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A survey exploring the impact of housing and husbandry on pet snake welfare

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Abstract

*Snake ownership is popular; however, housing and care may not always satisfy the animal's welfare needs. For example, snakes are often kept in environmental conditions that restrict their ability to stretch out fully or move around, using rectilinear locomotion. To date, little empirical data exist on the housing and husbandry of captive snakes and how these impact welfare. This study analyses survey responses from 744 snake owners worldwide and explores potential welfare concerns for snakes kept within private homes. It documents the most common housing and husbandry methods and compares the three most common families (Pythonids, Boids and Colubrids). Owner-reported data were used to derive scores for two potential welfare indicators: number of clinical signs of ill health and the number of reported negative (abnormal) behaviours. Using these indicators, associations were tested with snake-keeping variables, such as enclosure size, level of enrichment, temperature and humidity. Owners reported that 90.7% (n = 675) of snakes adopted rectilinear (straight-line or near straight-line) positions or movements. Snakes kept in enclosures > 1 snake length tended to have more enrichment types and were reported with fewer clinical signs of ill health. Some snakes were housed at unknown temperature (7.7%) or humidity (48.1%) ranges or in environmental conditions not in keeping with current recommended guidelines. Corn snakes (*Pantherophis guttatus*) were the most likely species to be kept at a humidity which did not match recommendations which may present a welfare concern. This study's results can be used to target husbandry guidance for future recommendations and care manuals.*

Keywords: *animal welfare, enclosure length, enrichment, housing, humidity, temperature*

Introduction

Snake-keeping is popular in Western countries with, for example, approximately 400,000 snakes of many species currently kept as pets in the UK (Pet Food Manufacturers Association [PFMA] 2021). Suitable housing and husbandry are essential for good snake health and welfare, and many publications describe recommendations for enclosure sizes, temperatures, humidities, enrichments, substrates, and hygiene measures to meet the essential physical and behavioural needs of snakes of different species (eg Royal Veterinary College [RVC] 2018a,b; Whitehead 2018b; Divers & Stahl 2019; Royal Society for the Prevention of Cruelty to Animals [RSPCA] 2019a,b; Varga 2019).

Although some snakes live long and healthy lives, research has concluded that approximately 75% of reptiles die within their first year in a new home (Toland *et al* 2012). Other studies have also indicated high morbidity and mortality rates among pet snakes in both wholesale and home environments (Laidlaw 2005; Ashley *et al* 2014). In addition, the RSPCA has described snakes as the most frequently rescued pet reptile in the UK (RSPCA 2017). A recent study by D'Cruze *et al* (2020) documented inadequate housing conditions for royal pythons (*Python regius*) at pet expositions and in privately kept racking systems (small trays stacked on top of one another used by breeders), reporting the majority of vivaria failed to meet current welfare recommendations derived by the RSPCA (2019a). A survey of 200 veterinary surgeons showed that only 19.5% believed that pet snakes' welfare needs were usually 'well met' or 'very well met' (Whitehead *et al* 2017). Even popular species such as the corn snake (*Pantherophis guttatus*) and royal python were viewed by delegates of the British Veterinary Zoological Society (BVZS) as maladapted to the environments commonly provided within private homes (Whitehead & Vaughan-Jones 2015). Sellers often advertise these species as 'easy-to-keep' and 'low maintenance' (RSPCA 2017; Warwick *et al* 2018), making them attractive to first-time snake owners. Husbandry information provided by reptile shops and disseminated online has been reported as anecdotal, contradictory and lacking an evidence-based approach (Arena *et al* 2018b). It's important that recommendations are rooted in science and reflect those aspects of care and housing shown to be most important to the welfare of the animals.

Many factors are likely to impact a snake's welfare, including their living environment (eg temperature, humidity, enrichment, substrate), interactions with their owner, activity routine (eg time spent outside of enclosure), diet, and regular healthcare. Snakes, being ectothermic, primarily derive heat from their surroundings; thus, correct temperatures (including gradients) are vital for physical activity, thermoregulation, metabolism, digestion, immunity and other processes (Frye 1991; Lillywhite & Gatten 1995; Mitchell 2004; Varga 2019). Similarly, humidity aids a healthy ecdysis (skin-shedding) cycle and respiratory system function (RSPCA 2019a,b). Cage enrichment is also considered necessary, with hides providing areas away from human observation (RSPCA 2019c), water pools offering bathing and drinking opportunities and further aiding ecdysis (RSPCA 2019d), and branches or similar climbing apparatus allow snakes to be more active, promoting healthier musculoskeletal condition and avoiding or reducing obesity (Frye 1991; Varga 2019).

An area of particular debate is enclosure size. Snakes are often kept in cages in sales racks, breeding systems, and private homes that prevent them from adopting straight-line body postures (Warwick *et al* 2019; D'Cruze *et al* 2020; Howell *et al* 2020). Lack of space and enrichment in rack systems were also highlighted in studies by Loughman (2020) and Hollandt *et al* (2021). Currently, the recommended *Guidance Notes for Conditions for Selling Animals as Pets in the UK* state a minimum enclosure length of two-thirds of the snake's body (Department for Environment, Food and Rural Affairs [DEFRA] 2018) and the Federation of British Herpetologists also advocate this recommendation (Newman 2018; Abou-Zahr 2019). Some authors argue that smaller enclosures can be better for animal welfare, for example, claiming that neonates often fail to thrive in larger enclosures, as well as concerns that owners may fail to accommodate for future changes in housing recommendations, and so many snakes may need to be rehomed (Abou-Zahr 2019). There is also a belief voiced online that snakes are 'agoraphobic' (Reddit 2015; Pets4Homes 2019). Others argue that 'sedentary' snakes (eg some pythons and boas) do not require large enclosures, whereas 'active' species (eg whip snakes [*Heirophis* spp] and racer snakes [*Coluber* spp]) do (Kaplan 2014; Divers & Stahl 2019); although to our knowledge, there has been no scientific evidence to support claims that smaller enclosure sizes offer any welfare benefit (eg Arena *et al* 2018b; Warwick *et al* 2019).

An increasing number of authors argue to the contrary, that snakes require accommodation that allows them to stretch to a full and unrestricted natural length, as well as move around (eg Arena *et al* 2018a,b; Toland 2018; Whitehead 2018a; RSPCA 2019a,b; Warwick *et al* 2019, 2021; Hollandt *et al* 2021). Straight-line postures and locomotion may alleviate gastrointestinal tension, gas, and discomfort, prevent the onset of certain musculoskeletal disorders and are a sign of relaxation and comfort, thus also potentially offering a useful indicator of good welfare (Warwick *et al* 2013, 2021). Therefore, these authors argue that vivaria should measure at least the snake's full length.

