

The Herpetological Bulletin

Issue 163, Spring 2023





THE HERPETOLOGICAL BULLETIN

The Herpetological Bulletin is a full colour, quarterly publication in English, without page charges to authors. It includes full-length papers, natural history notes, book reviews, and other items of general herpetological interest. Emphasis is placed on natural history and conservation as well as captive care that includes breeding, husbandry, veterinary, and behavioural aspects.

All *British Herpetological Society* (BHS) members have access to issues of *The Bulletin* once they have been uploaded to the Society's website. Certain articles are **open access** from the time of release, these include articles containing a hyperlink to an illustrative video and those **written by BHS members** (encouraging authors to become *BHS* members). Other articles remain 'subscription-only' for one year. A printed version of *The Bulletin* is also distributed to those *BHS* members who subscribe to hardcopy.

The Editors are keen to ensure that *The Bulletin* is open to as wide a range of contributors as possible. If a potential author has concerns about compliance with submission guidelines (see below) or the suitability of a manuscript, then please contact the Scientific Editor for discussion.

Editorial team of The Herpetological Bulletin

Scientific editor:	Prof. Rick Hodges	herpbulletineditor@gmail.com
Managing editor:	Mrs. Julie Tee	managingeditor@thebhs.org
Associate editors:	Dr. Stuart Graham	stuartgrahamuk@hotmail.co.uk
	Dr. Chris Michaels	christopher.michaels@zsl.org

Abbreviated Submission Guidelines for Contributing Authors

Authors should read and adhere to *The British Herpetological Society's* Ethical Policy and Guidelines, a full version of which can be found at https://www.thebhs.org/images/stories/BHS-ethicspolicy.pdf. All submissions are assessed for ethical considerations and publication may be refused for non-compliance. Contributors may therefore need to justify killing or the use of other animal procedures if these have been involved in the execution of the work. Likewise, full justification is required for studies involving the collection of endangered species or disturbance to their habitat(s).

- 1. See the BHS website for full 'Instructions for Authors' and a free download of a copy of *The Bulletin* showing house style.
- 2. Text contributions should be plain formatted with no additional spaces or tabs. Footnotes should not be used.
- 3. The References section must be formatted following The Bulletin house style (refer to this issue or a recent copy on the BHS website as a guide to style and format). Attention should be given to the format of citations within the text.
- 4. Images (photographs, graphs, illustrations) may be embedded within the text file of a submitted article but must also be submitted separately as PDF (preferred), TIFF or JPEG files. Images should be entirely relevant to the text and numbered sequentially with Arabic numbers (i.e. Figure 1. etc.). Images should be at a maximum 300 dpi resolution although higher resolution files may be requested in the case of images selected for the front cover or for other promotional purposes.
- 5. By submitting a manuscript, authors agree that the copyright for their article (including images) is shared with the publisher if and when the article is accepted for publication. This arrangement covers the rights of the BHS to reproduce and distribute the article, including reprints and photographic reproductions. However, authors also retain the right to use and distribute their article and its images as they see fit.
- 6. Where appropriate, authors will be requested to deposit their data sets, e.g. audio files, genetic analyses etc., in an archive with public access.
- 7. Authors are encouraged to submit relevant video footage that can be linked to their published articles. To do this, submit a title for the video and a short introductory text along with your manuscript. The video file itself, which is potentially very large, should be sent to the managing editor, Julie Tee, (managingeditor@thebhs.org) using Wetransfer (wetransfer.com) which is available free of charge. When an article is published, the video will be uploaded to the BHS video channel and a hyperlink inserted into the article to connect it to the video and vice versa. Articles with hyperlinks to videos will be open access from the time that they are uploaded to the BHS website (i.e. they will not be embargoed for a year).
- 8. Authors will be informed promptly of receipt of their manuscript but this does not infer acceptance for publication. All contributions are liable to assessment for suitability and ethical issues and all articles are subject to peer-review.
- 9. The Editor reserves the right to shorten or amend a manuscript, although substantial alterations will not be made without permission of the primary author. Occasionally, photographs and text from selected articles will be used for publicity purposes on the social media of the British Herpetological Society, where all relevant acknowledgements will be made.
- 10. Authors will be supplied with a portable document file (pdf) of their published article and a complimentary copy of the full printed issue.
- 11. All manuscript submissions and correspondence arising from The Bulletin should be sent to the Editor, herpbulletineditor@gmail.com
- 12. Articles reporting the results of experimental research, descriptions of new taxa, or taxonomic revisions should be submitted to *The Bulletin's* sister publication *The Herpetological Journal* (see inside back cover for Editor's address).

Note that the views expressed by contributors to *The Herpetological Bulletin* are not necessarily those of the Editor or the *British Herpetological Society*.

Front Cover: A neonate Vipera berus in the wheat chaff remaining after harvest in an arable field margin in Kent (England) photographed by Clifford Seabrook, see article on p.15.

THE HERPETOLOGICAL BULLETIN

Contents: Issue 163, Spring 2023

RESEARCH ARTICLES:

Reproduction and population traits of the Atlantic forest free frog <i>Bokermannonyla nylax</i> : an exploratory study in an	
urban forest fragment in São Paulo municipality, Brazil	
FRANCINE LUENGO FERREIRA & CYBELE SABINO LISBOA	1
Aspects of the natural history of the Sertao lancehead Bothrops lutzi from Brazil	
CICERO RICARDO DE OLIVEIRA, ROBSON WALDEMAR ÁVILA & IGOR JOVENTINO ROBERTO	9
Evidence that agri-environmental measures in arable fields could be a conservation benefit to northern vipers Vipera	
berus and other reptiles	
RICK HODGES, CLIFFORD SEABROOK, VANESSA WELSH & WILLIAM ALEXANDER	15

SHORT NOTES:

Further evidence of ophiophagy, including cannibalism, by the western whip snake <i>Hierophis viridiflavus</i> in Italy	
ANGELO VACCARO, GIOVANNI ALTADONNA & GIUSEPPE FABRIZIO TURRISI	21
The Madeira lizard Teira dugesii may have the greatest population density of any terrestrial vertebrate	
KEVIN ARBUCKLE & ALEXANDER J. NICHOLS ARBUCKLE	24
New insights into the distribution of the gharial <i>Gavialis gangeticus</i> in Bangladesh from the analysis of news reports	
MD. FAZLE RABBE, SUMAIYA AKTER, MD. MAHFUZAR RAHMAN & AZIZUL ISLAM BARKAT	28
After 160 years of 'silence': the advertisement call of the frog Ischnocnema verrucosa	
ALAN PEDRO DE ARAÚJO, RODRIGO BARBOSA FERREIRA, CLARISSA CANEDO, CÁSSIO ZOCCA & JOÃO VICTOR	
A. LACERDA	31

SHORT COMMUNICATIONS:

Pelvic spur use during courtship and mating in the red-tailed boa <i>Boa constrictor</i>	
RAFAEL KENJI ANZAI, NICOLAS FONTANA ELEUTERIO, TIAGO DE OLIVEIRA LIMA, RAFAEL HADDAD MANFIO &	
SELMA MARIA DE ALMEIDA SANTOS	35
First record of the Indian smooth snake Wallophis brachyura from Karnataka, India	
D. DEEPAK, S. BABU, H.N. KUMARA & R.S. NAVEEN	37

NATURAL HISTORY NOTES:

Common wall lizards <i>Podarcis muralis</i> at a new site in England registered by a citizen science reporting tool	
WILL JOHANSON & JENNY TSE-LEON	39
The first record of a viviparous lizard Zootoca vivipara predating a blue-tailed damselfly Ischnura elegans	
JOSHUA DARKIN	41
Aestivation of the spectacled caiman Caiman crocodilus in Colombia	
EDISON D. BONILLA-LIBERATO, NIDIA FÁRFAN-ARDILA & SERGIO A. BALAGUERA-REINA	42
Predation by a smooth snake Coronella austriaca of an aspic viper Vipera aspis in Spain	
ENEKO I. ESCALANTE, PRZEMYSŁAW ZDUNEK & ALEKSANDRA KOLANEK	44
Death-feigning in the lizard Leposoma scincoides	
CÁSSIO ZOCCA, JOÃO PEDRO KLOSS-DEGEN & RICARDO LOURENÇO-DE-MORAES	46

HERPETOLOGICAL BULLETIN REPORT .		48
----------------------------------	--	----

Reproduction and population traits of the Atlantic forest tree frog Bokermannohyla hylax: an exploratory study in an urban forest fragment in São Paulo municipality, Brazil

FRANCINE LUENGO FERREIRA¹ & CYBELE SABINO LISBOA^{2*}

¹Mendelics Análise Genômica, 02511-000, São Paulo, SP, Brazil ²Zoológico de São Paulo - Reserva Paulista, Setor de Herpetofauna. 04301-905, São Paulo, SP, Brazil

*Corresponding author e-mail: cyb.lisboa@yahoo.com.br

ABSTRACT – *Bokermannohyla hylax* is an endemic tree frog from the Atlantic Forest and despite being a common species, very little is known about its population traits and reproduction. We undertook acoustic and visual encounter surveys, and individual marking studies of a subpopulation in an urban forest fragment, the Parque Estadual das Fontes do Ipiranga, located in the São Paulo municipality. We detected a small population that breeds in only one forest stream, and deposits eggs inside burrows along the stream's clayey border. Our findings also suggest that this subpopulation might be vulnerable due to the specific characteristics of its reproduction, which may be affected by the degree of disturbance of this fragment.

INTRODUCTION

Brazil has the greatest amphibian species richness in the world, currently comprising 1,188 species of mostly anurans (Segalla et al., 2021). About 52 % of these species occur in the Atlantic Forest domain (625 sp.; Rossa-Feres et al., 2017), one of the main biomes in Brazil considered a global Biodiversity Hotspot (Ribeiro et al., 2011). The characteristics of this biome, which has a rough topography and numerous types of humid microhabitats, favours the endemism of species and also the specialisation of reproductive modes (Silva et al., 2012; Rossa-Feres et al., 2017). As a result, the Atlantic Forest is home to the greatest diversity of anuran reproductive modes (Haddad & Prado, 2005).

The Atlantic Forest has experienced an intense historical process of deforestation and fragmentation with only approximately 12 % of its original area remaining today (Ribeiro et al., 2011). In some areas of the Atlantic Forest in south-eastern Brazil, the depletion of previously flourishing anuran communities has been recorded and this can be attributed to habitat degradation and fragmentation (Haddad & Prado, 2005; Ribeiro et al., 2011; Almeida-Gomes & Rocha, 2015). Studies on life-history are essential to better understand the species-area relationship, which is fundamental to the success of actions that preserve biodiversity (Almeida-Gomes & Rocha, 2015).

Bokermannohyla hylax Heyer, 1985, is an endemic tree frog from the Atlantic Forest with a wide geographic distribution in the south and south-east of Brazil, from the south of Rio de Janeiro to north of Santa Catarina states (Napoli, 2000). It is a medium-sized species which presents yellowish-brown tones in the dorsum with an inguinal band and the ventral surface of its thigh is a characteristic purple colour (Heyer, 1985). The genus *Bokermannohyla* comprises 30 species (Frost, 2022), of which only a few have had detailed studies of their reproductive behaviour.

Despite being a common species, almost nothing is known about the life history of *B. hylax* (Carvalho-e-Silva & Pavan, 2010). The current investigation focuses on a subpopulation that occurs in an urban forest fragment located in the São Paulo municipality and describes some reproductive behaviour of this species, including calling activity and clutch characteristics, and also makes an estimate of population size. We also evaluated the marking methods we used, verifying their effectiveness in meeting our goals.

MATERIALS & METHODS

Study Area

The study was carried out at the Parque Estadual das Fontes do Ipiranga (PEFI), in the municipality of São Paulo, São Paulo state, south-eastern Brazil (Fig. 1). It is an Atlantic Forest fragment (around 495 ha; São Paulo, 2013) surrounded by urbanisation, covered by vegetation in different successional stages with characteristics representing both dense ombrophilous and semideciduous forests (Tanus et al., 2012). For data collection, we visited the Pirarungáua Stream, which is a small tributary (around 400 m of its extension have riparian forest) of the Ipiranga River, one of the main rivers in the municipality of São Paulo (Formenton-Silva & Rancura, 2020). We sampled in this stream only because the reproductive activity of *B. hylax* occurs only at this point within the PEFI (Lisboa et al., 2021) and we didn't find any other suitable habitat there.

The banks of the stream had a low clayey edge, where burrows with water accumulated inside can be found. The stream has a slow but steady flow of running water. The bank was surrounded by vegetation and the ground covered



Figure 1. Location of the two sampling sites (yellow dots) in the Parque Estadual das Fontes do Ipiranga, south-eastern Brazil, showing the close proximity of this forest fragment to the urban environment

with leaf litter. We sampled two stretches of the stream (23° 38.357' S, 46° 37.117' W; 815 m a.s.l. and 23° 38.334' S, 46° 36.903' W; 781 m a.s.l.), which were between 12 to 23 m in length, 1.20 to 1.70 m in width and the depth ranged from 0.5 to 0.42 m (measures were collected during the dry season). The width, depth and intensity of the watercourse may differ throughout the seasons due to the rainfall rate. The climate of the region is characterised by a dry winter (April to September) and a rainy summer (October to March), with average temperatures varying from 18 °C in the winter to 22 °C in the summer (Santos & Funari, 2002).

Data collection

We carried out monthly field campaigns, with two to four people, lasting from one to seven days in the period from September 2013 to June 2014, totalling ten months. Observations began between 18:00 h and 19:00 h and lasted at most until 23:00 h, totalling 39 days, giving a total of 91 hours in the field. To find individuals, we conducted acoustic and visual encounter surveys (sensu Crump & Scott Jr., 1994). During behavioural calling observation, we used a red light to minimise interference or disturbance of the individuals. After the observations, we captured the individuals to obtain morphometric information, such as snout-vent length (SVL), measured with a 0.05 mm precision caliper (Digemess®), and body mass (BM), measured on a scale with a capacity of 1000 g x 0.1 g (Digital Scale[®]). Measurements of SVL were always taken in the same position: we held the frog by its hind limbs while it supported itself with its hands in our finger; at that time, we kept the specimen body straight to avoid arching.

In order to obtain information about the population (described below) and also about the individual's behaviour, we used two methods of marking: photo-identification and Visible Implant Elastomer (VIE). Because individuals have different colour patterns, we used photo-ID for all individuals (Fig. 2A&B), which were photographed in three standard positions: left side, right side and back. The VIE was applied to the subcutaneous tissue (Fig. 2C) of the back, one of the limbs or both limbs of the individual, using three different fluorescent colours (green, pink and orange) or a combination between them.



Figure 2. Identifying individual *Bokermannohyla hylax* - **A.** & **B.** Natural colour patterns used for photo-identification, and **C.** Green visible implant elastomer applied subcutaneously into the left leg

We determined the sex of males through their calling activity or by the presence of vocal sacs and well-developed pre-pollical spines (Heyer, 1985). Females were determined by the presence of eggs in the abdominal region and also by the absence of vocal sacs. For individuals in which we could not detect these characteristics, we considered them to be 'undetermined sex'.

Population data analyses

For population size estimation we used a model for closed populations (i.e. no significative births, deaths, immigration, or emigration are assumed), due to the characteristics of our population and length of study (ten months): we studied an adult population (not enough time for births) and isolated from others (no immigration and emigration were considered). We performed analyses using the Schnabel-Schumacher method in the Ecological Methodology Version 7.4 software (Krebs, 2019), with 95 % of confidence limits (lower and upper).

Bioacoustic analyses

We recorded male's vocalisations with a SONY-PCM-D50 sound recorder, at a sample frequency of 44.1 kHz and a

sample size of 16 bits, which was positioned at a distance of 0.5 to 1.5 m from the calling male. We analysed 194 calls from nine males in the Raven Pro 1.4 software (K. Lisa Yang Center for Conservation Bioacoustics, 2011), using the following spectrogram parameters: window type Hann and size of 256 samples, which resulted in a 3 dB filter bandwidth of 248 Hz, overlap at 50 % (locked; hop size = 128 samples) for time grid, and DFT of 256 samples (grid spacing = 172 Hz) for frequency grid. We used the configurations of 52–64 % brightness, 60–70 % contrast, and a Fast Fourier Transform length (FFT) of 256 points. All other settings followed the software default values. We measured spectral traits using the spectrogram and temporal traits using the oscillogram.

To describe acoustic call traits, we followed Köhler et al. (2017). For spectral parameters, we obtained the dominant frequency with the Peak Frequency function and the minimum and maximum frequencies with the Frequency 5% and Frequency 95% functions, respectively. We also used the two last functions for estimating the bandwidth that concentrates 90% (BW 90%) of the energy of the call.

For temporal parameters, such as note duration, intervals between pulse groups, notes and calls, we used the Delta Time function. We measured call rate by calculating the ratio of the number of calls and the duration in which these calls were emitted. We measured pulses per note manually using the oscillogram and pulse rate by calculating both the ratio of the number of pulses and the duration of the note. We excluded notes that were masked by background noise from the pulse count. For the definition of note, we followed McLister et al. (1995), where 'note' refers to the unit of sound produced during a single airflow cycle (lung to vocal sac), and we determined the number of notes per call by observing the movement of the vocal sacs.

