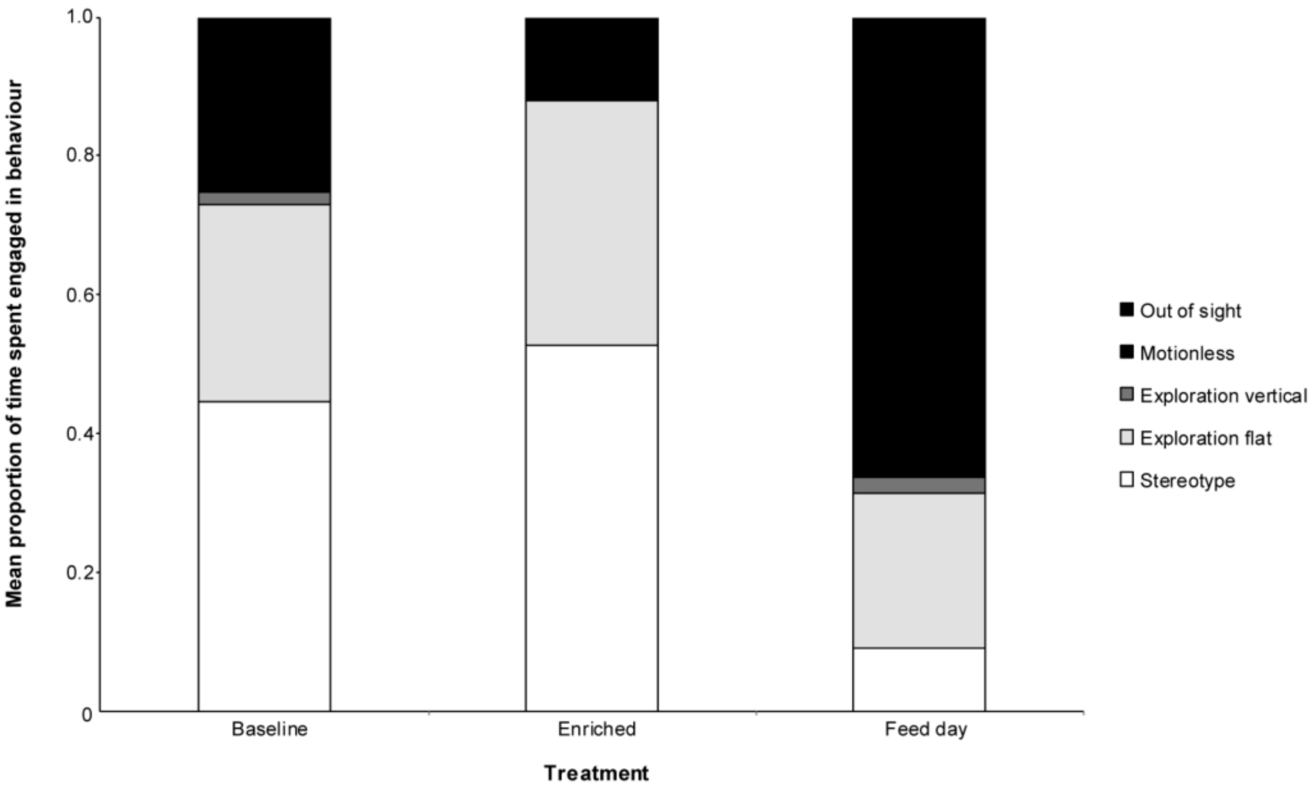
Figure 2



Results of focused observations. Bars represent the mean proportion of time spent on each behaviour over the six 30-min observation periods in each day.

we observed in wild conspecifics whether in relation to a barrier or in other contexts, despite detailed field studies documenting their behaviour in nature (Strüssmann 1990; Lopez & Giraudo 2004).

(ii) Excessive time is spent engaged in the behaviour: This criterion is subjective, but nearly 50% of observed time was spent engaged in the behaviour. Given the highly specific nature of the behaviour in association with there being no apparent immediate goal and restricted spatial distribution of the behaviour, an animal spending almost half its time engaged in this activity might reasonably be described as 'excessive.'

(iii) The behaviour has deleterious impacts on health, growth, reproduction or social interactions: The snake suffered some minor injuries to its rostral scales as a result of the behaviour. Its growth rate was the lowest amongst the conspecifics in the collection (although confounding variables and small sample size means a causative relationship cannot be established).