Larger enclosures better facilitate microclimates with a temperature gradient aiding thermoregulation (Varga 2019), provide more room for cage enrichment, and prevent self-inflicted injuries (Barten & Fleming 2014; Rossi 2019). A recent observational study in a zoological collection documented full-length stretching with approximately one-third of 65 captive snakes, including species classed as 'sedentary', and hence being more rarely observed to move naturally adopting active straight-line or near straight-line behaviour within their enclosures (Warwick *et al* 2019). This study showed that, if given the opportunity, many snakes of diverse species will utilise the space to adopt such postures. Therefore, restricting this ability could be argued to deny snakes the ability to express normal behaviour, which would contravene welfare requirements described in the Animal Welfare Act (2006), DEFRA (2010) and other frameworks. Consequently, DEFRA has considered updating its *Guidance Notes* to include a provision requiring enclosures that are > 1× snake length as an absolute minimum condition for commercial environments (DEFRA 2018). However, the debate continues and, in the absence of clear evidence, the 0.66 guidance currently still holds in the UK at the time of writing. This study therefore aims to explore the importance of enclosure size objectively.

Snake species vary significantly in their biology and lifestyles, and hence their optimal husbandry. Therefore, it would be valuable to explore how owners house and otherwise care for snakes from different genera and whether specific housing and husbandry issues are more prevalent within specific groups. Survey data from pet snake owners in Germany reported small enclosure sizes, and inappropriate temperature and humidity conditions (Pees *et al* 2014), whilst Howell *et al* (2020) reported that many snake-keepers in Australia did not meet government guidelines. However, there are a lack of studies and empirical data on pet snakes' care in the UK. Therefore, we surveyed snake owners in the UK and overseas, collecting both housing and husbandry data. Since welfare is reflected in both physical health and behaviour, we assessed widely documented indicators of health using 15 clinical signs (eg rostral abrasions) and 23 potentially negative behavioural signs (eg interacting with transparent boundaries). Although the performance of each behaviour in isolation may not be a sign of a welfare issue as some can be normal when performed in moderation, we produced a meaningful and valid scale by calculating the sum of all potentially negative behaviours. We followed a similar approach as previously used for pet rabbits (*Oryctolagus cuniculus*) (Rooney *et al* 2014) and guinea pigs (*Cavia porcellus*) (Harrup & Rooney 2020). Using these indicators, we tested for associations with housing and husbandry aspects and differences between the three most prominent snake families reported: Pythonids, Boids and Colubrids. In

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addition, because much is unknown about the longevity of snakes in captivity, we asked respondents about their previous snakes' lifespans and explored associations with current housing and husbandry.

We aimed to address the following research questions:

• How are pet snakes most commonly housed and cared for in private homes?;

• Do the methods of keeping vary between the three most prominent families (Pythonids, Boids and Colubrids)?;

• To what extent do current methods match current UK recommendations?;

• What proportion of pet snakes show each of 15 clinical signs and 23 potentially abnormal behavioural signs?; and

• Do aspects of housing and husbandry show associations with the number of clinical and behavioural welfare indicators?

Materials and methods

Questionnaire

This study was granted ethical approval by the University of Bristol Faculty of Health Science Ethics Committee on the 9th July 2019; reference number 91542. An online questionnaire was created using JISC Online Surveys®, divided into nine sections (Table 1), including 39 mandatory questions. Several questions included additional optional parts together, collecting a maximum of 99 variables from each participant.

Recruitment

The questionnaire was open from 13th August to 8th September 2019. Business cards and flyers were distributed across the UK, including Bath, Bristol, Birmingham, Exeter, Gloucester, London and Manchester. Advertising material was placed in general and exotic pet shops, and veterinary practices, wildlife centres, and at reptile shows. A link to the survey was posted on numerous forums for snake-keepers and social media, including Facebook groups dedicated to snake-keeping and breeding and pages run by establishments associated with reptiles. The survey was also shared with members of the BVZS via email. A chance to be entered into a draw to win a £100 Amazon voucher was available to all respondents to incentivise wide participation. Respondents needed to be at least 16 years old, the legal age to own a pet in the UK (GOV.UK 2019) and to own at least one snake. They were asked to select the snake whose name came first alphabetically (referred to throughout as the focal snake) and complete the survey only once; this avoided any bias from owners with multiple snakes selecting their best cared for or healthiest snake and prevented pseudo-replication.

Data handling and manipulation

The data file was exported into Microsoft Excel® (version 2018) and analysis carried out using SPSS® (version 26). All snakes recorded were classified into their corresponding family: Colubrids, Pythonids, Boids, Elapids, dwarf boas (*Tropidophis* spp) and dwarf pipe snakes (*Anomochilus* spp). For analysis involving enclosure size,

Table 1 Sections included in the questionnaire and related question content.

Section	Question contents
A Respondent	Age, location, number and species of snakes currently owned
B Snake	Name, sex, species, age, weight, length and acquisition source
C Housing	Size (length, width and height) of living enclosure, other animal(s) in the same enclosure, substrate used, types of enrichment provided
D Management	Temperature (cold and hot ends) and humidity of enclosure
E Routine	Frequency and period of time snake is let out of cage, on average
F Diet	Frequency of feeding different foodstuffs
G Health	Whether 15 different symptoms of poor health had been identified, either currently or in the past, and veterinary care
H Behaviour	Whether 26 different behaviours indicative of stress had been observed, either occasionally or often
I Longevity	Species and longevity of snake owned in the past

entries with incomplete data (n = 5) and snakes less than one year in age (n = 26) were eliminated because they were unlikely to be fully grown. An 'enclosure size in snake lengths' variable was produced by calculating 'length or height of enclosure (which ever was greatest)/snake length.' We made two additional binary variables describing whether the enclosure was > 1 and > 0.66 snake length, the latter representing the currently recommended advice in the UK (DEFRA 2018). We also produced an 'overall enrichment (OE) score' (0–3) per enclosure, counting the number of reported enrichment types present: hide, water-pool, and branches or similar climbing apparatus. We analysed whether snakes had an area to burrow separately as not all species require this. Optimal temperature and humidity requirements vary with the geographical location of species rather than with family. Hence, we compared the recorded values of the three most common species (royal python, corn snake and common boa constrictor [*Boa constrictor*]) to the currently recommended guidance in textbooks and online care manuals (RSPCA 2019a,b; Varga 2019). Reported temperatures of enclosures that fell within ± 1°C of recommended guidance were classified as suitable, whereas unknown temperatures and values outside these ranges were deemed inappropriate. Similarly, reported humidity values within ± 1% of the recommended guidelines were classified as suitable and unknown humidity, and values outside of these ranges as unsuitable.

We quantified snake health based on reports of external or internal physical signs potentially associated with stress in captive environments (Table 2). We counted the number of 'clinical signs observed (CSO)' of 15 listed (Table 2) either in the past or currently. In the literature,

Table 2 Clinical symptoms and negative behaviours indicative of captive stress in snakes. Behaviours which were species-specific (SS) or required a cage-mate (CM) are indicated (adapted from Warwick *et al* 2019).