We used linear regression based on Pearson's correlation coefficient (r) to assess whether dominant frequency, call rate and call duration were correlated with air temperature and SVL. The analyses were performed using the Past 2.17 software (Hammer et al., 2001) with significance set at the level of 0.05. All recordings were deposited in Fonoteca Neotropical Jaques Veilliard (FNJV 50714–50732).

RESULTS

Population characteristics

In total, we recorded 48 individuals of *B. hylax*, of which 35 were males (72.9 %), one was female (2.1 %), and 12 were of undetermined sex (25 %). Males had SVL ranging from 45.1 to 53.3 mm (mean \pm sd - 49.3 \pm 2.3 mm, N = 35) and BM from 5.4 to 8.7 g (6.84 \pm 0.87 g, N = 32). The only female found measured 55.4 mm and presented 8.98 g of BM. Individuals whose sexes were not determined had SVL ranging from 39 to 57 mm (51.5 \pm 5.3 mm, N = 9) and BM from 3.1 to 9.7 g (7.57 \pm 2.05 g, N = 9).

Thirty-seven individuals received VIE marking and all of them photo-ID. During the entire study period, the recaptured animals marked with VIE remained with the marking, however, in some of them there was migration of the polymer to the ends of the limbs. The natural marks present on the lateral region of the thighs and on the back



Figure 3. Male *Bokermannohyla hylax* calling - A. Exposed, and B. In a burrow on the banks of the stream

presented a unique pattern for each individual, thus allowing for the easy recognition of individuals through photo-ID.

We found the 48 individuals 122 times, of which 74 were recaptures referring to 28 individuals (58.3 % of the study population was recaptured). The Schnabel-Schumacher method estimated a total of 45.9 individuals (confidence limits: 37.1–60) and of 52.2 individuals (44.6–62.8), respectively. Twenty individuals were captured only once, but one individual was captured nine times. Regarding the time span between the first time the individual was found and the last time, most individuals were recaptured in the same month or in the month following capture, however, two individuals were recaptured after six months and one individual after seven months.

Calling activity and bioacoustic traits

Male calling activity was recorded throughout the study period (September to June), but the months with lower intensity were March and April. They began to call around 19:00 h, and the chorus became more intense around 21:00 h. Males' calling site varied, but it was always associated with the margins of the Pirarungáua Stream. We registered 61 times the marked males in calling activity. We found them mostly calling exposed (Fig. 3A), perched on branches, stems, or broad leaves (77 %, N = 47 times), but also hidden, on the floor in litter-covered stream puddles (19.7 %, N = 12 times) or in holes on the banks (3.3 %, N = 2 times; Fig. 3B). **Table 1**. Advertisement call variables of *Bokermannohyla hylax*, a total of 194 calls were recorded from nine males at 21.08 \pm 1.15 °C (19.2–22.7) air temperature. Data are presented as mean \pm standard deviation (range).

Call traits		Note A	Note B	Note C
Note duration (ms)		512.5 ± 127.7 (282–1014)	434 ± 64.4 (306–554)	61.8 ± 12.7 (47–86)
Dominant frequency (Hz)		1991.1 ± 253.9 (1378.1–2584)	2044.7 ± 163.1 (1722.7–2411.7)	1615 ± 321.6 (1033.6–2067.2)
Maximum frequency (Hz)		2456.1 ± 176.5 (2239.5–2928.5)	2599 ± 263.5 (2239.5–3273)	2261 ± 250.2 (1894.9–2756.2)
Minimum frequency (Hz)		1117.1 ± 199.5 (689.1–2067.2)	1078 ± 216.8 (689.1–1550.4)	818.3 ± 142.8 (689.1–1033.6)
Frequency bandwidth (Hz)		1339 ± 166.7 (516.8–1722.7)	1520.4 ± 207.3 (1205.9–2067.2)	1422.7 ± 209.9 (1205.9–1894.9)
Internote interval (ms)		-	-	156.9 ± 68.5 (12–221)
Pulses/note		53.9 ± 19.6 (25–156)	104.3 ± 28 (65–152)	23 ± 6.5 (14–30)
Pulse rate (pulses/second)		106.5 ± 34.7 (61.6–257.4)	239.3 ± 54.5 (137.5–342.1)	372 ± 64.9 (297.9–500)
Interval between pulse groups (ms)		40.5 ± 17.4 (4-1)	43.2 ± 16.3 (19–74)	-
Call rate (calls/min)	26.6 ± 11.6 (9.7 – 49.4)			
Intercall interval (ms)	26.6 ± 11.6 (9.7 – 49.4)			

We recognised only one call type in our records and field observations, the advertisement call (quantitative traits are summarised in Table 1). This call presents a multipulsed structure, released at a rate of 26.6 ± 11.6 calls/minute (range 9.7–49.4; N = 194). The intercall interval ranged from 169–9493 ms (2440.3 \pm 1954.3; N = 183). Advertisement calls (N = 194 calls from 9 males) are composed mostly by one single note (95.9 %) or eventually by two (4.1 %). In the single note call, we recognised two types of notes, herein referred to as Note A and Note B. In the two note calls, we also identified a third type, Note C, which is always emitted before Note A or Note B (Fig. 4).

Note A is the typical advertisement call and was the most frequent in our records (84 %). This note presents a duration of 512.5 \pm 127.7 ms (282–1014; N = 163) and a dominant frequency of 1991.1 \pm 253.9 Hz (1378.1–2584). Notes have 53.9 \pm 19.6 pulses (25–156; N = 106 notes), which are emitted at rates of 106.5 \pm 34.7 pulses/second (61.6–257.4). Pulses are usually arranged in well-defined pulse groups and, eventually, silent intervals between pulses can occur (up to four per note) which last 40.5 \pm 17.4 ms (4–91; N = 146 intervals).

Note B is released randomly during calling activity and appeared 11.8% of the time in our records. This note presents a duration of 434 ± 64.4 ms (306–554; N = 23) and a dominant frequency of 2044.7 ± 163.1 Hz (1722.7–2411.7). Notes have 104.3 ± 28 pulses (65–152; N = 20 notes), which are emitted at rates of 239.3 ± 54.5 pulses/second (137.5–342.1). Pulses

are usually arranged in well-defined pulse groups in the first third and juxtaposed in the final portion of the note, which sounds like an off-key call. Eventually, silent intervals between pulses of the first half of the note can occur (up to two per note) and they last 43.2 \pm 16.3 ms (19–74; N = 16 intervals).

Note C is also released randomly during calling activity, but less frequently (4.1 %), and it sounds like a hiccup. This note presents a mean \pm sd duration of 61.8 \pm 12.7 ms (range 47–86; N = 8) and a dominant frequency of 1615 \pm 321.6 Hz (1033.6–2067.2). Notes have 23 \pm 6.5 pulses (14–30; N = 7 notes), which are emitted at rates of 372 \pm 64.9 pulses/ second (297.9–500). Pulses are not arranged in pulse groups and there is no silent interval between pulses. The interval between Note C and Note A or B is 156.9 \pm 68.5 ms (12–221; N = 8 intervals).

Neither dominant frequency (r = -0.12; p = 0.76), call rate (r = -0.12; p = 0.76) or call duration (r = 0.25; p = 0.52) were correlated with air temperature. Call rate (r = 0.18; p = 0.65) and call duration (r = 0.44; p = 0.24) were also not correlated with SVL, but dominant frequency was inversely correlated with SVL (r = -0.77; p = 0.01).

Clutch and oviposition site

During the entire study period we found only one clutch of eggs, on 9 June 2014. The clutch contained approximately 120 eggs, wrapped in a gelatinous mass, deposited in a burrow formed in the stream's clayey border. We found



Figure 4. Audio spectrograms (below) and corresponding oscillograms (above) of the advertisement calls of *Bokermannohyla hylax* at the Parque Estadual das Fontes do Ipiranga - **A.** The call can be composed by one single note, or **B.** Composed of two notes. Three different notes were identified (Note A, B, and C). Air temperature during record was 22.7 °C.

this burrow due to the presence of a male calling at the entrance, where three eggs were observed (Fig. 5A), which were possibly dragged there by this male. The burrow was about 15 cm above the water surface. The entrance to the burrow measured 4 cm in diameter with a corridor with 17 cm in length reaching a 9 x 6 cm chamber with a thin layer of water, where most of the eggs were concentrated (Fig. 5B). The eggs were not completely submerged, just in contact with water. Another burrow found with the presence of a male vocalising, but without eggs, was measured and had the same entrance diameter, a corridor with 29 cm in total length and was located at the height of the water surface.

We collected 28 eggs and took them to the laboratory to monitor their development, from which 19 tadpoles emerged after seven days. On the following day after hatching, the tadpoles had a total length that ranged from 12.9 to 15.6 mm (14.2 \pm 0.8, N = 19) and body length that ranged from 3.2 at 4.5 mm (4.1 \pm 0.3, N = 19). On some occasions in the field, we recorded tadpoles of the species in the stream, close to the edge and in front of the burrows in the stream bank, where we often found males calling.

DISCUSSION

Population traits and marking effectiveness

Our findings suggest that the adult population of *B. hylax* in the PEFI might be small, as most encounters were related to recaptures and estimated population sizes were similar to our study population, with a maximum of 62 individuals. However, we must take into account that our samples were composed of males, as these are easier to detect, which may have contributed to an underestimation of the real population size (Pham et al., 2007). Moreover, imperfect detection is not a trivial fact in any field study (Schmidt & Pellet, 2010). Even without comparative population data for this species in larger forest areas, it is expected that isolated



Figure 5. Egg clutch of *Bokermannohyla hylax* found in a clay burrow at stream border - **A.** Entrance of the burrow with some eggs, **B.** Chamber inside the burrow, distance of 17 cm from the entrance, containing approximately 120 eggs. Red arrows are pointing to the eggs. Note that the chamber was opened manually.

areas such as the PEFI present unbalanced situations, such as very abundant or extremely reduced populations (Becker et al., 2007). The isolation may also have affected the body size of the individuals from our study site as males were smaller (45–53 mm) than those from the type locality in Boracéia municipality, State of São Paulo, Brazil (55–62 mm; Heyer, 1985). However, despite standardising our technique for collecting measurements to avoid biases, it remains possible that some of these differences are attributable to different methodological approaches. In this context, it would be interesting to carry out a more current study and measure the individuals of the type locality with the same methodology that we used or vice versa.

The reliability of our population data, obtained from capture and recapture, was supported by the marking methods, VIE and photo-ID, which proved to be efficient for this study. The association of both methods allowed us to recognise all the recaptured individuals, as it reduced the percentage of error or difficulties that each one can generate (Campbell et al., 2009; Ferner, 2010; McHarry et al., 2018) and, for B. hylax, these are good alternatives to replace the toe clipping method (Campbell et al., 2009). The VIE was visible due to the translucency of the skin at the application site and was helpful for identification in the field, sometimes without the need to capture the animal. However, the similarity of some colours (orange and pink were very similar in the skin) and elastomer migration (Campbell et al., 2009), created uncertainty on some occasions. The photo-ID method was essential to confirm the individual after comparison with registered photos, reinforcing the accuracy of this method for some species of anurans (Ferner, 2010). Although long-term studies with VIE are scarce, causing uncertainties about future problems in individuals (Antwis et al., 2014), the technique has already been shown to be efficient for salamanders, with records of individuals recaptured five years after marking (Lunghi & Bruni, 2018). In this study, we did not observe damage in the frogs caused by marking with VIE, as it was possible to find individuals up to six or seven months after application.

Calling activity

Apparently, B. hylax is active throughout the year in the PEFI, with a lower rate of reproductive activity between months March and April, corroborating the studies by Peres (2010) and Bertoluci et al. (2021). The calling site of males, perched in low vegetation or inside holes on the banks of the stream, also corroborates other studies (Pombal Jr. & Gordo, 2004; Silva et al., 2011; Carvalho et al., 2012; Bertoluci, 2021). Although our data showed a low rate of males calling in holes, these data are underestimated, as we only counted them if we could identify the individuals concerned, and often capturing them in holes was not possible. The choice of calling site can be related to the proximity to the females, because the location can influence the call intensity and sound propagation quality (Wells, 2007). Thus, it is possible that perched males of B. hylax were calling to attract more distant females, while buried males would likely attract females that were closer by.

In our recordings, it was only possible to identify the advertisement call, as the individuals observed did not

exhibit any differentiated behaviour that could allow us to characterise other types of calls, such as courtship for example (Wells, 2007; Köhler et al., 2017). We identified three types of notes emitted during the advertisement call, whose spectral and temporal parameters were very similar to those described by Carvalho et al. (2012). Comparing the description and structure of the notes, we assume that Note A of our study is the same 'Note A' of the study by Carvalho et al. (2012), however our Note B is probably related to the 'Note C' of these authors and our Note C is more similar to their 'Note D'. We did not identify in our recordings the note identified by them as 'Note B'.

Temporal parameters of the anuran calls are usually influenced by air temperature (Köhler et al., 2017). In our study, temporal features showed no correlation with the air temperature, probably due to the small range of air temperature when we made the recordings. Regarding the intrinsic factors of the calling male, the dominant frequency showed a negative correlation with SVL, i.e. the larger the individual's size, the lower the frequency emitted. This type of correlation is considered the most common among anurans (Wells, 2007) and can be explained by the fact that larger frogs have longer vocal cords. This affects the female's choice for mating, which recognises the suitable male through the call frequency (Köhler et al., 2017).

Clutch characteristics and reproductive mode

Based on our observations of the egg clutch we found inside a burrow and the encounter of tadpoles in the water body close to the edge that contains these burrows, the best fit for B. hylax is reproductive mode #4 (Haddad & Prado, 2005) described as "eggs and early larval stages are found in natural or constructed basins; subsequent to flooding, exotrophic tadpoles in ponds or streams". Although we were unable to observe the complete reproductive behaviour (courtship, amplexus and oviposition), we believe that our data, together with that of other studies (Bertoluci et al., 2003; Pombal Jr. & Gordo, 2004; Silva et al., 2011), provide evidence to support this reproductive mode. We also suggest that males can construct nests, as the burrow containing a clutch that we observed, and another one with no eggs that we opened, seem to have been built, as the entrance was very narrow and opened into a concave chamber. Silva et al. (2011) observed a male building a concave nest, pushing the earth to the edge with his hind limbs and leaving the backwater. We recorded several other burrows with calling males, most with the external characteristics similar to this one: made of clay and with the entrance disguised by roots or fallen dry leaves.

The clutch we found in this study had 120 eggs, but Bicudo et al. (2013) recorded about 400 eggs per clutch. There are several possible reasons for this difference including the size or age of females, the number of clutches produced by a female in one season, the existence of communal masses (Wells, 2007), or even to the variation among populations that is usually attributed to differences in temperature, altitude, or latitude (Morrison & Hero, 2003). We found the clutch in June, and Bicudo et al. (2013) found the clutches between the months of April and September, indicating that the greater oviposition activity of *B. hylax* is in the winter.

This can be advantageous for the species, as stream tadpoles tend to develop more slowly, metamorphosis will complete during the rainy season, when environmental conditions are more suitable for the froglets (Eterovick et al., 2010).

Considering the characteristics of the reproduction of *B. hylax*, the findings of our study suggests that subpopulations of this species that occur in disturbed fragments may be endangered by that (Becker et al., 2007). Reproductive modes that present aquatic larvae, especially stream-breeders, are particularly vulnerable, since they depend on forest humidity (Haddad & Prado, 2005; Costa et al., 2012). These factors, associated with the small size of this subpopulation that reproduces in only one forest stream, serve as a warning to the risks for the species' maintenance in the PEFI. This fragment is heavily impacted by fragmentation and urbanisation and the disappearance of some anuran species within an approximate interval of ca. 50 years has already been detected (Lisboa et al., 2021).

ACKNOWLEDGEMENTS

We thank two anonymous reviewers and Rick Hodges for their helpful insights and Fundação Parque Zoológico de São Paulo (FPZSP) for supporting this work. We are grateful to Cynthia Almeida Prado for being so attentive reviewing the manuscript. We would like to thank our colleagues for their help in the field, especially Ana Paula Brandão, Bruno Mathias, Carolina Anjos, Giovana Castro, Janaina Moraes, Rachel Venturini, Rodrigo Alves and Talyta Rocha. We also thank Caio Motta, Cinthia Brasileiro, Julián Faivovich, Leo Malagoli and Taran Grant for discussion during the study, and Tiago Pezzuti for helping to identify the tadpoles. We thank the Instituto Chico Mendes (ICMBio) for providing the SISBIO permit (No. 41426), the CGEn for the SisGen permit (No. AF05F82), and the Instituto de Botânica for giving us permission to work at the Parque Estadual das Fontes do Ipiranga.

REFERENCES

- Almeida-Gomes, M. & Rocha, C.F.D. (2015). Habitat loss reduces the diversity of frog reproductive modes in an Atlantic Forest fragmented landscape. *Biotropica* 47: 113–118.
- Antwis, R.E., Purcell, R., Walker, S.L., Fidgett, A.L. & Preziosi, R.F. (2014). Effects of visible implanted elastomer marking on physiological traits of frogs. *Conservation Physiology* 2: 1–9.
- Becker, C.G., Fonseca, C.R., Haddad, C.F.B., Batista, R.F. & Prado, P.I. (2007). Habitat split and the global decline of amphibians. *Nature* 318: 1775–1777.
- Bertoluci, J., Xavier, V. & Cassimiro, J. (2003). Description of the tadpole of *Hyla hylax* Heyer, 1985 (Anura, Hylidae) with notes on its ecology. *Amphibia-Reptilia* 24: 509–514.
- Bertoluci J., Sawakuchi, H.O., Ortiz, C., Brassaloti, R.A., Ribeiro-Júnior, J.W. & Famelli, S. (2021). Anuran fauna of the Parque Estadual Carlos Botelho - NúcleoSete Barras, southeastern Brazil: species composition, use of breeding sites, and seasonal patterns of breeding activity. *Biota Neotropica* 21: 1–12.