(iv) Only a subset of individuals engage in the behaviour: We gathered information from other collections in order to increase sample size and understand the stereotype within the context of the captive population of the species (Swaisgood & Shepherdson 2005); three of 17 snakes included in our results, or 18% of the population, were reported to engage in behaviours of this sort. Therefore, the behaviour is performed by only a subset of the population, but this subset is substantial in proportion.

(v) The behaviour causes 'distress': This is difficult to ascertain without a certain degree of subjectivity. Snake welfare has been poorly investigated (de Azevedo *et al* 2007; Benn *et al* 2019) and so, 'distress' cannot be properly identified in this taxon. The high mSPI values we measured, however, may suggest that distress could be caused by this behaviour (Plowman 2003). While enclosure use bias may be driven by thermal gradients in ectotherms, the area of the enclosure where the ARB was exhibited was at the same temperature as other areas of the enclosure and so did not correspond to any particular thermal resource. Without a good baseline for 'normal' mSPI values it is difficult to fully interpret these data in terms of distress, however, and we do so only very tentatively. It is important to note that estimates of resource area are difficult to make in a complex three-dimensional environment (Mendyk 2014) but, although this will influence the outcomes of mSPI calculations (Plowman 2003), any inaccuracies will be the same between treatments in this work.

Despite limitations in species knowledge and in the application of Garner's (2005) criteria to the case in question, we believe that there is good reason to consider the behaviour observed in this snake to be a stereotypy.

Snakes, especially males, often exhibit seasonal 'pacing' behaviour that reflects periods of reproductive activity and mate searching in nature (Hoser 2018), which might be mistaken for stereotyping (Mason 1991). The snake in this study performed the behaviour at similar levels for a continuous and continuing period of 16 months prior to being moved to a different collection (CJ Michaels, personal observation 2019), therefore encompassing more than a full annual cycle. We are therefore confident that the behaviour described here does not represent normal changes in activity due to reproductive urges.

The stereotypy falls under the category of locomotor stereotypies, which are the most common type of stereotypy reported from captive animals (Swaisgood & Shepherdson 2005). In reptiles, the few stereotypies documented (mainly in chelonians) are often locomotor in nature (Burghardt 2013); self-mutilation has also been reported in reptiles (see Burghardt 2013), but this was not ever noticed in the focal animal of this study. In other taxa, species' activity levels correlate with predisposition to stereotyping, especially locomotor stereotypies (Mason & Clubb 2004). *H gigas* engage in active foraging for a large proportion of their waking time (Strüssmann 1990; Lopez & Giraudo 2004) and are anecdotally reported to be prone to repetitive behaviours among herpetoculturists (CJ Michaels, personal observation 2019). The natural history of the species may therefore predispose this taxon to locomotor stereotyping more than, for example, snakes with ambush foraging strategies, or those that only occasionally engage in active foraging to secure a single large meal. The candidate ARB that we describe was qualitatively differentiable from general locomotion in the degree of repeated behavioural motifs within it, and so we argue that this does not simply represent normal locomotion when blocked by a transparent barrier. Indeed, other snakes of the same species did not engage in this behaviour at all. It is important to stress, however, that the anecdotal association of ARBs and false water cobras may well also be due more to the diurnal nature of this species, which would make ARBs more observable to keepers.

The determining factors behind the form and predictability of stereotyping can be difficult to ascertain, especially in poorly understood taxa such as snakes. The behaviour we describe may be a surrogate for a natural action, such as foraging, or a stereotyped escape response (Mason 2006). Either redirected foraging/exploratory behaviour or attempts to remove itself from a situation where the lack of opportunities foraging or exploratory behaviour generate frustration, may result in the behaviour we documented (Mason 2006). The direction of the stereotype towards the transparent glass pane may be a result of either perceived ability to travel through the barrier, or of the nature (angle and texture) of the glass, which may have facilitated the behaviour. In either case, the physical and unchanging structure of the enclosure may contribute to the predictability of form and location of the stereotypy by simply offering no reason to vary it (Mason 2006).

It is still unclear whether stereotyping is necessarily a marker of poor welfare at the time it is performed, or rather a coping mechanism developed in response to a problem that becomes fixed whether or not the problem is alleviated (Zwart 2001). In the present case, establishing impacts on welfare is challenging in a taxon where no validated assessments of welfare exist. Nonetheless, stereotypies are almost universally seen as an undesirable behaviour to be targeted for reduction — both in case it is associated with poor welfare, and as it may eventually lead to poor welfare through injury or other means. We adopted the same cautious approach and attempted to reduce the stereotypy. In some other taxa, stereotypies have been considered detrimental when they represent more than 10% of waking behaviour (Clegg *et al* 2015). The snake in this study spent up to 50% of its waking time engaged in stereotyping, and therefore could be considered a case requiring urgent action.