Clinical symptoms	Negative behaviours
Issues with shedding of the skin	Interacting with transparent boundaries
Parasites (eg mites, ticks, etc)	Wincing or withdrawal of head or tail when being gently touched
Cuts or scrapes on head	Putting head deliberately under objects or substrate
Respiratory problems	Unusually high level of physical activity
Problems with spectacles	Attempting to escape
Injuries from bites from prey or cage-mates	Unusually low level of physical activity
Inflammation of scales	Coiling unusually tight to humans or objects
Thermal burns	Freezing or tensing up when in general presence of a human
Reproductive issues	Flattening body against surface
Difficulty or complete obstruction when passing faeces	Hissing at humans or cage-mates
Skin abscesses	Using 'arch' of body to deflect physical contact from cage-mates or humans
Musculoskeletal disorders	Mock or real strikes at humans
Poor reproductive performance or sterility	Inflating or deflating body
Urinary tract disorders	Noticeable lack of eating
Disorders involving the cloaca/hemipenes (eg prolapses)	'Jumpy' movements when moving
	Unusually high level of 'nervousness'
	Biting objects, cage-mates or humans when food is not present
	Occupying unusual locations for excessive amounts of time
	Open mouth breathing
	Projection of hemipenes when in the presence of human or being handled
	Appearing limp, upside down or unconscious
	Regurgitation of food when in the presence of humans or being handled
	Urinating, defaecating or projecting substances from cloaca when handled
	Venom spitting in the presence of humans or when being handled (SS)
	Aggressive or defensive displays towards cage-mates (CM)
	Chasing cage-mates (CM)
	Biting cage-mates (CM)

specific signs, eg issues with shedding, parasites, respiratory problems, problems with spectacles, inflammation of scales and skin abscesses, have been associated with inappropriate temperature and humidity conditions (Varga 2019). Therefore, we created a 'refined signs (RS) score' (0–5) to focus on these signs. We calculated a score for 'negative behaviours observed' (NBO: 0–46) by attributing a score based on the reported frequency of occurrence: 0 = never or don't know; 1 = occasionally; 2 = often, for each of the 23 behaviours listed (Table 2). Although we listed 27 negative behaviours, four were species-specific or actions requiring a cage-mate (Table 2). Since they were not possible for all snakes, they were excluded from the overall score.

Statistical analysis

Data were not normally distributed, so non-parametric tests were used throughout. Kruskal-Wallis tests (Z) tested for differences between families in 'enclosure size in snake lengths' and 'OE score'. Pearson's Chi-squared test (χ^2) and Fisher's exact test (FET) tested for differences between families for types of enrichment, whether any of the five most commonly reported behaviours were seen, whether owners measured temperature and humidity, and whether these conditions were suitable or not. Spearman Rank Correlation (Rho) tested for associations between 'enclosure size in snake lengths' and 'OE score', and associations between 'CSO' and 'NBO' scores and parameters, such as 'enclosure size in snake lengths', 'OE

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Table 3 Reported characteristics of respondents completing the survey (n = 744).

Country	% of respondents	Age of respondents (years)	% of respondents	Snakes owned at present (n)	% of respondents	Route of acquisition of the focal snake	% of respondents
England	56.2	16–20	17.0	1	33.5	Exotic pet shop	24.9
Wales	4.6	21–29	47.3	2	19.5	Private breeder	24.5
Scotland	7.5	30–39	22.7	3	11.6	Rehomed from stranger	13.7
Northern Ireland	0.5	40–49	8.7	4	6.5	General pet shop	9.5
Republic of Ireland	0.5	50–59	3.0	5	4.8	Rehomed via friend/relative	8.9
United States	2.2	60+	0.5	6	2.2	Reptile show	5.0
Canada	2.6	Prefer not to say	0.4	7	2.8	Rescue centre/rescued	4.6
Australia	0.9			8	2.3	Bought via internet	3.0
Germany	0.7			9	1.9	Received as a gift	1.9
The Netherlands	0.5			10	1.5	Garden centre	1.6
Sweden	0.4			> 10	13.6	Owner bred it themselves	1.5
Finland	0.4					Other	0.9
South Africa	0.5					Don't know	0.1
Other	2.2						

score' and time spent out of the enclosure. Mann-Whitney *U* tests were used to test for the associations between 'CSO' and 'NBO' scores and binary variables: whether owners observed snakes fully stretched out; enclosures < 1 snake length, whether owners measured the temperature and humidity, and whether these conditions were suitable or not. Mann-Whitney *U* tests were also used to test for associations between 'RS score' and whether snakes were housed within the appropriate temperature and humidity ranges. The level of significance for all tests was $P < 0.05$. Throughout, 'NS' indicates results that were not significant and 'n' is referred to as the number of respondents or snakes reported.

Results

Respondents

During the survey period, 744 participants completed the questionnaire. Most of the respondents came from the UK (68.8%). The modal age category was 21–29 years (47.3%), and the most common number of snakes owned was one (33.5%; Table 3).

Snakes

The reported ages of snakes ranged from three months to over 31 years old, with a mean (± SD) of 5.7 (± 4.3) years. The proportion of males and females reported was quite even (46.5 and 43%, respectively), whilst 10.5% were of unknown sex. The most common sources of snake acquisition were 'exotics' pet shops (24.9%), private breeders (24.5%) and being rehomed from either a friend, relative or from someone unknown to the owner (22.6%; Table 3). The most common species reported were the royal python (34.8%) and corn snake (31.9%; Table 4). The most common families were Colubrids (45.6%), Pythonids (43.3%) and Boids (10.3%); followed by dwarf boas (0.5%), Elapids (0.1%) and file snakes (*Acrochordus* spp; 0.1%). Snake weights ranged from 0.01 to 150 kg, with an average of 2.5 (± 8.3) kg. Length of snakes ranged from 0.18 to 11.47 m, with an average of 1.25 (± 0.75) m. Most snakes were often (42.3%) or occasionally (48.4%) observed by owners to display straight-line positions within or outside their enclosure (Table 4).

Housing

Enclosure lengths ranged from 0.19 to 10.98 m (1.28 [± 1] m), widths 0.01 to 9.14 m (0.67 [± 0.68] m) and heights 0.02 to 10.03 m (0.67 [± 0.65] m). Median scores for 'enclosure size in snake lengths' were marginally significantly different between Pythonids (25th percentile = 0.8, 75th percentile = 1.29), Boids (0.79, 1.37) and Colubrids (0.79, 1.22; $Z = 6.0$; $P = 0.05$). More than half (54.7%) of snakes were kept in enclosures shorter in length or height than their body length. For owners in the UK (n = 512), 10.2% provided an enclosure size < 0.66 snake length and so did not comply with current recommended guidelines (DEFRA 2018). The most common substrates provided were bark (38.4%) and aspen (36.4%) (followed by leaves [23%] and soil [23%]), with the least common being gravel (0.8%) and large pebbles (0.8%).

Table 4 Number of each snake species reported by their owners to display straight-line positions within or outside their enclosure. Some species were classed as arboreal/semi-arboreal (A) and/or burrowing (B).