- Bicudo, E.P., Prado, C.P.A. & Baldissera Jr, F.A. (2013). Comportamento reprodutivo de *Bokermannohyla hylax* (Heyer, 1985) (Amphibia - Anura) do Forte dos Andradas, Guarujá, Estado de São Paulo, Sudeste, Brasil. *VI Congresso Brasileiro de Herpetologia, Salvador - Bahia, Brasil.*
- Campbell, T.S., Irvin, P., Campbell, K.R., Hoffmann, K., Dykes, M.E., Harding, A.J. & Johnson, S.A. (2009). Evaluation of a new technique for marking anurans. *Applied Herpetology* 6: 247–256.
- Carvalho, T.R., Giaretta, A.A. & Magrini, L. (2012). A new species of the *Bokermannohyla* circumdata group (Anura: Hylidae) from southeastern Brazil, with bioacoustic data on seven species of the genus. *Zootaxa* 3321: 37–55.
- Carvalho-e-Silva, S.P. & Pavan, D. (2010). *Bokermannohyla hylax. The IUCN Red List of Threatened Species.* https:// www.iucnredlist.org/species/55506/11320014. Accessed on 9 October 2021.
- Costa, T.R.N., Carnaval, A.C.O.Q. & Toledo, L.F. (2012). Climate change and its impacts on Brazilian amphibians. *Revista da Biologia* 8: 33–37.
- Crump, M. & Scott Jr, N.J. (1994). Standard techniques for inventory and monitoring: Visual-Encounter Surveys. In *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. 84–92 pp. Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.C. & Foster, M.S. (Eds.). Smithsonian Institution Press, Washington, D.C., USA.
- Eterovick, P.C., Lazarotti, I., Franco, B.P. & Dias, C.J. (2010). Seasonal variation of tadpole spatial niches in permanent streams: the role of predation risk and microhabitat availability. *Austral Ecology* 35: 879–887.
- Ferner, J.W. (2010). Measuring and marking postmetamorphic amphibians. In Amphibian Ecology and Conservation: a handbook of techniques, 123–141 pp. Dodd Jr, C.K. (ed.). New York: Oxford University Press Inc.
- Formenton-Silva, N. & Rancura, K.G.O. (2020). Parque Estadual das Fontes do Ipiranga: *Biodiversidade, Conservação e Educação*. 1st Edition. São Paulo, Brazil. Fundação Parque Zoológico de São Paulo.
- Frost, D.R. (2022). Amphibian Species of the World: an Online Reference. Version 6.1 (25 January 2020). American Museum of Natural History, New York, USA. http:// research.amnh.org/herpetology/amphibia/. Accessed on 2 July 2022.
- Haddad, C.F.B. & Prado, C.P.A. (2005). Reproductive modes in frogs and their unexpected diversity in the Atlantic Forest of Brazil. *BioScience* 5: 207–217.
- Hammer, Ø., Harper, D.A.T. & Ryan, P.D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1). https://palaeo-electronica.org/2001_1/past/issue1_01. htm.
- Heyer, W.R. (1985). New species of frogs from Boracéia, São Paulo, Brazil. Proc. Biol. Soc. Wash. 98: 657–671.
- K. Lisa Yang Center for Conservation Bioacoustics. (2011). Raven Pro: Interactive Sound Analysis Software. Version 1.4. Ithaca, NY: The Cornell Lab of Ornithology. https:// ravensoundsoftware.com/

- Köhler, J., Jansen, M., Rodriguez, A., Kok, P.J.R., Toledo, L.F., Emmrich, M., Glaw, F., Haddad, C.F.B., Rödel, M.O. & Vences, M. (2017). The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. *Zootaxa* 4251: 1–124.
- Krebs, C.J. (2019). *Programs for Ecological Methodology*. Version 7.4. https://www.zoology.ubc.ca/~krebs/books. html.
- Lisboa, C.S., Vaz, R.I., Malagoli, L.R., Barbo, F.E., Venturini, R.C. & Brasileiro, C.A. (2021). Herpetofauna from an Atlantic Forest fragment in São Paulo, Brazil. *Herpetological Conservation and Biology* 16: 436–451.
- Lunghi, E. & Bruni, G. (2018). Long-term reliability of Visual Implant Elastomers in the Italian cave salamander (*Hydromantes italicus*). Salamandra 54: 283–286.
- McHarry, K.W., Abbott, J.M., Hattem, M.G. & Hudgens, B.R. (2018). Efficacy of Visible Implant Elastomer Tags with Photographic Assist for Identifying Individuals in Capture-Mark-Recapture Studies using Larval Frogs. *Herpetological Conservation and Biology* 13: 576–585.
- McLister, J.D., Stevens, E.D. & Bogart, J.P. (1995). Comparative contractile dynamics of calling and locomotor Muscles in three hylid frogs. *The Journal of Experimental Biology* 198: 1527–1538.
- Morrison, C. & Hero, J.M. (2003). Altitudinal variation in growth and development rates of tadpoles of *Litori* schloris and *Litoria pearsoniana* in southeast Queensland, Australia. *Journal of Herpetology* 37: 59–64.
- Napoli, M.F. (2000). Taxonomia, variação morfológica e distribuição geográfica das espécies do grupo de Hyla circumdata (Cope, 1870) (Amphibia, Anura, Hylidae). Ph.D. Thesis, Universidade Federal do Rio de Janeiro. https:// pantheon.ufrj.br/bitstream/11422/3536/3/493356.pdf.
- Peres, P.B. (2010). Taxocenose de Anfíbios Anuros do Parque Ecológico e Ecoturístico de Pedras Grandes, Sul de Santa Catarina, Brasil. Unpublished Monograph. Universidade do Extremo Sul Catarinense, Brazil.
- Pham, L., Boudreaux, S., Karhbet, S., Price, B., Ackleh, A.S., Carter, J. & Pal, N. (2007). Population Estimates of *Hyla cinerea* (Schneider) (Green Tree Frog) in an Urban Environment. *Southeastern Naturalist* 6: 203–216.
- Pombal Jr., J.P. & Gordo, M. (2004). Anfíbios Anuros da Juréia. In *Estação Ecológica Juréia-Itatins*. Ambiente Físico, Flora e Fauna, 243–256 pp. Marques, O.A.V. & Duleba, W. (eds.). Ribeirão Preto, Brazil: Holos Editora.
- Ribeiro, M.C., Martensen, A.C., Metzger, J.P., Tabarelli, M., Scarano, F.R. & Fortin, M.J. (2011). The Brazilian Atlantic Forest: a shrinking biodiversity hotspot. In *Biodiversity Hotspots*, 405–434 pp. Zachos, F.E. & Habel, J.C. (eds.). Springer, Heidelberg, Germany.

- Rossa-Feres, D.C., Garey, M.V., Caramaschi, U., Napoli, M.F., Nomura, F., Bispo, A.A., Brasileiro, C.A., Thomé, M.T.C., Sawaya, R.J., Conte, C.E. et al. (2017). Anfíbios da Mata Atlântica: Lista de espécies, histórico de estudos, biologia e conservação. In *Revisões em Zoologia: Mata Atlântica*, 237–314 pp. Monteiro-Filho, E.L.A. & Conte, C.E. (orgs.). Curitiba, Paraná, Brazil: Universidade Federal do Paraná.
- Santos, P.M. & Funari, F.L. (2002). Clima Local. In Parque Estadual das Fontes do Ipiranga (PEFI): Unidade de Conservação que Resiste à Urbanização de São Paulo, 76– 93 pp. Bicudo, D.C., Forti, M.C. & Bicudo, C.E.M. (Orgs.). São Paulo, Brazil: Secretaria do Meio Ambiente do Estado de São Paulo.
- São Paulo. (2013). Lei nº 14.944, de 9 de janeiro de 2013: Autoriza a Fazenda do Estado a desafetar as áreas que especifica, integrantes do "Parque Estadual das Fontes do Ipiranga", e dá providências correlatas. Diário Oficial Poder Executivo - Seção I. São Paulo, 123(6): 3.
- Schmidt, B.R. & Pellet, J. (2010). Quantifying abundance: count, detection probabilities, and estimates. In Amphibian Ecology and Conservation: a handbook of techniques, 465–479 pp. Dodd Jr., C.K. (ed.). New York: Oxford University Press Inc.
- Segalla, M.V., Berneck, B., Canedo, C., Caramaschi, U., Cruz, C.A.G., Garcia, P.C.A., Grant, T., Haddad, C.F.B., Lourenço, A.C.C., Mângia, S. et al. (2021). List of amphibians of Brazil. *Herpetologia Brasileira* 10: 121–216.
- Silva, R.V., Dimitrov, V., Negri, D.D.B. & Carmo, C.F. (2011). Associações de *Bokermannohyla hylax* (HEYER, 1985) (Anura, Hylidae) ao estrato florestal e a vegetação no Alto da Serra de Paranapiacaba, São Paulo, Brasil. *Proceedings of the X Congresso de Ecologia do Brasil*. São Lourenço, Minas Gerais, Brazil.
- Silva, F.R., Almeida-Neto, M., Prado, V.H.M., Haddad, C.F.B. & Rossa-Feres, D.C. (2012). Humidity levels drive reproductive modes and phylogenetic diversity of amphibians in the Brazilian Atlantic Forest. *Journal of Biogeography* 39: 1720–1732.
- Tanus, M.R., Pastore, M., Bianchini, R.S. & Gomes, E.P.C. (2012). Estrutura e composição de um trecho de Mata Atlântica no Parque Estadual das Fontes do Ipiranga, São Paulo, SP. *Hoehnea* 39: 157–168.
- Wells, K. (2007). *The Ecology and Behavior of Amphibians*. Chicago and London. The University of Chicago Press. 1148 pp.

Accepted: 1 September 2022

Aspects of the natural history of the Sertao lancehead *Bothrops lutzi* from Brazil

CICERO RICARDO DE OLIVEIRA^{1,2*}, ROBSON WALDEMAR ÁVILA^{1,2} & IGOR JOVENTINO ROBERTO³

¹Programa de Pós-Graduação em Ecologia e Recursos Naturais, Departamento de Biologia, Campus do Pici, Universidade Federal do Ceará, Fortaleza - CE, CEP 60440-900, Brazil

²Núcleo Regional de Ofiologia, Bloco 905, Universidade Federal do Ceará, Campus do PICI, Avenida Humberto Monte, s/n, Fortaleza, Ceará 60455-760, Brazil

³Universidade Federal do Cariri, Instituto de Formação de Educadores, Laboratório de Biologia e Ecologia de Vertebrados, 63.260-000, Brejo Santo, CE, Brazil

*Corresponding author e-mail: riccicer@gmail.com

ABSTRACT - *Bothrops lutzi* is a secretive species mainly associated with the Cerrado, Carrasco and ecotonal areas of Cerrado-Caatinga vegetation. We gathered information about habitat use, diet and the parasites of this elusive species. The species was found exclusively in Carrasco vegetation habitats in the states of Piaui and Ceará, but not in the core Caatinga region. *Bothrops lutzi* appears to have a diet composed of invertebrates and small vertebrates, not changing during its ontogeny. Three endoparasites were identified, one of them, *Oswaldofilaria* sp., is the first record for a *Bothrops* spp.

INTRODUCTION

The secretive snake *Bothrops lutzi* Miranda-Ribeiro, 1915, is of the *Bothrops neuwiedi* complex (Silva & Rodrigues, 2008). The species is endemic to Brazil, occurring in the states of Bahia, Ceará, Goiás, Minas Gerais, Pernambuco, Piauí and Tocantins (Nogueira et al., 2019). *Bothrops lutzi* is mostly associated with the vegetation of Cerrado, Carrasco and ecotonal areas of Caatinga-Cerrado, with an isolated record in the Atlantic Forest of the state of Bahia (Loebmann, 2009; Guedes et al., 2014; Nogueira et al., 2019).

Brothrops lutzi is a locally rare snake (Loebmann & Haddad, 2010; Dal Vechio et al., 2013), consequently most information about this species deals with geographical distribution and taxonomy (Campbell & Lamar, 2004; Nogueira et al., 2019). In the present study, we present data on habitat use, diet and the parasites of *B. lutzi*.

MATERIALS & METHODS

Study area

We collected data during four field surveys, in three different areas (Table 1S, see Supplementary Material). Each area had four sampling points, following a gradient from Caatinga to Carrasco phytophysiognomies across east Piaui and west Ceará states in north-east Brazil (Table 1S). The four study areas were at least 20 km apart, and each sampling point was at least 1 km apart. Area 1 is mostly covered by arboreal Caatinga, with presence of 10 m canopy tree, shallow and clayey, rocky soils (Rocha et al., 2017). Areas 2 and 3 have Carrasco vegetation, a deciduous forest, with dense scrubland, sparse, short trees and white sandy soil (Araújo et al., 1999). Area 2 is more degraded than Area 3, with denser scrubland and fewer trees. In Area 3, there is a vegetation transitional gradient between Caatinga and Carrasco. The climate of the region is semi-arid (BSh, Koeppen's system), with a rainy season from January to May, and an extended dry season from June to December. The temperature ranges from 22 °C in the rainy season to 39 °C in the dry season, with a mean precipitation of 600 mm (Silva et al., 2013).

Sampling design

There were three field trips in the rainy season: 15 April–2 May 2014, 13–29 February 2016, and 8–22 May 2017; and one field survey in the dry season, 23 October–6 November 2014. In each area we collected data on the occurrence of *B. lutzi* (activity, habitat, microhabitat) using nocturnal visual constrained searches (VCS) (using four researchers), between 18:00 h and 22:00 h. Additionally, we installed pitfall traps with drift fences: there were four traps (60-litre buckets) per sampling point, separated by 1 m tall plastic fencing; incidental encounters were also recorded. For each field survey, in each area we had a standardise sampling effort of 64 pitfall traps/area, and 16 person/hours of VCS.

The Bothrops lutzi (Fig. 1) collected were euthanised according to ethical procedures of the Federal Council of Veterinary Medicine - CFMV (2013) and fixed according to Calleffo (2002), after authorisation by the Instituto Chico Mendes de Conservação da Biodiversidadel CMBio/SISBIO, number 66099-2, and approval by the Ethics Committee of the Universidade Regional do Cariri (CEUA/URCA, process #00260/2016.1). Specimens of *B. lutzi* were weighed on an electronic scale (precision 0.1 g) and the snout-vent length (SVL) and tail length (TL) measured with a Mitutoyo® digital caliper (precision 0.01 mm). Specimens were later deposited in the Herpetological Collection of the Regional University of Cariri (for accession codes see Table 1) state of Ceará, Brazil.



Figure 1. Adult female of *Bothrops lutzi* (URCA-H 11598), collected in Area 2, municipality of Pio IX, state of Piauí, north-eastern Brazil

We also gathered data of specimens of B. lutzi deposited in the Herpetological Collection of the Federal University of Ceará (UFC). They were all from the locality of Serra das Almas (RPPN Serra das Almas), municipality of Crateús, state of Ceará (for area description see Borges-Nojosa & Cascon, 2005). In the laboratory, all specimens were necropsied, sexed, and the contents of the gastrointestinal tract analysed under a stereoscopic microscope to investigate food content and/or endoparasites. The following organs - digestive tract, lungs, heart, liver and kidneys were analysed according to Amato et al. (1991). All prey items were counted and identified to the lowest taxonomic level possible, using specialised literature (Oliveira-Costa, 2011). Parasite fixation and conservation techniques were applied as recommended for each taxonomic group (Vidal-Martínez et al., 2001). For identification of parasite species, we referred to Vicente et al. (1993) and Gibbons (2010). The infection parameters analysed following Bush et al. (1997) were - % prevalence (number of parasitised host individuals divided by the total number of individuals), mean intensity of infection (number of helminths divided by the number of parasitised individuals) and mean abundance (number of helminths divided by total number of individuals in the sample).

RESULTS

In each sampling area, we undertook a total of 64 hours of visual active search and deployed a total 960 pitfall traps*days of effort. Individuals of *B. lutzi* (n = 10) were found only in Carrasco vegetation in Areas 2 and 3 (Table 1S). The visual active survey sampling effort resulted in an encounter rate of 0.05 snakes/hour (n = 3) in Area 2, where all the individuals were found in the rainy season (February and April) between 18:00 h and 20:00 h. Two adults were found foraging in sandy soil, and one juvenile was found coiled in scrubland. The pitfall traps captured five individuals of *B. lutzi*: three adults (455–550 mm SVL) in Area 2, and two in Area 3 (one juvenile and one adult). Two adult individuals of *B. lutzi* were recorded by opportunistic encounter, when crossing the roads at night.