It often proves difficult to reduce existing stereotypies, however. The enrichment interventions we used were designed to appeal to the dominant senses of the species, and to fit with what is known of its natural history in the wild (Michaels *et al* 2014); that is, we used scent trails to stimulate its olfaction, which is used to detect prey in nature, and to provide opportunities for frequent, small meals (Strüssmann 1990; Lopez & Giraudo 2004). Only 53% of published attempts to reduce stereotypies report success, and this is likely optimistic in the context of publication bias (Swaisgood & Shepherdson 2005). Unfortunately, our attempts to use enrichment to reduce stereotyping were also unsuccessful. Although our focused observations suggest a reduction in stereotyping in favour of motionlessness on the feed-day observation, this is really the result of short-term lethargy after consuming a food item. Our long-term dataset shows that this did not represent a real reduction in the stereotypy, and no significant change in behaviour was demonstrated over the whole intervention period. Constant satiation is not a viable means to address a stereotypy in this species.

The high proportion of time the snake spent engaged in this stereotypy may suggest that it is perhaps an entrenched behaviour and therefore resistant to reduction (Mason 1991; Mason & Latham 2004; Mason *et al* 2007). Alternatively, it is possible that the enrichment provided failed to address the underlying cause of the stereotypy, or that it did not improve the ability to cope as much as the stereotypy itself (Mason *et al* 2007). It is also possible that the enrichment did improve the animal's overall welfare, but this was not reflected in a reduction of stereotypic behaviour (Swaisgood & Shepherdson 2005). These unresolved questions highlight the importance of further work investigating stereotypies and welfare measures for snakes.

As is the case in most studies of stereotypies in non-model organisms within zoo collections, the present work deals with a small sample size (one individual). As all our behavioural data concern a single individual, conclusions cannot be statistically extrapolated to the wider *H gigas* population (Martin & Bateson 1993). They are nevertheless important within the field of reptile welfare, as they indicate that stereotypies can

https://doi.org/10.7120/09627286.29.4.371 Published online by Cambridge University Press

exist in snakes, and that they may be difficult to reduce once established. The capacity of reptiles and especially of snakes to suffer, and the need to approach welfare for these animals on a behavioural and psychological level as well as on a resource-orientated basis, is frequently neglected (Warwick *et al* 2013; Benn *et al* 2019). Such attitudes may be held among the general public (Landova *et al* 2012) but are also often present within the animal care community, and it is important that this bias is addressed. Collections working with snakes should be vigilant to notice and identify problem behaviours that may indicate poor welfare in snakes, to use species' biology to avoid or reduce these behaviours, and to consider the behavioural and psychological needs of species when planning captive collections in order to avoid rather than treat stereotypies. The focal individual in this study was exported to another collection in light of such long-term collection planning

Our focal observations were only taken from one day of each treatment, which means that excluding factors outside of our control as having potential effects on behaviour is difficult. However, the much more robust longitudinal dataset generated similar results and we feel lends enough support to the focal dataset to warrant its inclusion here.

Although we were able to make some comparisons of our behaviour against criteria defining stereotypies, we were constrained by the paucity of available data regarding 'normal' behaviour in both the wild and captivity not just for this species of snake, but for any species that might serve as a good analogue. Indeed, the presence of some field data for the species is unusual in that the majority of snakes in captivity lack field data entirely. We also, therefore, highlight the importance of gathering behavioural data for captive snake species in order to generate a better baseline understanding of these animals to inform welfare research. We also strongly encourage the development of validated assessments of welfare for snakes in order to allow better understanding of behaviours and management strategies on welfare.

Animal welfare implications

Our data show that snakes maintained in captivity may be susceptible to behavioural consequences of poor welfare, in the form of stereotypies, and that these may be resistant to reduction through enrichment. Our findings highlight that the behavioural and cognitive needs of captive snakes, and their impact on welfare, are poorly understood and in need of more research effort.

Acknowledgements

The authors would like to thank the Herpetology team at ZSL London Zoo (Ben Tapley, Francesca Servini, Joe Capon, Daniel Kane, Charlotte Ellis, Vincent Mertens and especially Martin Franklin), for help in collecting the long-term dataset used in this study, and for undertaking the routine husbandry of the animal in question. We would also like to thank Kimberley Carter (ZSL) for her comments and suggestions on the manuscript as well as both referees for their review of the manuscript.

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