Common name (scientific name)	Snakes surveyed (n)	Reported observed in rectilinear or near-rectilinear positions (n)
Royal python (*Python regius*)	259	241
Corn snake (*Pantherophis guttatus*)	237	214
Common boa constrictor (*Boa constrictor imperator*)	49	47
Western hognose snake (*Heterodon nasicus*) (B)	30	26
Carpet python (*Morelia spilota*) (A, B)	18	15
Reticulated python (*Malayopython reticulatus*)	17	12
Burmese python (*Python bivittatus*)	12	12
Californian king snake (*Lampropeltis californiae*)	12	11
Garter snake (*Thamnophis* spp)	11	11
Kenyan sand boa (*Eryx colubrinus*) (B)	9	8
Milk snake (*Lampropeltis triangulum*) (B)	7	7
Rainbow boa (*Epicrates cenchria*) (A)	6	6
Beauty rat snake (*Elaphe taeniural*)	5	4
Green tree python (*Morelia viridis*) (A)	5	1
Blood python (*Python brongersmai*)	5	5
Pacific gopher snake (*Pituophis catenifer catenifer*) (B)	4	4
Rosy boa (*Lichanura trivirgata*)	4	4
Russian rat snake (*Elaphe schrenckii*)	4	4
Dwarf boa (*Tropidophiidae* spp)	3	3
Mexican black king snake (*Lampropeltis getula nigrita*)	3	3
Amazon tree boa (*Corallus hortulanus*) (A)	2	1
Black rat snake (*Pantherophis obsoletus*)	2	2
Bull snake (*Pituophis catenifer sayi*)	2	2
African house snake (*Boaedon fuliginosus*)	2	2
Black-tailed cribo (*Drymarchon melanurus*)	2	1
Florida king snake (*Lampropeltis getula floridana*)	2	2
Olive python (*Liasis olivaceus*)	2	2
Yellow anaconda (*Eunectes notaeus*)	2	2
Asian vine snake (*Ahaetulla prasina*) (A)	1	1
Baron's green racer snake (*Philodryas baroni*)	1	1
Rhinoceros rat snake (*Gonyosoma boulengeri*)	1	1
Argentine boa (*Boa constrictor occidentalis*)	1	1
Arizona mountain king snake (*Lampropeltis pyromelana*)	1	1
Mexican baird's rat snake (*Pantherophis bairdi*)	1	1
Black-banded trinket snake (*Oreocryptophis porphyraceus*)	1	1
Cape file snake (*Limaformosa capensis*) (B)	1	1
False water cobra (*Hydrodynastes gigas*)	1	1
King rat snake (*Elaphe carinata*)	1	1
Madagascan hognose snake (*Leioheterodon madagascariensis*)	1	1
Northern green bush snake (*Philothammus irregularis*)	1	1
Southern white-lipped python (*Bothrochilus meridionalis*)	1	1
Spotted mulga snake (*Pseudechis butleri*)	1	1
Texas rat snake (*Elaphe obsoleta lindheimeri*)	1	1
Thayer's king snake (*Lampropeltis mexicana thayeri*)	1	1
Yellow rat snake (*Spilotes pullatus*)	1	1
Total	**733**	**669**

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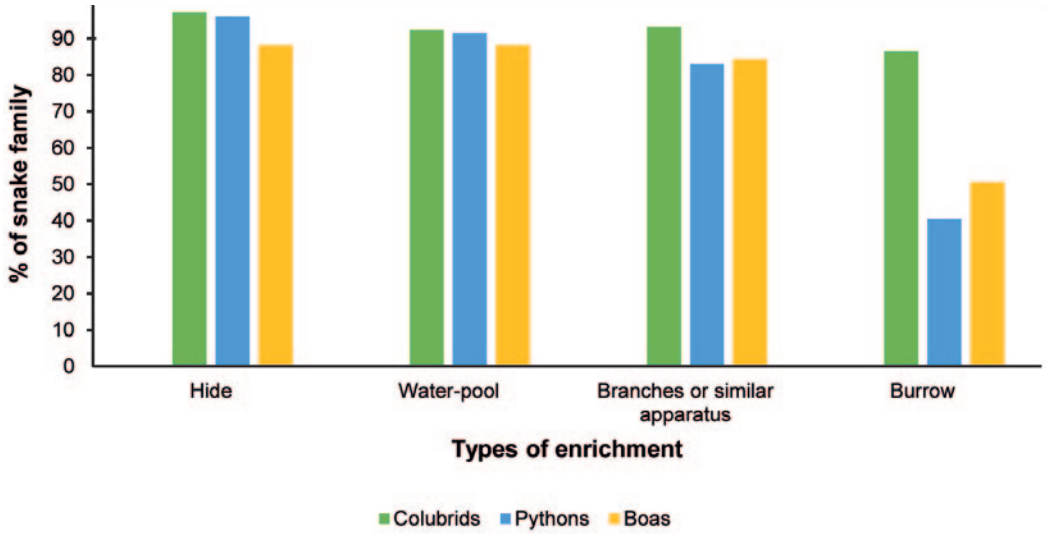
Figure 1



Reported frequency with which four enrichment types were provided to Colubrids (n = 339), Pythons (n = 322) and Boas (n = 77).

Enrichment

Most owners reported providing a hide (95.7%), water-pool (91.7%) and branches or similar climbing apparatus for their snake (87.8%), and over half provided an area to burrow (62.8%). We found Boids (88.3%) were significantly less likely to be provided with a hide than Colubrids (97.3%) and Pythonids (96%; FET = 10.2; $P < 0.05$; Figure 1). Colubrids (93.2%) were significantly more likely to be provided with branches or similar climbing apparatus, compared to Boids (84.4%) and Pythonids (82.9%; $\chi^2 = 17.3$; $P < 0.001$; Figure 1). In contrast, there was no significant difference in the likelihood of being provided with a water-pool between the three families (NS; Figure 1). Species classed as burrowing (Table 4) were significantly more likely to be provided with a burrow (90.3%) than other snakes (60.3%; $\chi^2 = 22.0$; $P < 0.001$). Colubrids (86.4%) were more likely to be provided with a burrow than Pythonids (40.4%) or Boids (50.6%; $\chi^2 = 154.88$; $P < 0.001$). 'OE scores' ranged from one to three (median = 3) and did not differ significantly between families (NS). Analysis revealed a small but significant positive correlation between 'OE score' and 'enclosure size in snake lengths' (Rho = 0.09; $P < 0.05$).

Monitoring and maintenance

Temperature

The majority of owners reported measuring the temperature (92.3%), but 7.7% did not. Of the former, most owners checked the readings at least once a day (76.1%; Table 5). Owners kept a significant number of royal pythons (41.7%), corn snakes (48.9%) and common boa constrictors (67.3%) in conditions not meeting current recommendations (Table 6). The analysis showed common boa constrictors were the most likely to be housed outside recommended thermal conditions ($\chi^2 = 11.4$; $P < 0.05$). In some cases, recorded temperatures reached very high and low values for the royal python (lowest recorded value: 15°C, highest recorded value: 45°C), corn snake (12°C, 40°C) and common boa constrictor (20°C, 37°C).

Humidity

Just over half of the respondents (51.9%) reported measuring the humidity, whereas 48.1% did not. Of the former, the majority checked the humidity reading at least once a day (75.6%; Table 5). Corn snakes (66.7%) were significantly more likely to be housed in unsuitable humidity conditions compared to royal pythons (37.8%) and common boa constrictors (34.7%; $\chi^2 = 46.2$; $P < 0.001$; Table 6). Similar to temperature, we found a wide range of humidities for snakes, including the royal python (lowest recorded value: 20%, highest recorded value: 89%), corn snake (30%, 78%) and common boa constrictor (17%, 80%).