Investigation of five *B. lutzi* (2 males, 2 females and 1 juvenile) collected during the field study (Table 1) revealed only one specimen URCA-H 13161 (male, SVL 495 mm) that had food in its digestive tract, a centipede (*Scolopendra* sp). Of the preserved, UFC specimens (n = 5), only two had food remains. UFC-2249 (male, SVL 302 mm) had parts of a teiid lizard, and UFC-2250 (female, SVL 205mm) had a *Scolopendra* sp. The other specimens had no evidence of stomach contents.

Regarding parasitism, three parasitic taxa were identified, namely: *Ophidascaris* sp., *Oswaldofilaria* sp. and *Physaloptera* sp., with an overall infection prevalence of 40 %, with four specimens infected with at least one parasite species, more information on infection can be found in Table 1.

DISCUSSION

In the states of Piauí and Ceará, we found B. lutzi exclusively in Carrasco and Cerrado vegetation, at altitudes above 600 m, in sandy soils (see Araújo & Martins, 1999, for the definition of Carrasco). Using a similar sampling effort in an area with arboreal Caatinga vegetation, at lower altitudes 200-300 m (Area 1), we found no B. lutzi, only specimens of Bothrops erythromelas. The occurrence of B. lutzi in Carrasco follows a clear distribution pattern along the Ibiapaba plateau in the state of Ceará, where the species is found exclusively in these areas (Borges-Nojosa & Cascon, 2005; Loebmann, 2009; Roberto & Loebmann, 2016). In the humid forests of Ibiapaba plateau only Bothrops gr. atrox occurs, whereas in the lower altitude areas in the Caatinga forest only *B. erythromelas* is found, showing the habitat specificity for each Bothrops species in the Serra da Ibiapaba Mountain range (Roberto & Loebmann, 2016). However, there are populations of B. lutzi found in the state of Bahia in a Cerrado enclave in Atlantic Forest (Marques et al., 2017), ecotone areas of Caatinga-Cerrado (Rodrigues & Prudente, 2011; Cavalcanti et al., 2014) and in the Cerrado of central Brazil (Recoder & Nogueira, 2007; Recoder et al., 2011).

Most inventories of herpetofauna show few records of *B. lutzi* despite being associated with long periods of sampling efforts. Amaral (1925), when describing *Bothrops neuwiedi piauiensis* (*B. lutzi*), mentioned that the species was locally abundant in Jurumenha and Fazenda Grande do Piauí, regions located in the middle Gurguéia river basin, in the state of Piauí, an area mostly covered by Caatinga-Cerrado ecotone vegetation. Almost one century later, Madella-Auricchio et al. (2017) sampled a larger region in the middle Gurguéia river basin, despite a sampling effort of two years of active visual search, did not find any *B. lutzi*, indicating the rarity of the species.

In the state of Piauí, in similar habitats from which the species was described, Rodrigues & Prudente (2011) employed 912 hours of active visual search and found only three *B. lutzi* (0.003 specimens/hour). Additionally, the authors installed pitfall traps (a total of 6,468 traps*days effort) without any captures of *B. lutzi*. In Serra da Capivara National Park, Cavalcanti et al. (2014) after 960 survey hours, found only two *B. lutzi* (0.002 specimens/hour), with 1,110 pitfall traps*days effort without any captures. In the state of Ceará, Borges-Nojosa & Cascon (2005) sampled the Carrasco **Table 1**. Information on *Bothrops lutzi* specimens from a preserved collection (UFC) or collected from the field in this study (URCA): SVL-snoutvent length; TL- Tail length; NP- Number of parasites; P%- Prevalence; MII±SD- Mean Intensity of Infection ± standard deviation, and MA-Mean abundance

Voucher	Sex	Life stage	SVL	TL	NP	Infection site	Parasites	Р%	MII±SD	MA	Stomach contents
UFC-2268	male	juvenile	271	45							
UFC-2249	male	adult	302	51							teiid lizard
UFC-2250	male	juvenile	205	30							Scolopendra sp.
UFC-2251	female	adult	440	79							
UFC-2252	male	adult	350	57	2	stomach	Physaloptera sp.				
					2	small intestine	Physaloptera sp.				
URCA-H-13161	male	adult	495	71	3	stomach	Physaloptera sp.	30	5 ± 0.8	1.5	Scolopendra sp.
					2	small intestine	Physaloptera sp.				
URCA-H-11598	female	adult	691.95	64.62	6	large intestine	Physaloptera sp.				
					15	coelomic cavity	<i>Oswaldofilaria</i> sp.	10	15	1.5	
URCA-H-11596	female	adult	455	70	2	small intestine	<i>Ophidascaris</i> sp.	10	2	0.2	
URCA-H-13162	male	adult	303	52							
URCA-H-11597	female	juvenile	187	33							

vegetation in Serra das Almas Mountain and had an encounter rate of 0.004 specimens/hour (243 hours/1 specimen). The other areas of Cerrado in the states of Tocantins (Recoder et al., 2011) and Bahia (Marques et al., 2017) also yielded few records, despite the intense sampling effort. Our sampling effort in the Carrasco had a higher encounter rate of 0.05 specimens/hour, and we also captured five individuals in pitfall traps with a total 960 traps*days effort, being the area with the highest encounter rate for the species so far. Regarding the differences within the two successfully sampled areas in the Carrasco, the higher encounter rate of Area 2 can reflect habitats preferences of *B. lutzi*, since Area 3 is more influenced by the less favourable Caatinga vegetation.

Most species of the *Bothrops neuwiedi* group have a generalist diet, reflecting an ancestral state (Martins et al., 2002), consuming mammals, lizards, amphibians, chilopods, and birds (Martins et al., 2002; Valdujo et al., 2002; Nogueira et al., 2003; Sawaya et al., 2008). Most species also undergo an ontogenetic shift in their diets, changing from ectotherms in juvenile stage to endotherms in adults (Martins et al., 2002). We found lizards in the digestive trait of a *B. lutzi* juvenile, and centipedes in both juvenile and larger adults. However, due to the small sample size, it is not possible to confirm whether *B. lutzi* follows this pattern of ontogenetic change, as observed in its phylogenetic sister species *B. erythromelas* (Machado et al., 2014) necessitating further studies on this topic.

Centipedes are an important food source for *Bothrops* spp, being part of the diet of at least 15 species (Parker,

1926; Dixon & Soini, 1986; Greene, 1992; Marques et al., 2002; Martins et al., 2002; Valdujo et al., 2002; Nogueira et al., 2003; Boada et al., 2005; Monteiro et al., 2006; Sawaya et al., 2008; Barbo et al., 2016; Silva et al., 2017; Bisneto & Kaefer, 2019; Barbo et al., 2021). Most records of predation of centipedes were associated with juvenile snakes (Martins et al., 2002; Barbo et al., 2016; Silva et al., 2017). However, *B. alcatraz* and *B. germanoi*, small insular species, prey mostly on centipedes through all life stages (Marques et al., 2002; Barbo et al., 2021). Moreover, only a few records of centipede predation by adults are available for *B. asper*, and *B. mattogrossensis* (Boada et al., 2005; Monteiro et al., 2006). For *B. lutzi*, centipedes (*Scolopendra* spp.) could be an important part of the diet of both juvenile and adult stages.

The observed parasitic fauna of *B. lutzi* were all nematodes (*Ophidascaris* sp., *Oswaldofilaria* sp. and *Physaloptera* sp.), a common pattern in Neotropical snakes (Vicente et al., 1993). A more precise identification of the nematodes from this study was not possible because only female specimens were found that do not have taxonomic characters for identification to species level. These parasites are known to have a heteroxen life cycle, and use invertebrates, amphibians, and rodents as intermediate and/or paratenic hosts (Bush et al., 2001), thus snakes are probably infected by ingesting intermediate hosts with infectious larvae encysted in the musculature or viscera (Anderson, 2000).

There are approximately 21 species of *Ophidascaris* parasitising snakes worldwide, with nine species occurring

in Brazil (Vicente et al., 1993; Siqueira et al., 2005). This nematode has been reported parasitising the gastrointestinal tract of *Bothrops jararaca* and *B. atrox* (Vicente et al., 1993; Siqueira et al., 2005). Herein, we present the first record for *B. lutzi*. Individuals of *Ophidascaris* can cause damage to the host, due to the migration of larvae through the viscera (Jacobson, 2007).

Oswaldofilaria Travassos 1933, comprises thirteen species that parasitise mainly crocodilians and lizards from Australia, Africa, and South America (Pereira et al., 2010; Bursey et al., 2014; Vieira et al., 2019). Previously, in Brazil only Oswaldofilaria carinii has been found parasitising a snake, Phalotris tricolor Sonin 1975. This genus does not seem to be a common snake parasite, and this study presents the first case of it infecting a Bothrops sp. as a host.

The genus *Physaloptera* Rudolphi 1819, comprises 100 species. They are commonly found infecting snakes (Goldberg et al., 2004) in Brazil, such as: *Micrurus surinamensis* (Ávila et al., 2013), *Philodryas nattereri* (Oliveira et al., 2019), *Philodryas olfersii* (Araújo et al., 2020), *B. neuwiedi* (Gouveia et al., 2012), *B. jararaca*, (Vicente et al., 1993) and *B. moojeni* (Silva, 2014). In this study, there was only larval infection, suggesting that the hosts were either intermediate or paratenic. This is the first record of *Physaloptera* sp. using *B. lutzi* as a host.

Bothrops lutzi is classified as Least Concern (IUCN, 2022). However, the habitat of the species is being severely impacted by habitat loss, especially deforestation that has made way for the expansion of crop monocultures such as soy, which has severely impacted the Cerrado domain and ecotone areas (Grecchi et al., 2014). This could have had a direct impact on populations of *B. lutzi*, a rare species, with rather specific habitat requirements. We clearly need to know much more about the natural history and biology of this elusive and endemic Brazilian species.

ACKNOWLEDGEMENTS

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) for the scholarship granted to CRO (# 88882.454307/2019-01). RWA thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for granting research grants (PQ # 303622 / 2015-6; 305988 / 2018-2; 307722/2021-0). IJR thanks "Programa de Desenvolvimento Científico e Tecnológico Regional - PDCTR (CNPq/Funcap) Edital 03/2021,DCT-0182-00049.01.00/21 and 04863348/2022 for fellowship (PDCTR 301304/2022-0). We thank Castiele Bezerra, for helping in the collection of data for UFC specimens.

REFERENCES

- Amaral, A. (1925). A general consideration of snake poisoning and observations on Neotropical pit-vipers. *Contributions of the Harvard Institute of Tropical Biology and Medicine* 2: 1–64.
- Amato, F.R., Boeger, W.A. & Amato, S.B. (1991). Protocolos para laboratório - Coleta e processamento de parasitos de pescado. Rio de janeiro: Imprensa Universitária-UFRRJ, 81 pp.

- Anderson, R.C. (2000). *Nematode Parasites of Vertebrates. Their development and transmission*. New York, CABI publishing, 650 pp.
- Araújo, F.S. & Martins, F.R. (1999). Fisionomia e organização da vegetação do carrasco no planalto da Ibiapaba, estado do Ceará. Acta Botanica Brasilica 13: 1–13.
- Araújo, F.S., Martins, F.R. & Shepherd, G.J. (1999). Variações estruturais e florísticas do carrasco noplanalto da Ibiapaba, estado do Ceará. *Revista Brasileira de Biologia* 59: 663–678.
- Araújo, K.C., Silva, C.S., Machado, H.T.S., Oliveira, C.R. & Ávila, R.W. (2020). Endoparásitos de Philodryas olfersii (Lichtenstein, 1823) en ambientes de restinga del delta del Río Parnaiba, nordeste de Brasil. *Neotropical Helminthology* 14: 129–141.
- Ávila, R.W., Morais, D.H., Anjos, L.A., Almeida, W.O. & Silva, R.J. (2013). Endoparasites infecting the semiaquatic coral snake *Micrurus surinamensis* (Squamata: Elapidae) in the southern Amazonian region, Mato Grosso State, Brazil. *Brazilian Journal of Biology* 73: 645–647.
- Barbo, F.E., Gasparini, J.L., Almeida, A.P., Zaher, H., Grazziotin, F.G., Gusmão, R.B., Ferrarini, J.M.G. & Sawaya, R.J. (2016). Another new and threatened species of lancehead genus *Bothrops* (Serpentes, Viperidae) from Ilha dos Franceses, southeastern Brazil. *Zootaxa* 4097: 511–529.
- Barbo, F.E., Grazziotin, F.G., Pereira-Filho, G.A., Freitas, M.A., Abrantes, S.H.F. & Kokubum, M.N.C. (2021). Isolated by dry lands: integrative analyses unveil the existence of a new species and a previously unknown evolutionary lineage of Brazilian Lanceheads (Serpentes: Viperidae: *Bothrops*) from a Caatinga moist-forest enclave. *Canadian Journal of Zoology* 100: 147–159.
- Bisneto, P.F. & Kaefer, I.L. (2019). Reproductive and feeding biology of the common lancehead *Bothrops atrox* (Serpentes, Viperidae) from central and southwestern Brazilian Amazonia. *Acta Amazonica* 49: 105–113.
- Boada, C., Salazar, D., Lascano, A.F. & Kuch, U. (2005). The diet of *Bothrops asper* (Garman, 1884) in the Pacific lowlands of Ecuador. *Herpetozoa* 18: 77–79.
- Borges-Nojosa, D.M. & Cascon, P. (2005). Herpetofauna da Área Reserva da Serra das Almas, Ceará. In *Análise das Variações da Biodiversidade do Bioma Caatinga*, 243–258 pp. Araújo F.S., Rodal M.J.N. & Barbosa M.R.V. (Eds.), Brasília, Ministério do Meio Ambiente.
- Bursey, C.R., Goldberg, S.R. & Grismer, L.L. (2014). New species of *Oswaldofilaria* (Nematoda; Filarioidea; Onchocercidae) and other helminths in *Acanthosaura cardamomensis* (Sauria; Agamidae) from Indochina Peninsula. *Acta Parasitologica* 60: 112–115.
- Bush, A.O., Fernández, J.C., Esch, G.W. & Seed, J.R. (2001) Parasitism: The Diversity and Ecology of Animal Parasites. Cambridge University Press, NY, 524 pp.
- Bush, A.O., Lafferty, K.D., Lotz, J.M. & Shostak, A.W. (1997). Parasitology meets ecology on its own terms: Margolis et al. Revisited. *Journal of Parasitology* 83: 575–583.
- Calleffo, M.E.V. (2002). Anfíbios. In *Técnicas de coleta e preparação de vertebrados para fins científicos e didáticos*. 45–73 pp., Auricchio P., Salomão M.G. (Eds). Instituto Pau Brasil de História Natural, São Paulo.

- Campbell, J.A. & Lamar, W.W. (2004). *The Venomous Reptiles of Latin America*. Cornell University Press, Ithaca, NY. 425 pp.
- Cavalcanti, L.B.Q., Costa, T.B., Colli, G.R., Costa, G.C., França,
 F.G.R., Mesquita, D.O., Palmeira, C.N.S., Pelegrins,
 N., Soares, A.H.B., Tucker, D.B. & Garda, A.A. (2014).
 Herpetofauna of protected areas in the Caatinga II: Serra
 da Capivara National Park. *Check List* 10: 18–27.
- CFMV Conselho Federal de Medicina Veterinária (2013). Métodos de eutanásia. In *Guia Brasileiro de Boas Práticas de Eutanásia em Animais*, 28–29 pp. Comissão de ética, Bioética e bem-estar animal. Brasília, Distrito Federal.
- Dal Vechio, F., Recoder, R., Rodrigues, M.T. & Zaher, H. (2013). The reptiles of the Estação Ecológica de Uruçuí-Una, State of Piauí, Brazil. *Papéis Avulsos de Zoologia* 53: 225–243.
- Dixon, J.R. & Soini, P. (1986). *The Reptiles of the Upper Amazon Basin*, Iquitos Region, Peru. Milwaukee Public Museum, Milwaukee. 154 pp.
- Gibbons, L. (2010). *Keys to the Nematode Parasites of Vertebrates*. Supplementary Volume. CABI International, Wallingford. 416 pp.
- Goldberg, S.R., Bursey, C.R. & Telford, S.R. (2004). Helminths of six species of snakes from Honshu Island, Japan. *Comparative Parasitology* 71: 49–60.
- Gouveia, R.V., Silva, D.A.N., Novelli, I.A. & Vieira, F.M. (2012). *Bothropoides neuwiedi* (Neuwied's Lancehead). Endoparasites. *Herpetological Review* 43: 340.
- Greechi, R.S., Gwyn, Q.H.J., Bérnié, G.B., Formaggio, A.R. & Fahl, F.C. (2014). Land use and land cover changes in the Brazilian Cerrado: A multidisciplinary approach to assess the impacts of agricultural expansion. *Applied Geography* 55: 300–312.
- Greene, H.W. (1992). The ecological and behavioral context of pitviper evolution. In *Biology of the Pitvipers*, 107–117 pp., Campbell, J.A., Brodie, E.D. (Eds.). Selva, Tyler.
- Guedes, T.B., Nogueira, C. & Marques, O.A.V. (2014). Diversity, natural history, and geographic distribution of snakes in the Caatinga, Northeastern Brazil. *Zootaxa* 3863: 1–93.
- IUCN (2022). *Red list of threatened species 2022.1* https:// www.iucnredlist.org/. Accessed on 29 September 2022.
- Jacobson, E.R. (2007). *Infectious Diseases and Pathology of Reptiles: Color Atlas and Text*. CRC Press, Taylor & Francis Group, USA. 716 pp.
- Loebmann, D. & Haddad, C.F.B. (2010). Amphibians and reptiles from a highly diverse area of the Caatinga domain: composition and conservation implications. *Biota Neotropica* 10: 227–256.
- Loebmann, D. (2009). Reptilia, Squamata, Serpentes, Viperidae, *Bothrops lutzi*: distribution extension, geographic distribution map. *Check List 5*: 373375.
- Machado, T., Silva, V.X. & Silva, M.J.J. (2014). Phylogenetic relationships within *Bothrops neuwiedi* clade (Serpentes, Squamata): Geographically highly-structured lineages, evidence of introgressive hybridization and Neogene/ Quaternary diversification. *Molecular Phylogenetics and Evolution* 71: 1–14.
- Madella-Auricchio, C.R., Auricchio, P. & Soares, E.S. (2017).

Reptile species composition in the Middle Gurguéia and comparison with inventories in the eastern Parnaíba River Basin, State of Piauí, Brazil. *Papéis Avulsos de Zoologia* 57(28): 375–386.

- Marques, O.A.V., Martins, M. & Sazima, I. (2002). A new insular species of pitviper from Brazil, with comments on evolutionary biology and conservation of the *Bothrops jararaca* group (Serpentes, Viperidae). *Herpetologica* 58: 303–312.
- Marques, R., Rödder, D., Solé, M. & Tinôco, M.S. (2017). Diversity and habitat use of snakes from the coastal Atlantic rainforest in northeastern Bahia, Brazil. *Salamandra* 53: 34–43.
- Martins, M., Marques, O.A.V. & Sazima, I. (2002). Ecological and phylogenetic correlates of feeding habits in Neotropical pitvipers of the genus *Bothrops*. In *Biology of the Vipers*. 307–328 pp. Schuett, G., Höggren, M. & Greene, H.W. (Eds.), Biological Sciences Press, Carmel, Indiana.
- Miranda-Ribeiro A. (1915). *Lachesis lutzi*, uma variedade de *Lachesis pictus Tschudi*. *Arquivos do Museu Nacional, Rio de Janeiro* 17: 3–4.
- Monteiro, C., Montgomery, C.E., Spina, F., Sawaya, R.J. & Martins, M. (2006). Feeding, reproduction, and morphology of *Bothrops mattogrossensis* (Serpentes, Viperidae, Crotalinae) in the Brazilian Pantanal. *Journal* of Herpetology 40: 408–413.
- Nogueira, C., Argôlo, A.J.S., Arzamendia, V., Azevedo, J.A., Barbo, F.E., Bérnils, R.S., ... Martins, M. (2019). Atlas of Brazilian snakes: Verified point-locality maps to mitigate the Wallacean shortfall in a megadiverse snake fauna. South American Journal of Herpetology 14: 1–274.
- Nogueira, C., Sawaya, R.J. & Martins, M. (2003). Ecology of the pitviper, *Bothrops moojeni*, in the Brazilian Cerrado. *Journal of Herpetology* 37: 653–659.
- Oliveira, M.C., Lima, V.F., Pinto, C.L.M., Silva, É.G., Teles, D.A., Silva, C.F. & Almeida, W.O. (2019). New record of *Physaloptera* sp. (Nematoda: Physalopteridae) parasitizing *Philodryas nattereri* (Ophidia: Dipsadidae) in Brazil. *Herpetology Notes* 12: 1031–1034.
- Oliveira-Costa, J. (2011). Entomologia Forense, Quando os Insetos São Vestígios. 3° edição, Ed. Millennium, Campinas-SP, Brazil. 420 pp.
- Parker, H.W. (1926). The reptiles and batrachians of Gorgona Island, Colombia. *Annals and Magazine of Natural History, London* 17: 549–554.
- Pereira, F.B., Souza Lima, S. & Bain, O. (2010). *Oswaldofiariacha baudin*. sp. (Nematoda: Onchocercidae) from a South American tropidurid lizard (Squamata: Iguania) with an update on *Oswaldofilariinae*. *Parasite* 17: 307–318.
- Recoder, R.S. & Nogueira, C. (2007). Composição e diversidade de répteis Squamata na região sul do Parque Nacional Grande Sertão Veredas, Brasil Central. *Biota Neotropica* 7: 267–278.
- Recoder, R.S., Teixeira, M., Camacho, A., Nunes, P.M.S., Mott, T., Valdujo, P.H., ... Rodrigues, M.T. (2011). Répteis da Estação Ecológica Serra Geral do Tocantins, Brasil Central. *Biota Neotropica* 11: 263–281.

Roberto, I.J. & Loebmann, D. (2016). Composition,

distribution patterns, and conservation priority areas for the herpetofauna of the state of Ceará, northeastern Brazil. *Salamandra* 52: 134–152.

- Rocha, A.M., Luz, A.R.M. & Abreu, M.C. (2017). Composição e similaridade florística de espécies arbóreas em uma área de Caatinga, Picos, Piauí. *Pesquisas Botânica* 70: 175–185.
- Rodrigues, F.S. & Prudente, A.L.C. (2011). The snake assemblage (Squamata: Serpentes) of a Cerrado-Caatinga transition area in Castelo do Piauí, state of Piauí, Brazil. *Zoologia* 28: 440–448.
- Sawaya, R.J., Marques, O.A.V. & Martins, M. (2008). Composition and natural history of a Cerrado snake assemblage at Itirapina, São Paulo state, southeastern Brazil. *Biota Neotropica* 8: 127–149.
- Silva, K.M.P., Almeida-Santos, S.M. & Bertani, R. (2017). Hundred legs good, two fangs better: adult centipede (Scolopendridae) devoured by a juvenile Amazon lancehead, *Bothrops atrox* (Viperidae). *Acta Amazônica* 47: 171–174.
- Silva, L.A.F. (2014). Helmintofauna associada a répteis provenientes da Reserva Particular do Patrimônio Natural Foz do Rio Aguapeí, Estado de São Paulo. Dissertação. Universidade Estadual Paulista Júlio de Mesquita Filho, Instituto de Biociências, Campus de Botucatu. 43 pp.
- Silva, V.M.A., Medeiros, R.M., dos Santos, D.C. & Gomes Filho, M.F. (2013). Variedade pluviométrica entre regimes diferenciados de precipitação no estado do Piauí. *Revista Brasileira de Geografia Física* 6: 1463–1475.

- Silva, V.X. & Rodrigues, M.T. (2008). Taxonomic revision of the *Bothrops neuwiedi* complex (Serpentes, Viperidae) with description of a new species. *Phyllomedusa* 7: 45– 90.
- Siqueira, L.R., Panizzutti, M.H.M., Muniz-Pereira, L.C. & Pinto, R.M. (2005). Description of a new ascaridoid parasite of *Bothrops jararaca* (Reptilia, Ophidia) in Brazil. *Revista Brasileira de Zoologia* 22: 587–590.
- Sonin, M.D. (1975). Filariata of animals and man and diseases caused by them. 2. Diplotriaenoidea. Essent Nematodology. 409 pp.
- Valdujo, P.H., Nogueira, C.C. & Martins, M. (2002). Ecology of *Bothrops neuwiedi pauloensis* (Serpentes: Viperidae: Crotalinae) in the Brazilian Cerrado. *Journal of Herpetology* 36: 169–176.
- Vicente, J.J., Rodrigues, H.O., Gomes, D.C. & Pinto, R.M. (1993). Nematóides do Brasil. Parte III: Nematóides de répteis. *Revista Brasileira de Zoologia* 10: 19–168.
- Vidal-Martínez, V.M., Aguirre-Macedo, L., Scholz, T., González-Solís, D. & Mendoza-Franco, E.F. (2001). Atlas of helminth parasites of cichlid fish of Mexico. *Academy of Sciences of the Czech Republic, Prague*. 165 pp.
- Vieira, F.M., de Souza, T.T., Novelli, I.A., Lima, S.S., Muniz-Pereira, L.C. & de Sousa, B.M. (2019). Nematode parasites of lizards (Squamata, Sauria) from the Cerrado biome in the State of Minas Gerais, Brazil. *Herpetology Notes* 12: 855–863.

Accepted: 19 October 2022

Please note that the Supplementary Material for this article is available online via the Herpetological Bulletin website: https://thebhs.org/publications/the-herpetological-bulletin/issue-number-163-spring-2023

Evidence that agri-environmental measures in arable fields could be a conservation benefit to northern vipers Vipera berus and other reptiles

RICK HODGES^{1*}, CLIFFORD SEABROOK¹, VANESSA WELSH¹ & WILLIAM ALEXANDER²

¹Kent Reptile and Amphibian Group, c/o KMBRC, Brogdale Farm, Brogdale Rd, Faversham, Kent, ME13 8XZ, UK ²Castle Farm, Shoreham, Kent, TN14 7UB, UK

*Corresponding author e-mail: rickhodges123@gmail.com

ABSTRACT – In Britain, some reptiles species have been formally recorded inhabiting arable field margins but previous reports on the incidence of northern vipers or adders *Vipera berus* in this situation have been anecdotal. In 2017, reptile monitoring was initiated in a field margin that had been created ten years earlier and was located near two chalk grassland nature reserves with established viper populations. In the first three years of recording, numbers of vipers in the field margin were low and limited to a few juveniles and adults. In the fourth year, there was a noticeable increase in number, which were now represented by all life stages. In the fifth year the population doubled again and then remained stable in the sixth year. A similar encounter trajectory was observed for grass snakes, while slow worms and common lizard encounters had different trajectories. There was some evidence of vipers moving between the nature reserves and field margin, even crossing a road to do so, but at least 75 % of vipers in the field margin were only ever detected there. The arable field was mostly used for cropping cereals and oilseeds but, exceptionally, in the three years from 2016 to 2018 it was put down to herbal leys of red clover and grass. In the USA and continental Europe, red clover is known to be a preferred dietary item of voles *Microtus* spp and has been associated with vole population increase. It is suggested that the increase in the viper population in the field margin may relate to a rise in the number of voles, which are an important component of the viper diet. Likewise, for grass snakes, small mammals may contribute 25 % or more of their diet. The use of herbal leys may present an important opportunity for the conservation of northern vipers in field margins and other adjacent habitats.

INTRODUCTION

n Britain, the northern viper or adder Vipera berus is a widespread species but is of some conservation concern (Gardner et al., 2019; Julian & Hodges, 2019). These vipers occupy a range of habitats including lowland heath, chalk grassland, moorland and woodland rides (Beebee & Griffiths, 2000) but, to date, evidence for their colonisation of arable field margins is only anecdotal. During a 2-year study in England, the occurrence of reptile species in field margins was investigated by the Amphibian and Reptile Conservation Trust (Salazar et al., 2016). This involved ten farms, across four counties (Oxfordshire, Berkshire, Wiltshire, and Hampshire), each with eight 100 m study transects in their field margins. While viviparous lizards Zootoca vivipara, slow worms Anguis fragilis and grass snakes Natrix helvetica were detected, northern vipers were not. It was suggested that the patchy distribution of vipers, rather than any rejection of field margins, accounted for their apparent absence.

Arable field margins, sometimes referred to as buffer strips, are supported by agri-environmental schemes for the benefit of the environment and of wildlife. Typically, in Britain they are managed under a combination of Entry Level and Higher Level Stewardship schemes (ELS & HLS), where the margin can be created by sowing or by natural regeneration. For margins that are 6 m or more wide, the half closer to the crop may be mown annually in the autumn, where the cuttings are removed or chopped and spread. The half margin further from the crop would be cut in the autumn on a longer cycle of every few years. As far as possible the margins are excluded from spray treatments of fertiliser, herbicide or pesticide.

During a long-term study of vipers on two chalk grassland nature reserves in west Kent (England), it became apparent that a small number of individuals were moving between the two reserves and that the potential corridor between them must have been the margin of an arable field. From 2017 onwards, this prompted a more detailed study of this margin and the results presented here show an increasing colonisation of the field margin by vipers over a period of six years. Some insights are offered into the factors that may have favoured this rise in viper numbers.

MATERIALS & METHODS

Study location

The arable field under study is located in the Darent valley of west Kent (England) and has a total area of about 13 ha (approx. location $51^{\circ} 21' \text{ N}$, $0^{\circ} 11' \text{ E}$). It occupies part of a slope (inclined at about 5° - 7°) on the eastern side of the



Figure 1. The location of the arable field relative to transport infrastructure and two chalk grassland nature reserves. Note that Reserve 2 is the other side of the road from both the arable field and Reserve 1. Photo from Google Earth.

valley and has a long history of cereal agriculture since at least the 1940s. It was a patchwork of smaller fields until the 1960s and since then has become one large field. On the slope above the field there is a belt of woodland above which there is a chalk grassland nature reserve (Reserve 1, Fig. 1). On the slope above this reserve there is a road and above that woodland and then, at the top of the slope, livestock and arable fields. Also beyond the road and on the slope just to the south-east of the arable field there is a second chalk grassland reserve (Reserve 2, Fig. 1). Both chalk grassland reserves have viper populations. For comparative purposes, reptile monitoring results for the field margin are compared mostly with those for chalk grassland Reserve 2 as since 2008 it has been subject to more intensive reptile monitoring than Reserve 1 (Table 1).

Since 2007, a 6–8 m uncultivated margin has been maintained in the arable field as part of the environmental stewardship scheme (ELS/HLS)(Fig. 2). The 3 m of field margin closest to the crop, which is grassy, is cut usually in November/December while the portion further from the crop is more 'woody' and cut for woody growth every few years, also in November/December.

Monitoring technique

A detailed account of our reptile monitoring methodology has already been published (Hodges & Seabrook, 2018). The data presented here were collected from 2017 to 2022 during visits to the field margin and the two chalk grassland reserves in the reptile active period from March to October; the number of annual visits varied between the sites (Table 1). For each visit, we followed standard survey paths (Table 1) and at intervals along the paths there were refuge positions where paired artificial refuges of galvanised-corrugated iron and roofing felt (each 50 cm x 60 cm) were placed. In the field margin, refuge positions were divided equally between the grassier and 'woody' portions. Vipers were recorded at refuge locations and along the survey paths. To facilitate individual recognition, close-up photographs were taken of viper head-scale patterns (Benson, 1999) when they were located under refuges or, by using a long-focus lens when



Figure 2. Margin of the arable field in 2022 - A. In January soon after mowing, and B. In August soon after harvesting winter wheat

they were basking in the open; the patterns were coded and then entered into a database. The study involved no animal handling in order to minimise disturbance and stress. Different life stages were defined as follows: neonates had not yet hibernated; juveniles had hibernated only once; and the sub-adult stages in the case of males were normally completed in two years and in females three years. Adults were recognised by having completed a total at least 4 hibernations in the case of males and, normally, a minimum of five in the case of females. In this study, assigning age class to individuals was relatively easy as many vipers had been observed initially as neonates, juveniles, or young subadults and consequently the surveyors were well acquainted with the relationship between size and age. The sex of adults and sub-adults was determined by colouration and body proportions (Smith, 1951; Beebee & Griffiths, 2000) while that of juveniles was assigned by colour and confirmed when they had developed to later stages. Full details of the life stages of all 'known' adders and their observations across six years are presented in Table 1S and the dataset of viper observations by year is given in Table 2S (see Supplementary Material).

Table 1. Characteristics of the monitoring regime in the arable fieldmargin and two chalk grassland reserves 2017–2022

Parameter		Field margin	Reserve 1	Reserve 2
	Survey path length	1.08 km	0.82 km	1.03 km
	Open habitat (ha)	0.78 ha	1.1 ha	3.28 ha
	No. refuge positions	10	10–11	16
	No. surveys/season	26–64	8–27	66–70

Statistical analysis

To enable comparison between reptile encounter rates between sites and between years in situations where monitoring parameters may vary, encounter rates were expressed as an Encounter Index (EI) (Hodges & Seabrook, 2018). The EI for any particular year is estimated as the geometric mean of encounters at refuges (Encounters_r) and those along the survey path (Encounters_{sp}), normalised by the annual monitoring effort as follows:

Encounter Index =
$$\frac{\sqrt{2(\text{Encounters}_r * \text{Encounters}_{sp})}}{\text{Monitoring effort}}$$

where monitoring effort is

Monitoring effort = monitoring infrastructure * no. annual visits

and monitoring infrastructure is

Monitoring infrastructure = $\sqrt{2}$ (No. refuges * Survey path length)

The EI was used for vipers, grass snakes and viviparous lizards but slow worms are almost only recorded at refuges, so instead, a simple encounter rate was calculated as the number of observations per refuge pair, per visit. In the case of vipers, EI values were plotted against the numbers of



Figure 3. The Encounter Index values for *Vipera berus* in an arable field margin and in chalk grassland Reserves 1 and 2 detected 2017–2022. The coloured numbers show the number of individually recognised vipers detected in each year at each location (except for neonates, which are excluded to avoid distortions created by sudden high numbers at the end of the season).



Figure 4. Life stages of individually recognised *Vipera berus* detected 2017–2022 - **A.** In the field margin, and **B.** In Reserve 2. Bars are stacked neonate to adult, from bottom to top and the data for the field margin is shown in Table 1S.

known individuals to assess the extent to which rises in EI were actually a result of increasing numbers of vipers, rather than perhaps the improvement of weather conditions. EI values over time were assessed visually, as there was not a sufficient number of time points for meaningful time series analysis, and the dependence of a given year's result on previous years precluded valid analysis through other means (e.g. ANOVA or Kruskal-Wallis).