Routine

The majority of owners let their snake out of their enclosure several times a week (35.5%) or approximately weekly (24.6%). The reported time ranged from 0.05 to 20 h, with a median of 0.5 (25th percentile = 0.3, 75th percentile = 1) h, which did not vary significantly between the three families (NS).

Cage companions

Most snakes were described as living on their own (93%), whilst a minority were housed with conspecifics (2.4%), one with another snake species (0.1%) and some with different animals (4.7%), which included isopods, springtails, centipedes and worms, or crested geckos (*Correlophus ciliatus*) and dyeing dart frogs (*Dendrobates tinctorius*).

Table 5 Reported frequency at which owners measured the temperature and humidity of their snake's enclosure (n = 744).

	% of respondents	
How often measured	**Temperature**	**Relative humidity**
More than once a day	41.8	21.8
Once a day	28.5	17.5
Every two days	3.8	3.1
A couple of times a week	11.2	4.0
Once a week	4.2	3.2
Fewer than once a week	3.0	2.3
Never	7.7	48.1

Table 6 Compliance of owners at meeting published optimal temperature and humidity ranges for the three main snake species (extracted from RSPCA 2019a,b; Varga 2019).

	n	Temperature (°C)			Relative humidity		
		Guidelines	**% of owners reporting measuring temperature**	**% of owners reporting within published ranges**	**Guidelines**	**% of owners reporting measuring humidity**	**% of owners reporting within published ranges**
Royal python	259	Cool end: 24–26°C Hot end: 30–34°C	96.1	58.3	50–60%; up to 80 during ecdysis	69.1	62.2
Corn snake	237	Cool end: 20–24°C Hot end: 28–30°C Dropping overnight to 16–20°C	90.1	51.1	30–70%	35.9	33.3
Common boa constrictor	49	Cool end: 28–30°C Hot end: 31–32°C No lower than 26°C at night	93.9	32.7	50–80%	69.4	65.3

Table 7 Frequency with which owners reported feeding different food types to their snake.

Family	**n**	**Percentage of owners providing the following food type (%)**							
		Mice		**Rats**		**Rabbits**	**Chicks**	**Quails**	**Fish**
		Dead	**Live**	**Dead**	**Live**				
Colubrids	339	92.0	3.5	24.5	2.7	0.0	13.0	4.1	3.8
Pythonids	322	32.9	4.3	80.1	5.9	5.9	16.1	7.8	0.6
Boids	77	29.9	1.3	72.7	2.6	13.0	14.3	10.4	0.0
Total	**738**	**59.8**	**3.7**	**53.8**	**4.1**	**3.9**	**14.5**	**6.4**	**2.0**

Feeding and supplementation

The main food items given were dead mice (59.8%), rats (53.8%) and chicks (14.7%; Table 7). Whereas rarer items of unspecified live status included gerbils and hamsters (0.8%), frogs and lizards (0.4%), guinea pigs (0.4%), eggs (0.4%), piglets and lambs (0.3%), squirrels (0.3%) and snakes (0.3%). Most snakes were fed every 6–10 (49.5%) or 11–15 (25.9%) days. A small number of owners (8.6%) reported giving their snake dietary supplements. The most common were multivitamins and minerals (7.4%), calcium powder via dusting (3%) and a calcium and vitamin D combination (2.4%).

Indicators of physical health

Most respondents reported their snake as a healthy weight (91.5%), whilst 3.9 and 3.9% thought their snake was either under- or overweight, respectively; four owners thought their snake was very underweight and one very overweight. Of the 15 clinical signs listed (Table 8), the most commonly seen in the total sample were issues with shedding of the skin (observed currently or in the past: 28.2%), parasites (11.2%), rostral cuts and scrapes and other head lesions (7.4%) and respiratory problems (5.6%). We found that Pythonids were the most likely to be reported to have

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Table 8 Frequency at which various clinical symptoms were reported in snakes. Statistical test results show the comparisons for each clinical symptom between the three families.

Clinical symptom	% of snakes with specific clinical symptom currently or in the past				Statistical value; *P*-value
	Boas (n = 77)	Pythons (n = 322)	Colubrids (n = 339)	All snakes (n = 744)	
Issues with shedding of the skin	24.7	37.3	20.4	28.2	**χ^2 = 23.9; *P* < 0.001**
Parasites (eg mites, ticks, etc)	27.3	14.3	5.9	11.8	**χ^2 = 31.0; *P* < 0.001**
Cuts or scrapes on head	6.5	6.8	8.0	7.3	NS
Respiratory problems	30.0	1.2	4.4	5.7	NS
Problems with spectacles	2.6	5.9	2.4	3.9	NS
Injuries from bites from prey or cage-mates	2.6	3.1	2.7	2.8	NS
Inflammation of scales	3.9	3.1	1.8	2.6	NS
Thermal burns	2.6	3.4	0.9	2.2	NS
Reproductive issues	0.0	1.6	2.1	1.6	NS
Difficulty or complete obstruction when passing faeces	1.3	1.6	1.2	1.3	NS
Skin abscesses	3.9	0.3	0.3	0.7	**FET = 7.8; *P* < 0.05**
Musculoskeletal disorders	1.3	0.0	1.2	0.7	NS
Poor reproductive performance or sterility	0.0	0.3	1.2	0.5	NS
Urinary tract disorders	0.0	0.3	0.3	0.3	NS
Disorders involving the cloaca/hemipenes (eg prolapses)	1.3	0	0.3	0.3	NS

Significant results are marked in bold, and the others are non-significant (NS).

shedding issues (37.3% compared to 20.4 and 24.7 for Colubrids and Boids, respectively; χ^2 = 23.8; $P < 0.001$). 'CSO scores' ranged from 0 to 6, with a median of 0 (reported in 55.5%). Overall, Boids (one) and Pythonids (one) had significantly higher median CSO scores compared to Colubrids (0; $Z = 18.7$; $P < 0.001$).

Just over one-third of respondents (34.5%) had taken their snake to a veterinary practice during its lifetime. Of these, most had visited a vet between one and three times (88.7%). Most of these owners saw the veterinarian for a routine appointment (65.8%) or health or behavioural problem (33.9%) for their most recent visit. Of the 87 respondents who reported the reason they last visited a veterinarian, the most common issues were respiratory infections (28.7%), parasites (16.1%) and problems with scales (10.3%).

Behavioural indicators of welfare

Results showed that Colubrids (eight) had the significantly highest median 'NBO score' compared to Pythonids (six) and Boids (6.5; $Z = 25.4$; $P < 0.001$). Of the 23 negative behaviours listed (Table 9), the most commonly seen were interacting with transparent boundaries (observed often or occasionally = 52.8%), wincing or withdrawal of the head when gently touched (52.4%), putting head under substrate or objects (52.1%), an unusually high level of activity (51.1%) and attempting to escape (45.9%). Colubrids scored significantly higher for attempts to escape (one) and putting their head under substrate (one) or objects compared to Pythonids ($Z = 33.7$; $P < 0.001$ and $Z = 36.0$; $P < 0.001$, respectively). However, there was no difference in median score for reported interaction with transparent boundaries, unusually high activity level, or withdrawal of the head when gently touched between the three families (NS).

Associations between housing and husbandry parameters and indicators of welfare

We found a small but significant positive correlation between 'NBO' and 'CSO' scores (Rho = 0.13; $P < 0.01$), showing that snakes reported as having more clinical signs also tended to show more reported negative behaviours.

Health

We also found a small but significant negative correlation between 'enclosure size in snake lengths' and 'CSO score' (Rho = –0.11; $P < 0.05$). Snakes kept in enclosures < 1 snake length had a significantly higher 'CSO score' compared to those in vivaria ≥ 1 snake length ($U = 75{,}621$; $P < 0.01$). There was no correlation between 'CSO score' and average time spent out of the enclosure or 'OE score' (NS). Nor was there any difference in 'CSO score' depending on whether owners measured the temperature or humidity or whether these conditions matched current recommended guidelines for temperature and humidity (NS). Similarly, there was no association between 'RS score' and whether owners measured the temperature and humidity (NS).

Table 9 Percentage of owners reporting observing each of 23 negative behaviours in their snake.

Negative behaviour	Percentage of snakes reporting showing behaviour at frequency				
	n	Never	Occasionally	Often	Don't know
Interacting with transparent boundaries	744	18.1	52.8	28.1	0.9
Wincing or withdrawal of head or tail when being gently touched	744	46.8	41.9	10.5	0.8
Putting head deliberately under objects or substrate	744	45.4	34.5	17.6	2.4
Unusually high level of physical activity	744	46.1	45.6	5.5	2.8
Attempting to escape	744	53.2	41.3	4.6	0.9
Unusually low level of physical activity	744	58.5	33.3	3.6	4.6
Coiling unusually tight to humans or objects	744	62.0	32.4	4.3	1.3
Freezing or tensing up when in general presence of a human	744	66.5	29.0	4.0	0.4
Flattening body against surface	744	64.5	28.6	3.4	3.5
Hissing at humans or cage-mates	736	71.2	23.9	4.8	0.1
Using 'arch' of body to deflect physical contact from cage-mates or humans	705	72.5	22.8	3.4	1.3
Mock or real strikes at humans	730	75.2	20.5	3.7	0.5
Inflating or deflating body	744	74.2	18.0	2.4	5.4
Noticeable lack of eating	741	79.4	19.0	1.2	0.4
Urinating, defaecating or projecting substances from cloaca when handled	742	79.1	17.7	2.3	0.9
'Jumpy' movements when moving	744	79.8	16.1	3.1	0.9
Unusually high level of 'nervousness'	744	83.2	12.5	2.3	2.0
Biting objects, cage-mates or humans when food is not present	685	89.8	7.4	2.3	0.4
Occupying unusual locations for excessive amounts of time	744	89.2	8.3	0.4	2.0
Open mouth breathing	740	95.1	3.6	0.3	0.9
Projecting of hemipenes when in the presence of human or being handled	682	97.0	1.8	0.0	1.2
Appearing limp, upside down or unconscious	744	98.3	1.2	0.0	0.5
Regurgitation of food when in the presence of humans or being handled	739	98.2	1.2	0.0	0.5

Behaviour

There was no significant correlation between 'enclosure size in snake lengths' and 'NBO score', nor a difference between snakes in enclosures < 1 or ≥ 1 snake length (NS). We found no relationship between 'NBO score' and average time spent out of the enclosure or 'OE score' (NS); whether owners reported measuring temperature or humidity, or whether these conditions matched current recommended guidelines (NS).

Longevity (lifespan)

In total, 237 respondents provided data on the age of death of their previous snake, which ranged from four months to over 30 years, with an average age of 8.1 (± 6.9) years. Of these, 21.9% died in the first year of life, and another 30.3% died in the second year, meaning over 52.1% had died by two years. There was no significant difference in the previously owned snake's longevity between the three families, nor was there when comparing snakes currently kept in enclosures < 1 or ≥ 1 snake length (NS); whether owners recorded measuring the temperature or humidity (NS).

Discussion

There has been a paucity of data on the current housing and husbandry conditions of snakes kept privately within homes. This study gathered data from 744 respondents predominantly in the UK, providing information on how pet snakes are kept and highlighting several potential welfare concerns.

Snakes

Common acquisition sources included 'exotic' pet shops (24.9%) and private breeders (24.5%). Many snakes (27.2%) had at least one previous owner, either privately rehomed or via a rescue centre. This could be a potential concern because research has found that the quality of care information tends to diminish as it passes down from the previous owner (RSPCA 2017). In total, 53 snake species were recorded in this study, with royal pythons and corn snakes represented significantly more frequently than any other species, making up to 34.8 and 31.9% of the snakes in the survey, respectively. These results are unsurprising

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because both species are often regarded as the 'easiest-to-keep' among snake hobbyists (Whitehead & Vaughan-Jones 2015), together with the bearded dragon (*Pogona vitticeps*), crested gecko, leopard gecko (*Eublepharis macularius*) and Hermann's tortoise (*Testudo hermanni*), they account for 70% of trade for the UK pet reptile market (RSPCA 2017). When classifying snakes by family, the most common were the Colubrids (45.6%) and Pythonids (43.3%). The conservation status for all but one of the 53 species reported were classed as 'least concern' on the IUCN red list, with the Burmese python (*Python molurus*) (n = 12) marked as 'vulnerable' (IUCN 2020).

Snakes are often described as apparently stoical animals (Whitehead 2016). However, 15 clinical and 23 behavioural problems were described in our study, and all were reported in our sample. Although the modal number of clinical signs seen was zero and behaviour signs was six, some individuals were reported to have shown as many as six clinical signs and others 16 negative behaviours.

Reptile owners are known to be poor at identifying issues (health and behavioural) due to a lack of scientific knowledge and judgements based on folklore guidance (Whitehead 2018b); thus, it is very likely that the frequencies reported here are underestimated. As for many other types of animals, snakes' tendency to mask signs of distress makes identifying physical ailments and abnormal behaviours challenging even to professionals. Their lack of vocal and facial communications likely further exacerbate under-reporting (Warwick 2014). It is essential to seek veterinary advice when managing exotic animals. However, only one-third of owners (34.5%) reported ever visiting a veterinary surgeon. Such results mirror previous literature, showing that it's common practice for many reptile keepers to self-diagnose issues without veterinary advice (Whitehead 2018b).