For vipers and grass snakes a Pearson correlation coefficient (r) was determined for their annual EI values to indicate the degree to which the populations were following the same trajectory. The increase in numbers of known vipers was plotted against the annual crop plantings since 2007 to look for any associations between the cropping history since 2007 and change in viper numbers.

RESULTS

Viper populations

The encounter rate of vipers in the field margin was more or less constant from 2017 to 2019 and thereafter began to rise (Fig. 3), doubling in 2020 and doubling again in 2021 before apparently stabilising in 2022. The numbers of individual vipers observed in the field margin increased more or less in proportion to the encounter rate, indicating a genuine rise in viper numbers rather than purely the same vipers being detected more frequently. The monitoring results for Reserves 1 and 2 followed different trajectories. In Reserve 1 the encounter rate remained low throughout and the field margin viper population diverged from it in 2020. Reserve 2 maintained a much higher encounter rate than the field margin or Reserve 1 until at least 2020, thereafter it began to fall and by 2022 had converged with the field margin (Fig. 3). The numbers of individual vipers recorded in Reserve 2 was again more or less in proportion to the encounter rate except in 2021 when the number (40) appears rather high for the observed encounter rate (Fig. 3).

During 2017 to 2019, the life stages of vipers in the field margin were confined to only a few adults and juveniles but in 2020 for the first time all life stages (neonates, juveniles, sub-adults and adults) were detected (Fig. 4A). No neonates were detected in 2021, while in 2022 greater numbers of neonates (7) and adults were detected but no juveniles. In contrast, from 2017 to 2022 all life stages were detected in Reserve 2 (Fig. 4B). The details of the life stages and their observations across six years in the field margin are presented in Table 1S (see Supplementary Material).

Potential impacts of field cropping pattern

In the period from the inception of the field margin in 2007 to 2015, the field supported crops of cereals and oilseed (Fig. 5). For the three years from 2016 to 2018 the field was put down to herbal leys (red clover/grass) that were harvested three times annually for big bale silage, no herbicide was used and there was reduced fertiliser application. At the end of the third year the red clover was ploughed in. It is noticeable that the rise in viper numbers was detected from four years after the start of herbal ley cultivation (Fig. 5).

Other reptile species

During the period of study, encounters with grass snakes in both the field margin and Reserve 2 (Fig. 6) were much lower that for vipers (Fig. 3). Nevertheless, the grass snake encounter rate had a similar trajectory to that of vipers, apart from a noticeable fall in 2022, and was closely correlated (r = 0.92, df = 10, p < 0.001).

The detection rate of slow worms in the field margin was actually higher than that in Reserve 2 from the start of the study period and was particularly high in 2021 (Fig. 7).

The encounter rate for viviparous lizards in the field margin remained lower than that in Reserve 2 throughout the study period (Fig. 8).

Interconnections between viper populations

A few vipers were observed to have moved between the field margin and two reserves, although no individual was detected in all three locations. Of the 41 individual vipers known in the field margin, eight vipers (6 males and 2 females) were also encountered in Reserve 1, which is further up the same slope, and two vipers (1 male and 1 female) were shared with Reserve 2 (Fig. 9). Reserve 1 also shared 2 vipers (both males) with Reserve 2. To share vipers with Reserve 2 requires them to cross the road; a total of 4 vipers are known to have crossed the road. Of these vipers (3 males and 1 female) one, a sub-adult female, generally took up a position close to the road and crossed it four times between May 2020 and April 2022 (Fig. 10).



Figure 5. The crops grown in the field under study in the period 2007–2022 plotted against the number of individual vipers detected in the period of study 2017–2022 (excluding neonates), herbal leys in pink



Figure 6. Encounter index for grass snakes *Natrix helvetica* in the field margin and in Reserve 2 in the period 2017–2022



Figure 7. Encounter rates for slow worms *Anguis fragilis* in the field margin and on Reserve 2 in the period 2017–2022

DISCUSSION

Our observations of vipers in the margin of this arable field over a period of six years make it clear that such margins can support a viper population. During the period of study there was an increase in viper population as evidenced by the simultaneous rise in encounter rates, the number of individuals known from their head scale patterns, and in the number of life cycle stages represented. Of the 41 individual vipers observed in the field margin, 10 were also observed in other locations which suggests that as many as



Figure 8. Encounter index for viviparous lizards *Zootoca vivipara* in the field margin and on Reserve 2 in the period 2017–2022



Figure 9. Numbers of vipers of all stages found exclusively in one location or shared between locations in the period 2017–2022. The four vipers shared with Reserve 2 must have crossed a road.

75 % of the vipers could have been primarily resident in the field margin. The viper increase was mirrored by increase in grass snake numbers, although grass snakes themselves were recorded much less frequently and did relatively poorly in 2022. The weather in 2022 was particularly hot and dry and was associated with lowered recording rates of all four widespread reptile species at several site in west Kent (unpublished data).

It was noticeable that the encounters with slow worms and common lizards followed quite different trajectories from the two snake species. The field margin constitutes a meadow habitat and was potentially more favourable for slow worms than the chalk grassland by offering a greater food supply and possibly better protection of its food supply (molluscs and worms) from desiccating conditions. It was therefore not surprising that the field margin had greater slow worm encounter rates during the whole study period. Conversely, common lizards were encountered less frequently in the field margin than in Reserve 2. This was perhaps not surprising as in the taller grass of the field margin they were more difficult to detect and had fewer basking opportunities.

It is of interest to speculate why the number of vipers and grass snakes both increased over the period of study. It seems unlikely that it could simply be the lag time for the field margin to become suitable for reptiles since the margin was likely to have been in a stable vegetative state within two or three years of establishment, i.e. at least seven years



Figure 10. Observation on the road crossing behaviour of one individual sub-adult female viper, red stars are refuge positions. The dates closest to refuge positions indicate observations of this snake.

before this study. Instead, perhaps the cultivation of herbal leys (red clover and grass) in the arable field from 2016 to 2018 holds the clue. The absence of herbicide and pesticide spraying with this crop would be expected to be beneficial for wildlife. Furthermore, the clover crop would potentially provide both cover and food for the prey of snakes. In the USA, red clover crops are associated with much increased vole populations, where Microtus pennsylvanicus commonly prefers red clover to other crops (Thompson, 1965; Prieur & Swihart, 2020) and the European common vole Microtus arvalis prefers red clover to cereals (Lantová & Lanta, 2009); it is assumed that in Britain the field vole Microtus agrestis would have a similar dietary preference. Voles are an important food source for vipers (Smith, 1951) and in the case of grass snakes it has been suggested that in southeastern England that 25 % or more of their diet may consist of small mammals (Gregory & Issac, 2004). An increase in vole numbers could both attract more snakes to the field margin and provide a more abundant food supply. This would lead to better body condition and higher reproductive output for both species and may account for why the trajectories of the two species were closely correlated. About 4 years after the herbal leys were first planted, the viper population rose and the first neonates were detected. This may well be a typical lag time for both viper and grass snake population response.

In the case of fields taken out of agricultural production for 'set aside', it takes about 2 years for the numbers of field voles *M. agrestis* to begin to rise (Tattersall et al., 2000). The detection of neonates in 2020 and then again in 2022, i.e. in alternate years, suggests the presence of a small number of adult females that are reproducing in synchrony in alternate years; female *V. berus* typically reproduce every other year or less frequently if conditions are unfavourable (Bauwens & Claus, 2019).

We detected relatively few movement of vipers from the chalk grassland reserves to the field margin, and most of these were from Reserve 1, which clearly offers an immediate source of vipers for the colonisation of the field margin. Vipers also came from Reserve 2, crossing the road to do so. During the course of our long-term investigation of reptiles in this area we have observed several fatalities of adders on this road both from motor vehicles and, in one case, a bicycle, indicating the risk for animals crossing. It was surprising to find one individual that was willing to cross the road relatively frequently, even though at busy times of the day there would be vehicles passing along it every two or three minutes; early morning and late afternoon would be much quieter (a vehicle every 10 to 15 minutes). Such a willingness to cross the roads suggests that Reserve 2 was also potentially a greater source of colonisation than might have been expected.

In this particular study the potentially important factors for viper colonisation of the field margins seem to be - 1) A supply of immigrants from nearby colonies (even crossing a road to get there), 2) A field margin established for 10 years since the initiation of the study (immigration takes time, potentially linked to maturation of suitable habitat to attract and hold immigrants), 3) Mowing of field margin restricted to the period when reptiles are inactive, November–February, and 4) A herbal ley crop possibly offering food and shelter for prey species. For the future, we will continue to monitor the fate of the viper population to observe whether it declines with time since herbal ley cultivation. The next crop of herbal leys is expected in 2026 or beyond and a positive response to this by the viper population would strengthen our confidence in what is currently a circumstantial association. If red clover/grass leys really do improve prey availability then their use could offer a significant advantage in the conservation of northern vipers in arable field margins and adjacent habitats as well as to other predators such as barn owls.

ACKNOWLEDGEMENTS

Thanks are due to Kent Wildlife Trust and Butterfly Conservation for facilitating reptile monitoring on their nature reserves and to the volunteers who help maintain these habitats, and to Emma Gardner for valuable comments on the manuscript. We are grateful to Christopher Michaels for acting as Editor for this manuscript and for the insights of Jim Foster and Richard Griffiths in their reviews.

REFERENCES

- Bauwens, D. & Claus, K. (2019). Intermittent reproduction, mortality patterns and lifetime breeding frequency of females in a population of the adder (*Vipera berus*). *PeerJ* 7:e6912. http://doi.org/10.7717/peerj.6912.
- Beebee, T. & Griffiths, R.A. (2000). Amphibians and reptiles: a natural history of the British herpetofauna. The New Naturalist series. Harper Collins, London. 270 pp.
- Gardner, E., Julian, A., Monk, C. & Baker, J. (2019). Make the Adder Count: population trends from citizen science survey of UK adders. *The Herpetological Journal* 29: 57–70.
- Gregory, P. & Issac, L.A. (2004). Food habits of the grass snake in southeastern England: Is *Natrix natrix* a generalist predator? *Journal of Herpetology* 38(1): 88–95.
- Hodges, R.J. & Seabrook, C. (2018). Long-term monitoring for adders: an evolving methodology. *The Glasgow Naturalist* 27, supplement 'The Amphibians and Reptiles of Scotland', 7 pp.
- Julian, A. & Hodges R.J. (2019). The Vanishing Viper: themes from a meeting to consider better conservation of *Vipera berus*. *The Herpetological Bulletin* 149: 1–10.
- Lantová, P. & Lanta, V. (2009). Food selection in *Microtus arvalis*: the role of plant functional traits. *Ecological Research* 24: 831–838
- Prieur, A. & Swihart, R.K. (2020). Palatability of common cover crops to voles (*Microtus*). Crop Protection 133, 105141.
- Smith, M.A. (1951). *The British Amphibians and Reptiles*. The New Naturalist series. Collins (London). 318 pp.
- Salazar, R., Foster, J. & Thompson, P. (2016). Evaluating the importance of agri-environment scheme buffer strips to widespread amphibians and reptiles [Environmental Stewardship Monitoring and Evaluation Framework Reference ECM6147]. Amphibian and Reptile Conservation Trust. Final report to Natural England. 70 pp.
- Tattersall, F.H., Avundo, A.E., Manley, W.J., Hart, B.J. & Macdonald, D.W. (2000). Managing set-aside for field voles (*Microtus agrestis*). *Biological Conservation* 96: 123–128.
- Thompson, D.Q. (1965). Food preferences of the meadow vole (*Microtus pennsylvanicus*) in relation to habitat affinities. *The American Midland Naturalist* 74(1): 76–86.

Accepted: 24 November 2022

Please note that the Supplementary Material for this article is available online via the Herpetological Bulletin website: https://thebhs.org/publications/the-herpetological-bulletin/issue-number-163-spring-2023

Further evidence of ophiophagy, including cannibalism, by the western whip snake *Hierophis viridiflavus* in Italy

ANGELO VACCARO¹, GIOVANNI ALTADONNA² & GIUSEPPE FABRIZIO TURRISI^{3*}

¹Corso Ara di Giove 282, int. 26, 95030, Pedara, Catania, Italy²Contrada Filangeri s.n.c., Vill. Pistunina, 98125, Messina, Italy³Via Cristoforo Colombo 8, 95030, Pedara, Catania, Italy

*Corresponding author e-mail: giuseppefabrizioturrisi@gmail.com

he western whip snake Hierophis viridiflavus Lacépède, 1833, has two subspecies, the nominate one, occurring in Spain, France, Corsica and Sardinia, and H. v. carbonarius Bonaparte, 1833, that is widespread in the Italian peninsula and Sicily (Speybroeck et al., 2020). The species occupies many habitat types where it feeds on a broad range of prey that varies widely, depending on geographical area and habitat type (Vanni & Zuffi, 2010; Capula et al., 2014). Ophiophagy, including the consumption of vipers and cannibalism, is a relatively frequent feeding habit, and has been related to reduced availability for prey such as lizards and rodents, combined with high abundance of conspecific or other species of snake (Capula et al., 2014). There is detailed documentation of only three cases of cannibalism by H. viridiflavus including one case of oophagy (Schmidlin et al., 1996) and two involving cannibalised adult snakes (Naulleau, 1987; Capula et al., 2014). In addition, there is a video (Tiglio, 2013) shot in Sicily showing a black adult swallowing a smaller sub-adult tail first. Here we report four field observations of ophiophagy, three of cannibalism and an attempted predation of an Italian Aesculapian snake Zamenis lineatus. The observations were made at four different Italian sites (one in Tuscany and three in Sicily). The snakes were not captured, so it was not possible to take morphometric data.

The first case is of a black adult attempting to swallow another black adult (Fig. 1) of about the same size (estimated to be at least 1 m). This was observed at 17.56 h for 30 to 40 minutes on 4 June 2020 at Tremestieri (Messina municipality, Messina province, Sicily, Italy, 38° 08'37.1" N, 15° 31'21.8" E, about 30 m a.s.l.) in a moderately urbanised area. After various attempts to escape, the grasped individual became immobilised with its head held firmly and the two individuals tightly entwined. At this time, very gradually and very slowly, the first snake started to swallow the anterior part of the second one beginning from the head with typical lateral, alternate movements of the head, apparently to facilitate the swallowing; about 10 centimetres of the body of the other individual was swallowed in about 20-30 minutes. Then the swallowed snake was regurgitated, apparently due to external disturbance.

The second case of attempted cannibalism involved a large adult (>1 m) with the typical colour pattern of the nominate subspecies, swallowing a smaller sub-adult specimen (Fig. 2) at the locality Isola d'Elba, Monte Lentisco (Rio dell'Elba



Figure 1. Cannibalistic behaviour by an adult *Hierophis viridiflavus* which is swallowing an adult conspecific in Tremestieri (Messina province, Sicily, Italy)

municipality, Livorno province, Tuscany, Italy, 42° 51'44.96" N, 10° 24'38.93" E, about 120 m a.s.l.) along a dirt road at the edge of holm oak shrubs. The observation lasted more than 15 minutes. The adult was surprised while swallowing the other sub-adult conspecific with the body of the former firmly anchored to a large stone, giving vigorous yanks, and the other one trying to escape by anchoring itself to a small plant (*Rosmarinus*). The field observation documented only the start of the swallowing then, unfortunately, the observation was interrupted to avoid disturbance by observers. At the site, there were potential rich trophic sources of other reptiles (e.g. *Tarentola, Hemidactylus, Podarcis*), a good bird fauna and many small mammals.

The third case of cannibalistic behavior was of a juvenile specimen swallowing another conspecific juvenile on 14 September 1985 at the locality Parco Archeologico Valle dei Templi (Agrigento province, Sicily, Italy, 37° 17'27.67" N, 13° 35'39.29" E, 100 m a.s.l.), in an open xeric habitat. The swallowing snake was about 50 cm long and the conspecific being swallowed less than that. It was only possible to take a picture (Fig. 3) that, albeit poor, clearly shows the smaller



Figure 2. An adult *Hierophis viridiflavus* swallowing a sub-adult conspecific at the Isola d'Elba (Livorno province, Tuscany, Italy)



Figure 3. A juvenile *Hierophis viridiflavus* swallowing a juvenile conspecific at the Parco Archeologico Valle dei Templi (Agrigento province, Sicily, Italy)

juvenile almost completely swallowed, with only the tail protruding.

In the case of attempted ophiophagy, a melanistic adult *H. viridiflavus* was attempting to consume a similar sized (approx. 1 m) *Zamenis lineatus* (Fig. 4). This behavior was observed on 1 May 2021 at the locality Le Vigne (Biancavilla municipality, Etna volcano, Catania province, Sicily, Italy, 37° 39'16.48" N, 14° 54'44.09" E, about 800 m a.s.l.), in an open habitat within a context of mixed woody formations (*Quercus* sp. and *Pinus* sp.), and remains of cultivated areas. The two individuals were observed tightly intertwined, with the *Z. lineatus* trying to constrict *H. viridiflavus*, this was apparently a successful defense as after a few minutes of observation the two snakes separated and disappeared.