Owners reported 44.5% of snakes experienced at least one of the 15 clinical signs. Problems with skin-shedding (28.2%) were the most common, in line with previous findings (Warwick *et al* 2013; Hedley 2014). Abnormal skin-shedding, known as dysecdysis, is usually caused by poor husbandry, such as inappropriate temperature or humidity, a lack of rough surface to rub against, and is often exacerbated by parasites (Mitchell 2004). In our study, parasites (11.8%) were the next most common signs found across all snake types. Pythonids were more likely to be reported to display shedding issues and parasites than Boids and Colubrids. One may hypothesise that this situation is due to inappropriate temperature and humidity conditions commonly reported in royal pythons and common boa constrictors, although no discernible association was detected here. Rostral cuts and scrapes (7.3%) were also reasonably common and have previously been described as a result of captive stress (Warwick *et al* 2019).

Boids and Pythonids were reported to show significantly more clinical signs than Colubrids. Whether this reflects a difference in the ease of identifying issues, the owners' knowledge level or the snakes' overall health in the three families is yet to be determined. However, it suggests that education resources focusing on identifying and preventing health problems may be useful for these snake owners. Respondents reported most snakes (98.1%) displaying at least one of the 23 negative behaviours. The most common seen were interacting with transparent boundaries (52.8%), wincing or withdrawal of the head when gently touched (52.4%), putting head under substrate or objects (52.1%), an unusually high level of activity (51.1%) and attempting to escape (45.9%), all of which have been previously described as behaviours associated with captive stress (eg Benn *et al* 2019; Warwick *et al* 2019). The behaviours in the NBO include those which, when performed rarely and in the correct context, could be described as normal, such as retreating from touch. Still, when performed frequently, they are a sign of repeated exposure to aversive stimuli which the animal cannot avoid, and hence are potentially problematic. Therefore, although each sign in isolation cannot be taken to be a sign of a welfare problem, the NBO scale gives a meaningful approximation of the level of negative behaviour and aversion experienced. Similar scales have been validated and used in rabbits (Rooney *et al* 2014) and guinea pigs (Harrup & Rooney 2020), and we suggest they are similarly useful for snakes.

It has been postulated that some individual captive snakes may survive longer than their wild counterparts, with factors such as predation, starvation and climatic pressures not being an issue for pets (Paré & Lentini 2010). For example, recorded lifespans of some individual captive corn snakes are between 15 to 25 years, with some reportedly living to 32 years; and successfully maintained Boids have been estimated to live 20 to 30 years on average, with certain examples surviving past 40 years (Slavens & Slavens 2003). However, the evidence for captive snakes generally outliving their wild counterparts is limited, with no controlled large-scale robust studies representing the diversity of species involved. This is compounded by the complexity of ageing reptiles based on their physical features (Paré & Lentini 2010). In this study, we found that amongst owners who previously owned snakes (n = 237), the average age at death of their last snake was 8.1 years, and of these snakes, 22% died by one year, and a further 30% didn't make it past their second year of life.

Enclosure size

We found that 90.1% of owners reported observing their snake stretch out to full length. Although it would have been beneficial to note whether snakes were in their enclosure at the time of recording, these findings support recent work by Warwick *et al* (2019), confirming that snakes will utilise available space to adopt straight-line postures. In our study, owners reported 45 out of 53 species adopting these positions, including species often described as 'sedentary', such as certain Boids and Pythonids, which may be less likely to be viewed in these postures since they move less often (Divers & Stahl 2019). In addition, because many, if not most, snakes are nocturnal, observations by diurnal humans may underestimate the frequency. Therefore, our results support the

behavioural need for enclosures at least the snake's length to permit full-length stretching, thereby fulfilling normal behavioural patterns (DEFRA 2018; Divers & Stahl 2019).

Supporting previous findings that larger enclosures promote better snake welfare and are associated with fewer self-inflicted injuries (eg Warwick *et al* 2013, 2019; Rose *et al* 2014; Divers & Stahl 2019; Rossi 2019; Spain *et al* 2020), we also found that snakes kept within enclosures < 1 snake length were reported to show a higher frequency of clinical signs of captivity stress. Previous research suggests that small enclosures can also limit the amount of exploration and movement of snakes (Arena *et al* 2018a), with spatial ecological studies reporting a range of snakes covering vast home ranges, including the carpet python (*Morelia* spp: 4.5–20 hectares; Corey & Doody 2010), racers:19.6–21.9 hectares; Carfagno & Weatherhead 2008), rat snakes (*Elaphe* spp: 3.5–16.7 hectares; Blouin-Demers *et al* 2007; Carfagno & Weatherhead 2008) and the Burmese python (*Python* spp: 22.5 km^2; Hart *et al* 2015).

Over half (54.7%) of owners kept snakes in enclosures shorter in length or height than the snake's length. These results, along with previous research of snakes in private homes and exotic pet expositions (D'Cruze *et al* 2020), and zoological collections (Nash 2016; Mendyk 2018), show that a significant number of snakes are kept under restrictive conditions preventing full length stretching and relevant movement. Furthermore, 10% of UK owners failed to meet the recommended guidelines of more than two-thirds of the snake's length from snout-to-tail (DEFRA 2018). However, we suggest that one body length may be a more logical recommendation because we saw a significant difference in clinical signs when snakes were grouped according to < 1 length, but not –0.66.

Collectively, these findings suggest that vivaria should provide at least the snake's full length. However, because many, if not most, snake species may reasonably be expected to move while adopting straight-line behaviour and manifest multiple activity habits (ie involve combinations of subterranean, aquatic, terrestrial, and arboreal patterns), increasingly authors are taking a precautionary view that all enclosures for all species ought to allow snakes to stretch and move in all dimensions (Warwick *et al* 2019, 2021). Analysis of differences between enclosures that meet this enhanced requirement, and the remainder of the population, would be a valuable future step.

We found no correlation between 'enclosure size in snake lengths' and the number of negative behaviours. In contrast, the literature suggests that overly restrictive conditions can elicit abnormal behaviours, often due to acute and chronic stress (Warwick *et al* 2013, 2019). For example, Kreger and Mench (1993) reported a significant rise in corticosterone levels in royal pythons restrained in containers before handling. Our results may have been affected by most snakes being nocturnal; thus, they are usually at rest and inactive during the day (Warwick *et al* 2019), making identifying abnormal behaviours challenging, and owners may not notice or accurately report relevant behaviours. Although the NBO scale was based on those behaviours described in the literature as signifying stress, some of the definitions may have been difficult for the owners to accurately determine, such as whether a snake is coiling 'abnormally' tightly compared to tightly. Therefore, we suggest future studies should aim to validate these behaviours, confirm owners' ability to recognise them, and use 24-h filmed recordings as well as owner reports to assess the level of behavioural indicators more objectively.

Enrichment

The majority of snakes were provided with a hide (95.7%), water-pool (91.7%) and branches or similar climbing apparatus (87.8%), as recommended by the RSPCA (2019c,d). These results contrast with previous research into royal pythons at pet expositions and private homes (D'Cruze *et al* 2020), where hides and water sources were often absent.

Cage enrichment is deemed crucial for snake welfare, as water provides a drinking source and helps with shedding, and hides provide a cool spot under humid conditions and away from human observation (Varga 2019; Warwick *et al* 2019). In particular, royal pythons usually consume their food in the dark and, therefore, may become anorexic if adequate seclusion is not provided (Varga 2019). Branches provide important opportunities for expression of natural behaviour (Rose *et al* 2014). For example, Rose *et al* (2014) found that corn snakes were more active and spent less time hiding when housed with plenty of branches than in more barren surroundings. Also, preference tests using the Eastern Indigo snake (*Drymarchon couperi*) found they will optionally choose more natural conditions (Mehrkam & Dorey 2015).