The known cases of ophiophagy available in the literature for *H. viridiflavus* together with our new records are summarised in Table 1. The addition of cannibalism by a juvenile specimen makes it clear that this behaviour may be shown from an early age. The attempted predation of *Z. lineatus* is the first record for this species although there is a known case of an adult *H. viridiflavus* preying upon a juvenile *Zamenis longissimus* (Capula et al., 2014). Occasional feeding by cannibalism and ophiophagy are not unusual in snake



Figure 4. Attempted predation of an adult *Zamenis lineatus* by a similar sized *Hierophis viridiflavus* at Etna volcano (Biancavilla municipality, Catania province, Sicily, Italy). After a few minutes of being observed the snakes separated and disappeared.

species with wide ranging diets and from time to time the tables may be turned as *H. viridiflavus* has been observed as the prey species for *Malpolon monspessulanus* in northwestern Italy (Ottonello et al., 2006) and *Coronella austriaca* in northern Italy (Di Nicola et al., 2020).

 Table 1.
 Summary of known records of ophiophagy, including cannibalism, in *Hierophis viridiflavus*

Prey species	Approximate life stage	Type of observation	Country	Reference
Hierophis viridiflavus	eggs	gut content	France	Schmidlin et al. (1996)
Hierophis viridiflavus	adult	gut content	France	Naulleau (1987)
Hierophis viridiflavus	adult	museum sample	Italy	Capula et al. (2014)
Hierophis viridiflavus	adult	field observation	Italy	This study
Hierophis viridiflavus	adult	field observation	Italy	This study
Hierophis viridiflavus	juvenile	field observation	Italy	This study
Hierophis viridiflavus	sub-adult	field observation	Italy	Tiglio (2013)
Zamenis lineatus	adult	field observation	Italy	This study
Zamenis Iongissimus	juvenile	gut content	Italy	Capizzi et al. (2008)
Vipera aspis	adult	field observation	France	Duron & Acolat (1957)
Vipera aspis	adult	field observation	Italy	Capula et al. (2014)
Vipera aspis	adult	museum sample	Italy	Vanni & Lanza (1977); Filippi (1994)
Vipera aspis	adult	field observation	Italy	Capula et al. (2014)

ACKNOWLEDGEMENTS

We are grateful to Antonio Zappalà (Catania) for giving us the photograph shown in Figure 4 and to Elisabetta Spadaro (Donnalucata, Ragusa) for logistical support during the field research at Isola d'Elba.

REFERENCES

- Capizzi, D., Capula, M., Rugiero, L. & Luiselli, L. (2008). Dietary patterns of two sympatric Mediterranean snakes (*Hierophis viridiflavus* and *Zamenis longissimus*) along a gradient of habitat alteration. *The Herpetological Journal* 18: 141–146.
- Capula, M., Grano, M., Cattaneo, C. & Contini, F. (2014). Ophiophagy in *Hierophis viridiflavus* (Lacépède, 1789) (Serpentes, Colubridae): More than occasional? *Scripta Herpetologica*. Studies on Amphibians and Reptiles in honour of Benedetto Lanza: 49–54.
- Di Nicola, M.R., Zecchin, L., D'Amico, M. & Faraone, F.P. (2020). Ophiophagy in *Coronella austriaca*: first case of predation on *Hierophis viridiflavus* and first direct observations of predation on *Vipera aspis*. *Herpetology Notes* 13: 1107–1110.
- Duron, P. & Acolat, L. (1957). La couleuvre verte et jaune (*Zamenis viridiflavus* Lacépède) peut contribuer à la destruction des Vipères. *Annales scientifique de l'Universitéde Besançon, Zoologie et Physiologie* 6: 179–183.
- Filippi, I. (1994). Io sto con le vipere. Ricerche sui rettili italiani. *Ediemme Editrice*, Firenze. 235 pp.
- Naulleau, G. (1987). Les Serpents de France: Couleuvre verte et jaune. *Revue Francaise d'Aquariologie Herpetology* 11: 32–35.

- Ottonello, D., Oneto, F., Salvidio, S. & Lamagni, L. (2006). Il Colubro lacertino, *Malpolon monspessulanus*, nell'Italia Nord Occidentale: distribuzione, dieta e morfometria. Atti del 6° *Congresso Nazionale della Societas Herpetologica Italica* (Roma, 27.IX-1.X.2006): 173–181.
- Schmidlin, L., Bonnet, X. & Tege, C. (1996). Natural history notes: *Coluber viridiflavus* (European whip snake). Cannibalism. *Herpetological Review* 27: 143.
- Speybroeck, J., Beukema, W., Dufresnes, C., Fritz, U., Jablonski, D., Lymberakis, P., Martínez-Solano, I., Razzetti, E., Vamberger, M., Vences, M., et al. (2020). Species list of the European herpetofauna – 2020 update by the Taxonomic Committee of the Societas Europaea Herpetologica. *Amphibia-Reptilia* 41: 139–189.
- Tiglio, S. (2013) Biacco cannibale (*Hierophis viridiflavus*)
 Serpente Cannibalismo Cannibal snake Cannibalism. YouTube video https://www.youtube.com/watch?v=_VglGQo0wlo.
- Vanni, S. & Lanza, B. (1977). Predation by the European whip snake, Coluber viridiflavus Lacépède, on the asp viper, Vipera aspis (Linnaeus). Natura, Società Italiana di Scienze naturali, Museo civico di Storia Naturale e Acquario civico di Milano 68: 285–289.
- Vanni, S. & Zuffi, M.A.L. (2010). *Hierophis viridiflavus* (Lacépède, 1789). In *Fauna d'Italia*, vol. XLV, Reptilia Corti C., Capula M., Luiselli L., Razzetti E., Sindaco R. (eds.), Calderini-II Sole 24 Ore, Bologna 2011: 509–516.

Accepted: 1 September 2022

The Madeira lizard *Teira dugesii* may have the greatest population density of any terrestrial vertebrate

KEVIN ARBUCKLE^{*} & ALEXANDER J. NICHOLS ARBUCKLE

Department of Biosciences, Faculty of Science and Engineering, Swansea University, Swansea, SA2 8PP, UK

*Corresponding author e-mail: kevin.arbuckle@swansea.ac.uk

Population density is a key demographic parameter that is fundamental to ecology, evolution, and conservation. All else being equal, denser animal populations should have lower extinction risk, higher intraspecific competition, greater genetic diversity, greater reproductive investment, and contribute more to energy flow through ecosystems, both by providing more resources to predators and by a tendency to be more generalist in their ecology than rarer species (Gaston & Kunin, 1997). Hence, understanding and documenting population densities of species gives important insight into their natural history beyond their population dynamics.

The Madeira lizard *Teira dugesii* is a lacertid species endemic to Madeira (both the Madeiran and the Selvagens archipelagos) and is the only native terrestrial reptile on those islands (Arnold & Ovenden, 2002). On Madeira, the species is typically very bold, allowing people to approach closely, and is found throughout the island from sea level to the top of the highest peaks at ~1850 m a.s.l. (Arnold & Ovenden, 2002). The Madeira lizard is found in a wide range of habitats including arid islands like Deserta Grande and rocky coasts within the spray zone (pers. obs.), and has a similarly broad diet (Sadek, 1981). Lizards occur almost everywhere on the island with sufficient cover for shelter, particularly holes in walls, tree bark, and other vegetation, including in the middle of the city of Funchal.

Perhaps as expected from the highly generalist habits of the species, it is frequently reported to be very abundant on the islands it inhabits. For instance, Arnold & Ovenden (2002) state it is "extremely common, sometimes with up to 4 individuals per square metre", and Galán & Vicente (2003) refer to there being "very high densities over most of the island of Madeira". Moreover, Koleska et al. (2017) published an observation of an aggregation of ">30 males and females on a single spot", and added that "many more individuals (>100) were observed on cracked sun-exposed rocks in the surroundings". While the latter authors provided a photo of the particular observation they document, showing many lizards using what appears to be a particularly good basking spot, there is no indication of the area over which the >100 other lizards were observed, or whether the photographed aggregation was typical or unusual. Indeed, with the exception of Arnold & Ovenden's (2002) statement of "up to 4 individuals per square metre" we were unable to find quantitative statements or data on the population densities of Madeira lizards.



Figure 1. Illustration of high density of *Teira dugesii* on a representative wall with holes for shelter. This style of wall is common throughout the island and is a frequent lizard habitat.

Following a visit to Madeira on 15–22 April 2022, we were struck by the very high density of Madeira lizards throughout the island. We noticed comparably high abundances of lizards wherever there were suitable shelters (present over most of the island) such as rock outcrops, walls with holes, or vegetation, such that across the island we could readily find a great many individuals as soon as the sun shone on surfaces with nearby shelters (Fig. 1), as can also be seen in a video we recorded (BHS video, 2023). Consequently, we visited Madeira again on 23–30 May 2022 with the aim of estimating the density of Madeira lizards in a representative sample of suitable habitat within the gardens of the Quinta Jardins do Lago hotel.

Our primary estimate of density was based on surveys of walls containing holes which were in the sun at the time of survey, to ensure lizards would be active and hence visible. Such walls have several features which enable the most accurate estimates of density to be made. First, by using open walls (not covered by vegetation) our view was not obstructed and an accurate count of individuals could be made. Note that individuals could be identified due to substantial variation in colour-pattern, size, and location



Figure 2. Top of Galapagos tortoise shelter showing lizards basking on top and two in the foreground emerging from the gaps between bamboo that led to a tray under the roof

on the wall. Second, this is a representative habitat for the lizards, and similar walls (or analogous cliffs and outcrops) are found throughout the island, so such surveys should give meaningful natural history information. Third, the walls are easy to define and sample systematically to ensure representative surveys, such that we did not bias sampling towards disproportionately high-density areas. Finally, it is straightforward to calculate the surface area of walls and hence calculate density as number of lizards per m².

On 24 May 2022 we sampled all walls around the gardens that met the a priori criteria of being free from vegetation, containing holes for shelter (i.e. not cemented), and in the sun at the time of sampling. These criteria were designed only to enable accurate counts in suitable habitat for the lizards, and resulted in ten surveys. Upon identifying each wall, we remained ~3 m away and observed the wall for five minutes, counting the number of individual lizards active on the wall surface. The distance was sufficient to avoid disturbance to the lizards and the timeframe was chosen since this was apparently sufficient for all or most lizards in the wall to become active (no new individuals were visible towards the end of the sampling period). We then measured the dimensions of the wall with a measuring tape and calculated its surface area in m². It is possible that some lizards remained sheltering in holes, such that our density estimates are underestimated, but our sampling strategy was optimised to provide as accurate a measure as possible.

Although our wall surveys are our primary estimates due to their relative accuracy, we also took two supplementary approaches to illustrate density measures with other methods and locations. We used a series of line transects along all paths in the gardens which were bordered with vegetation (providing shelter), and counted all lizards spotted basking or fleeing within 1 m of the path edge. There were 18 transects meeting the criteria of having vegetation along their borders, and we calculated density as number of lizards per m of path. These transects were surveyed on 29 May 2022, but as there **Table 1**. Data from wall surveys including calculated density estimates in individuals per m², and conversions of these estimates to individuals per hectare and per km² to enable comparisons with previous studies of vertebrate population densities

Location	Observation start time	No. of lizards	Area of wall (m ²)	Density (per m²)	Density (per hectare)	Density (per km²)
1	11:30 h	17	1.548	10.982	10,982	10,982,000
2	11:45 h	7	4.305	1.626	1,626	1,626,000
3	12:02 h	18	1.872	9.615	9,615	9,615,000
4	12:22 h	9	3.1	2.903	2,903	2,903,000
5	12:35 h	2	0.425	4.706	4,706	4,706,000
6	12:45 h	13	0.624	20.833	20,833	20,833,000
7	12:54 h	8	0.86	9.302	9,302	9,302,000
8	13:07 h	16	1.578	10.139	10,139	10,139,000
9	14:12 h	10	2.675	3.738	3,738	3,738,000
10	14:28 h	16	2.981	5.367	5,367	5,367,000
			Mean:	7.921	7,921	7,921,000

was intermittent rather than full sun, basking conditions were varied. This factor, as well as the more limited visibility of lizards in path-side vegetation, will likely have resulted in substantial underestimation of density. We tried to estimate the effect of weather by resampling the two transects that were undertaken under the most cloud cover. Resampling was undertaken within one hour of the original samples to minimise the chances of lizards leaving or entering the area in substantial numbers.

Our final supplementary density measure made use of a bamboo shelter for a resident Galapagos tortoise. This structure enabled visibility both of lizards basking on top (analogous to wall surfaces) and also inside the roof of the structure, as this was visible from the side through gaps in the bamboo (Fig. 2). The roof had a relatively shallow gap of ~5 cm underneath which had a metal tray at its base, so we counted all lizards using this shelter at 14:38 h on 24 May 2022 and measured the surface area of the roof to calculate the density as the number of individual lizards per m².

Densities estimated from wall surveys were very high in all ten walls sampled, with a mean of almost eight lizards per m^2 and densities as high as >20 lizards per m^2 ; the lowest density recorded was still >1 lizard per m^2 (Table 1). Although prone to substantial underestimation, estimates of lizard densities from our line transects along pathways were still high, with a mean of ~1 lizard per m (Table 2). Notably, when the two transects that were surveyed under the most overcast conditions were repeated in sunny conditions the estimated densities increased ~twofold. This indicates the impact that the intermittent sun during the transects likely had in compounding the underestimation of density, and so reinforces the high densities of Madeira lizards reported here. Finally, we counted 31 lizards on and just under the 2.660 m² roof of the tortoise shelter, giving a density of **Table 2**. Data from line transects along paths, including calculated density estimates in individuals per m and the two resampled transects

Transect	Observation start time	Number of Transect lizards length (m)		Density (lizards/m)
1	12:46 h	8	26	0.308
2	12:48 h	7	14	0.5
3	12:52 h	6	5	1.2
4	12:55 h	16	13	1.231
5	12:57 h	29	20	1.45
6	13:00 h	3	5	0.6
7	13:04 h	16	12	1.333
8	13:07 h	6	9	0.667
9	13:09 h	7	17	0.412
10	13:10 h	8	23	0.348
11	13:13 h	11	18	0.611
12	13:15 h	20	14	1.429
13	13:19 h	15	21	0.714
14	13:23 h	27	24	1.125
15	13:25 h	15	14	1.071
16	13:26 h	17	9	1.889
17	13:29 h	14	25	0.56
18	13:32 h	9	16	0.563
Resample				
1	13:37 h	19	26	0.731
5	13:41 h	69	20	3.45
	I	Mean of origi	nal samples:	0.89
		Mean of res	amples only:	2.09
Mea	1.02			

11.654 lizards per m². Notably, this is within the range of the wall surveys but slightly higher than the estimates from most walls, perhaps reflecting the fact that we could also view lizards which may have stayed hidden inside the shelter rather than just those which were active on the surface.

Taking the mean density calculated from the wall surveys as the most accurate estimate, our data suggest population densities of Madeira lizards as almost twice the value stated by Arnold & Ovenden (2002), though it is unclear what (if any) data the latter is based on. The estimated density of Madeira lizards in our study is higher than the highest values reported for birds or mammals, and is towards the high end of estimates from reptile and amphibian populations compiled by Santini et al. (2018a). Importantly, those authors caution that the values reported in their compilation are not means, and extreme values may be unrepresentative; in this vein we note that 40 % of our individual wall samples had higher densities than the maximum in that compilation. Indeed, Rodda et al. (2001) reported that many population density estimates make little attempt to be representative and in fact target specific areas for their disproportionately high-density populations. In contrast, we aimed to choose a representative location based on our casual observations of Madeira lizards

across the island and took repeated samples from conditions specified a priori to estimate a mean.

Rodda et al. (2001) report that the highest density terrestrial vertebrate population is their estimates of 13,400 and 52,800 *Sphaerodactylus macrolepis* geckos per hectare. Our mean estimate of 7,921 *T. dugesii* per hectare therefore appears to fall short of this record in number of individuals. However, since most vertebrates living in high densities are small, Rodda et al. (2001) argue that biomass density may be a better comparison across species than number of individuals, for which their estimates of *S. macrolepis* density is 3.60–15.26 kg per hectare. Since *T. dugesii* are much larger than those geckos, we estimate their biomass density using our mean individual density multiplied by a mean body size of 4.84 g (Galán & Vicente, 2003) as 38.34 kg per hectare, over twice the previous record density for terrestrial vertebrates.

Many factors have been found to influence population density (Santini et al., 2018b), but an important promoter of high population density is low predation rate (Salo et al., 2010). Although no direct data on total predation rates exist for Madeira lizards, these may be expected to be low compared to many other lizards. Despite many individuals having regenerated tails (pers. obs.), which may be from predation or intraspecific aggression, and occasional records of predation from species that don't usually prey upon vertebrates (Rocha et al., 2010), potential predators of lizards are few in number on Madeira. The native fauna of the island contains no snakes, larger lizards, terrestrial mammals, or corvids, and while some other birds such as shrikes, hoopoes, and starlings may occasionally eat lizards, they are all relatively rare on Madeira (Bowler, 2018). Only diurnal raptors are likely notable predators but the rate at which they feed on T. dugesii is unknown. Even more indirectly, low predation rate is known to favour slower life histories (Promislow & Harvey, 1990; Sparkman et al., 2013), and consistent with this, Madeira lizards tend to have higher longevity and larger eggs than other lacertid species (Galán & Vicente, 2003; Jesus, 2012), even compared to insular species which also tend to have slower life histories (Novosolov et al., 2013).