More than half of snakes (62.8%) were provided with a place to burrow, with Colubrids significantly more likely to have one than Pythonids and Boids. This seems appropriate, as burrowing species were more likely to be provided with a burrow than other snakes. There was a positive correlation between larger 'enclosure size in snake lengths' and 'OE score', which fits in with the previous reasoning that more spacious enclosures provide more enrichment room (Whitehead 2018a). However, there was no significant association between the 'OE score' and 'NBO score.'

It could be argued that our 'OE score' lacked sensitivity and could have been more refined; for example, we did not assess the number of each enrichment type in the enclosure. Future studies should also examine whether owners provide water bowls large enough for snakes to submerge and bathe in fully and whether hides are large enough for snakes to conceal themselves in completely.

Temperature

Most owners (93.1%) measured the temperature, but of these, almost one-quarter (24%) checked the value less than once a day; in contrast to the recommended guidelines for snakes, stating that temperatures should be species-specific and checked daily (DEFRA 2018).

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Thermoregulation is crucial for reptiles; snakes should be housed in enclosures that provide two areas with different temperatures, giving them the option to select an external environment that suits their needs (DEFRA 2018). However, focusing on the main species (royal pythons, corn snakes and common boa constrictors), only 52.8% were housed in enclosures that provided suitable temperature ranges recommended for the species in question.

Our results show that common boa constrictors were more likely to be kept at an inappropriate temperature than corn snakes and royal pythons, with temperatures reaching as low as 20°C and as high as 37°C. This may be an artefact of the relatively small number of boa owners, or it could be due to the narrower recommended temperature ranges for this species, making it easier for owners to narrowly miss recordings. However, it also raises a potential husbandry concern and suggests better information provision is needed, especially for this species.

These results present concern, as low temperatures are known to predispose snakes to stress and hypothermia (Mitchell 2004), leading to secondary infections, such as stomatitis and pneumonia (Hedley 2014). Similarly, high temperatures can cause heat stress and rapid deterioration of bodily functions (Mitchell 2004) and may pose a risk if heat sources are inappropriately placed or faulty (Warwick *et al* 2013). There was no difference in 'CSO' or 'NBO scores' between snakes housed in suitable temperature ranges and those that were not in our sample. However, given that owners often miss relevant observational signs (Whitehead 2018b), it would be valuable to test these associations with observer-generated data, such as using video recordings and in-person assessments of enclosures as previously mentioned.

Humidity

Like temperature, current guidance states that humidity should be checked daily (DEFRA 2018). Only 58.9% of owners measured the humidity, with approximately one-quarter (24.4%) checking the readings less than once a day. Of the three main species, only 50% were housed in suitable species-specific humidity. These results agree with Pees *et al* (2014), who saw a large proportion of reptiles in Australia kept in enclosures with humidity that deviated from recommended guidance. Colubrid owners (34.2%) were significantly less likely to measure humidity than Boid (64.9%) and Pythonid (60.2%) owners.

We found no correlation between 'CSO' or 'NBO scores' and humidity maintenance at suitable ranges, and hence we cannot conclude that overall health and behaviour are affected by the humidity. However, the figures show an apparent disregard among snake owners for humidity maintenance, which is known to be vital for maintaining a healthy shedding cycle and preventing respiratory problems (RSPCA 2019a,b), skin irritation and dermatitis (Mitchell 2004). The number of these problems reported in our sample was too low to investigate specific associations thoroughly.

Feeding and supplementation

A significant proportion of owners living outside the UK fed their snake live prey, including mice, rats and chicks. This included (but was not limited to) the USA where laws allow the use of live vertebrates as food. However, in the UK, two owners fed live fish and one fed live mice and rats to their snake, which is prohibited (DEFRA 2018) because it is deemed inhumane for the prey and can cause injury to the snake (Cooper & Williams 2014; Rendle 2019).

First-time owners

Colubrids have been highlighted as a welfare concern throughout our study, with the most negative behaviours seen in this family and owners reporting largely inadequate temperature and humidity maintenance. Since corn snakes are commonly sold to first-time owners as 'easy-to-keep' pets (Whitehead & Vaughan-Jones 2015), we suggest a proportion of these keepers are unaware of the full extent of their snake's husbandry requirements. As previous research has shown, many beginner reptile owners fail to research their animal's needs before purchase and instead rely on pet stores for care information; with many even trusting their advice over veterinary professionals (RSPCA 2017). This can be highly problematic for novice owners because pet expositions often fail to provide housing conditions that fulfil snakes' welfare needs (D'Cruze *et al* 2020). Moreover, studies show that only staff in a small number of pet shops sampled were competent enough to advise on signs of ill health in reptiles (Williams & Jackson 2016). These factors, along with the plethora of differing information online, can make it difficult for even the most dedicated first-time keeper to access reliable and accurate information.

Animal welfare implications

There is currently conflicting and unreliable online guidance regarding snake husbandry. Therefore, research exploring the housing and husbandry conditions conducive to good welfare is vital to ensure evidence-based recommendations reach owners. Our study highlighted various concerns for snake welfare. Snakes are commonly housed in conditions preventing straight-line postures and movement, and these snakes showed a greater frequency of clinical signs. It is hoped that our findings can be used to help shape housing recommendations and policies in the future.

Although we did not see a significant association between temperature or humidity and welfare parameters in the study, a significant proportion of snakes were housed in commonly considered sub-optimal conditions. The results highlighted corn snakes as a welfare concern; therefore, it is hoped that our research can ensure that more accurate and reliable information is made accessible to these owners.

Conclusion

This extensive survey of owners gives up-to-date information on the current housing and husbandry standards of pet snakes in the UK and abroad. As the first study of this size, we provide valuable baseline data to compare against future surveys and assess the impact of future interventions. The

survey highlighted several potential welfare concerns relating to how snakes are kept in private homes. For example, many snakes were housed in enclosures preventing stretching out to full and natural length and these smaller enclosures were associated with an increased frequency of clinical signs related to captivity stress. A number of snakes were also reported in enclosures less than two-thirds of their length, and therefore these conditions did not follow the current recommended minimum. Smaller enclosures were also associated with lower levels cage enrichment.

A significant number of owners failed to measure the temperature and humidity daily, and a proportion of those respondents kept their snakes in sub-optimal ranges. These factors all present a cause of concern for snakes kept in private homes.

Many snakes experienced at least one of the 15 clinical signs, and the main issues observed across snakes were shedding problems, parasites, and rostral cuts and scrapes. Similarly, most snakes experienced at least one of the 23 negative behaviours, with the most common including interacting with transparent boundaries, wincing or withdrawal of the head when being touched, putting the head under the substrate, usually high level of activity and attempts to escape. This study relies on owner reports and, therefore, problems may have been under-reported.

Declaration of interest

None.

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