Although achieving comparable estimates of population density across species is challenging, we here report that the Madeira lizard has a very high population density, indeed one of the highest amongst terrestrial vertebrate species in terms of number of individuals. If biomass is incorporated, this species may in fact have the highest biomass density of any terrestrial vertebrate so far recorded. We suspect this is a consequence of unusually low predation pressure on Madeira lizards from the paucity of predators on Madeira, and encourage more detailed studies into the natural history of this species.

ACKNOWLEDGEMENTS

We thank the staff at the Quinta Jardins do Lago hotel for their incredible hospitality and permission to study the lizards in their gardens. This study was approved by the Swansea University Ethics Committee (approval number SU-Ethics-Staff-180822/512).

REFERENCES

- Arnold, E.N. & Ovenden, D.W. (2002). A Field Guide to the Reptiles and Amphibians of Britain and Europe, 2nd edition. London: Collins Publishers. 288 pp.
- BHS video (2023). Large numbers of Madeira lizards (*Teira dugesii*) on a rocky wall in the gardens of the Quinta Jardins do Lago hotel. Recorded by Arbuckle, K. https:// youtu.be/m6qhtVE7WZI.
- Bowler, J. (2018). *Wildlife of Madeira and the Canary Islands*. New Jersey: Princeton University Press. 224 pp.
- Galán, P. & Vicente, L. (2003). Reproductive characteristics of the insular lacertid *Teira dugesii*. *The Herpetological Journal* 13: 149–154.
- Gaston, K.J. & Kunin, W.E. (1997). Rare-common differences: an overview. In *The Biology of Rarity: Causes and Consequences of Rare-Common Differences*, 12–29 pp. Kunin, W.E. & Gaston, K.J. (Eds.). London: Chapman & Hall.
- Jesus, J. (2012). Evidence of high longevity in an island lacertid, *Teira dugesii* (Milne-Edwards, 1892). First data on wild specimens. *Acta Herpetologica* 7: 309–313.
- Koleska, D., Vrabec, V. & Kulma, M. (2017). *Teira dugesii* (Squamata: Lacertidae) – high aggregation. The *Herpetological Bulletin* 139: 31–32.
- Novosolov, M., Raia, P. & Meiri, S. (2013). The island syndrome in lizards. *Global Ecology and Biogeography* 22: 184–191.
- Promislow, D.E.L. & Harvey, P.H. (1990). Living fast and dying young: a comparative analysis of life-history variation among mammals. *Journal of Zoology* 220: 417–437.

- Rocha, R., Paixão, M. & Gouveia, R. (2010). Predation note: Anthus berthelotii madeirensis (Passeriformes: Motacillidae) catches Teira dugesii mauli (Squamata: Lacertidae) in Deserta Grande, Madeira Archipelago. Herpetology Notes 3: 77–78.
- Rodda, G.H., Perry, G., Rondeau, R.J. & Lazell, J. (2001). The densest terrestrial vertebrate. *Journal of Tropical Ecology* 17: 331–338.
- Sadek, R.A. (1981). The diet of the Madeiran lizard *Lacerta dugesii*. *Zoological Journal of the Linnean Society* 73: 313–341.
- Salo, P., Banks, P.B., Dickman, C.R. & Korpimäki, E. (2010). Predator manipulation experiments: impacts on populations of terrestrial vertebrate prey. *Ecological Monographs* 80: 531–546.
- Santini, L., Isaac, N.J.B. & Ficetola, G.F. (2018a). TetraDENSITY: a database of population density estimates in terrestrial vertebrates. *Global Ecology and Biogeography* 27: 787–791.
- Santini, L., Isaac, N.J.B., Maiorano, L., Ficetola, G.F., Huijbregts, M.A.J., Carbone, C. & Thuiller, W. (2018b). Global drivers of population density in terrestrial vertebrates. *Global Ecology and Biogeography* 27: 968–979.
- Sparkman, A.M., Bronikowski, A.M., Billings, J.G., Von Borstel, D. & Arnold, S.J. (2013). Avian predation and the evolution of life histories in the garter snake *Thamnophis elegans*. *American Midland Naturalist* 170: 66–85.

Accepted: 1 September 2022

New insights into the distribution of the gharial *Gavialis gangeticus* in Bangladesh from the analysis of news reports

MD. FAZLE RABBE^{1*}, SUMAIYA AKTER¹, MD. MAHFUZAR RAHMAN² & AZIZUL ISLAM BARKAT¹

¹Wildlife Research Laboratory, Department of Zoology, University of Dhaka, Bangladesh ²Department of Disaster Science and Climate Resilience, University of Dhaka, Bangladesh

[°]Corresponding author e-mail: fazle_zool@du.ac.bd

The gharial *Gavialis gangeticus* Gmelin, 1789, is a fish-eating crocodile that is Critically Endangered and has already become extinct in Pakistan, Myanmar, and Bhutan (Lang, 2019; Uetz, 2021). The current distribution of this species includes some restricted localities in north India, the lowlands of Nepal, and in Bangladesh - the Padma-Brahmaputra basin (i.e. the major river system). Only 300–900 mature individuals of this species are surviving and its range in Bangladesh is very confined (Lang, 2019) where it is rare, but present in the rivers Padma, Jamuna and Brahmaputra (Khan, 2008; Chakma, 2009; Hasan et al., 2014; Jaman, 2015).

In Bangladesh, gharials are occasionally found as by-catch in fishing nets (IUCN Bangladesh, 2016). Limited information on gharials is available from the published literature (Sarker et al., 2003; 2008; Rashid et al., 2014; IUCN Bangladesh, 2016). The majority of these information sources used interviews and questionnaire surveys for data collection, with little data coming from direct observation. Here, we assess news reports of gharial catch from 2016 to 2022 (until August) in Bangladesh, and investigate trends in catch by year and month, fate after catch, and identify the likely hotspots of occurrence.

We searched online news portals for news reports of gharials. We searched by keywords (e.g. gharial, river, fisherman) on Google using English and Bengali language (the official and native language of Bangladesh). We used combinations of the keywords to do this, such as 'gharial' + 'rescue/dead', 'gharial' + 'river name' + 'district name' and 'gharial' + 'rescue/dead' + 'fisherman' etc. We used information such as date and location of the incident to avoid duplicate records in the dataset. For each report, we recorded the following information: 1) day, 2) month, 3) year, 4) district, 5) river where caught, 6) condition which was 'rescued and





Figure 1. Number of reports of gharial catch in the river systems of Bangladesh from 2016 to August 2022 by - A. Year, and B. Month

Figure 2. The number of reports of gharials in the river systems of Bangladesh from 2016 to August 2022 by - **A.** Where trapped, and **B.** Where released

New insights into the distribution of the gharial Gavialis gangeticus in Bangladesh



Figure 3. Map showing the full range of the gharial at the top, below the records of gharial captures in Bangladesh collected in the present study and the gharial hotspots inferred from them

released', 'rescued for captive breeding', or 'unknown', 7) place of release, 8) exact location of gharial catch with GPS, 9) number of individual, and 10) cause of capture/trap. We extracted location data (GPS) using Google Maps from the centre of the area, if not specified clearly in the report. We produced a map showing hotspots with the Kernel Density function by ArcMap (version 10.3). We used chi-square test to examine the significant differences in the categorised data among years and months. All plots and analyses were done in R version 3.4.4 (R Core Team, 2018).

A total of 14 reports on gharial catch have been recorded, of which 42.86 % (n = 6) were from 2020. No reports have been found for 2017 or 2019 (Fig. 1). The number of reports between years did not differ significantly (χ^2 = 2.571, df = 3, p = 0.463). All the reports stated that gharials were caught in fishing nets, all of them were entangled in the dry season, and all gharials reported in the news were 70 to 165 cm long which is the typical size range of sub-adult gharials. The highest catch was found in the month of November (n = 6, 42.86%) followed by October (n = 5, 35.71%) but the monthly reports did not differ significantly (χ^2 = 8.857, df = 4, p = 0.064) (Fig. 1).

The fourteen gharials were trapped in four rivers of Bangladesh. Among them, the maximum was recorded for

Jamuna (n = 7, 50 %) followed by Padma (n = 5, 35.71 %) and single individuals were found for the rivers Brahmaputra and Nabaganga. The variation in gharial capture rate was not significantly different for the four rivers (χ^2 = 7.714, df = 3, p = 0.052). Eight of the 14 gharials captured were rescued and released on-site, three were collected for captive breeding and kept in safari park (n = 2) and zoo (n = 1) (Fig. 2). The other three individuals were entangled in fishing nets but their subsequent fate was not reported.

The trapped gharials in the reports came from ten districts and all of these districts are situated adjacent to waterbodies. Among them, three reports were from upstream of the Jamuna river (Gaibandha) and formed a small hotspot. While five were from downstream of the Jamuna river (Sirajganj, Tangail and Manikganj) and two at the junction of Padma-Jamuna (Pabna and Rajbari) forming the largest hotspot (Fig. 3). The other records from upstream and downstream of Padma along with Nabaganga showed a lower density.

It is evident from the reports that gharials have been using the major rivers as well as their tributaries and distributaries. People living in these areas are principally dependent on the agro-fisheries sector for their livelihood. All the records we obtained of the gharials were caught in fishing nets, which

Time period	Padma	Jamuna	Brahmaputra	Nabaganga	Teesta	Mahananda	Total
2016-2022*	5	7	1	1	0	0	14
2000–2015	39	17	1	0	0	1	58
1980–1999	16	24	0	0	0	0	40
1955–1979	9	15	0	0	1	0	25

Table 1. Number of records of gharials from different time periods in different rivers according to IUCN Bangladesh (2016) and the currentstudy*, which is based on news reports, all other studies used questionnaire surveys

are a serious threat to the gharial throughout its range (IUCN Bangladesh, 2016). Rashid et al. (2014) collected gharial catch reports which documented the trapping of 21 gharials in fishing nets from 2009 to 2012. This indicates that the gharial population may have been much higher previously, compared to the present time. In the case of these 21 gharials, 17 were released on-site and 4 were taken for breeding purposes (two in Dhaka zoo and Rajshahi zoo, both died later, and two in Bhawal National Park). We documented three cases of gharials taken into captivity, where two individuals caught in the Padma river were sent to a safari park and one caught in the Jamuna river was sent to Dhaka zoo. None of the individuals that were released on-site were injured and we found no incidents of killing or death in captivity.

Until the late 1980s, gharials were known to nest regularly in Bangladesh at sites including - Char Khidirpur (Padma river); Pechakhola, Pabna district and Baladuba Char, Kurigram district (Jamuna river) (Rashid et al., 2014). The present study did not find any records of nesting or breeding gharials. The gharials reported in the news were sub-adults and from this we assume the likely occurrence of breeding or adult individual near the hotspots identified.

The full range of the species shown in the upper portion of Figure 3 suggests that gharial is present specifically at the junction of the Jamuna-Padma river (Fig. 3). However, we found a greater number of records of the species elsewhere. Most records were from the Jamuna river and the hotspot analysis highlights this area. The previous surveys in different rivers suggested a relatively high population in both the Padma and Jamuna rivers (Table 1). No individual was previously recorded from Nabaganga river and the present study found no records of any gharials in the Teesta and Mahananda rivers (Table 1).

Based on the previous data (Table 1), IUCN Bangladesh (2016) identified four hotspots in the Padma and one in the Jamuna river. The Kajla hotspot of the Jamuna river, located in Sariakandi, Bogura, is near to the hotspot of Gaibandha recognised in this study. The four hotspots identified in the Padma river are located in Chapainawabganj and Rajshahi districts. From the current analysis, we found a large hotspot downstream of the Jamuna at its junction of the Padma river.

We recommend initiating an immediate monitoring programme for released gharial individuals as well as a rigorous systematic survey of the gharial population in the Padma-Jamuna river system to record abundance, distribution and the identification of potential breeding grounds. Once identified these should be declared as protected areas and supported with an awareness campaign for fishermen.

REFERENCES

- Chakma, S. (2009). Gavialis gangeticus. In Encyclopedia of Flora and Fauna of Bangladesh. Volume 25. Amphibians and Reptiles, 181–182 pp. Kabir, S.M.H., Ahmad, M., Ahmed, A.T.A., Rahman, A.K.A., Ahmed, Z.U., Begum, Z.N.T., Hassan, M.A., Khondker, M., (Eds.), Dhaka, Bangladesh, Asiatic Society of Bangladesh.
- Hasan, M.K., Khan, M.M.H. & Feeroz, M.M. (2014). Amphibians and Reptiles of Bangladesh: A Field Guide. Dhaka, Bangladesh, Arannayk Foundation, 177 pp.
- IUCN Bangladesh (2016). *Gharials of Bangladesh*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, 92 pp.
- Jaman, M.F. (2015). Gavialis gangeticus. In IUCN Bangladesh. Red List of Bangladesh Volume 4: Reptiles and Amphibians.
 61 pp. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh.
- Khan, M.M.H. (2008). Protected Areas of Bangladesh: A Guide to Wildlife. Nishorgo Program, Bangladesh Forest Department, Dhaka, Bangladesh, 293 pp.
- Lang, J., Chowfin, S. & Ross, J.P. (2019). *Gavialis gangeticus* (errata version published in 2019). *The IUCN Red List of Threatened Species 2019*: e.T8966A149227430. Accessed on 12 February 2022.
- Rashid, S.M.A., Khan, A. & Alam, A.B.M.S. (2014). Transboundary Sanctuary between Bangladesh and India for Gharial (*Gavialis gangeticus*) Conservation. *Proceedings* of the International Symposium on River Biodiversity: Ganges-Brahmaputra-Meghna River System. 130–138.
- Sarker, N.J., Huda, S.M.Q., Khan, S.I. & Haque, M.N. (2008). Investigation on the status, distribution and conservation problems of the Gharial (*Gavialis gangeticus*) in Bangladesh. *Bangladesh Journal of Zoology* 36: 1–9.
- Sarker, N.J., Khan, S.I. & Jaman, M.F. (2003). Population status and distribution of Gharial (*Gavialis gangeticus*) in Bangladesh. *Ecoprint* 10: 7–12.
- Uetz, P., Freed, P. & Hošek, J. (2021). <u>*The Reptile Database*</u>. http://www.reptile-database.org. Accessed on 8 February 2022.

Accepted: 19 September 2022

After 160 years of 'silence': the advertisement call of the frog Ischnocnema verrucosa

ALAN PEDRO DE ARAÚJO^{1,2*}, RODRIGO BARBOSA FERREIRA^{1,3,4}, CLARISSA CANEDO⁵, CÁSSIO ZOCCA^{1,3} & JOÃO VICTOR A. LACERDA³

¹Projeto Bromélias, Instituto de Ensino, Pesquisa e Preservação Ambiental Marcos Daniel (IMD), Av. Eugênio Pachêco de Queirós, s/n, Jardim Camburi, 29090–160, Vitória, ES, Brazil

²Universidade Federal de Goiás (UFG), Instituto de Ciências Biológicas, Departamento de Ecologia, Programa de Pós-Graduação em Ecologia e Evolução. Av. Esperança, s/n, Campus Samambaia, 74690–900, Goiânia, GO, Brazil
 ³National Institute of the Atlantic Forest (INMA), Av. José Ruschi, 4, Centro, 29650–000, Santa Teresa, ES, Brazil
 ⁴Universidade Federal do Espírito Santo (UFES), Programa de Pós-Graduação em Biologia Animal (PPGBAN), Campus Goiabeiras, 29075-910, Vitória, ES, Brazil

⁵Universidade do Estado do Rio de Janeiro (UERJ), Instituto de Biologia, Departamento de Zoologia, Rua São Francisco Xavier, 524, PHLC 510, Maracanã, 20550-900, Rio de Janeiro, RJ, Brazil

*Corresponding author e-mail: alannpedro@gmail.com

INTRODUCTION

Anurans may communicate using different signals (e.g. acoustic, chemical, seismic, tactile and visual) in isolation or in a multimodal context (Starnberger et al., 2014). Vocal communication is a conspicuous trait displayed in reproductive, defensive and agonistic social contexts (Toledo et al., 2015; Ferreira et al., 2019a). Advertisement calls are species specific and are emitted for mate attraction, thus making them useful as a taxonomic tool (Köhler et al., 2017). However, basic information about the vocal repertoire of many species of anurans is still lacking, which hampers species delimitation.

Ischnocnema verrucosa Reinhardt & Lütken, 1862, is endemic to Brazil and restricted to the south-east of the country. *Ischnocnema* comprises 39 species in six species series (*I. guentheri*, *I. lactea*, *I. parva*, *I. ramagii*, *I. venancioi* and *I. verrucosa*), there are three species unassigned to any series (*I. manezinho*, *I. nanahallux* and *I. sambaqui*), and many unnamed species (Canedo & Haddad, 2012; Taucce et al., 2018; Thome et al., 2020). The genus is a taxonomic problem with many populations not identified to the species level (e.g. Mascarenhas et al., 2015; Santos-Pereira et al., 2016; Comitti, 2017; Fiorillo et al., 2018; Ferreira et al., 2019b; Zornosa-Torres et al., 2020; Monteiro & Cremer, 2021).

These identification uncertainties within *Ischnocnema* usually relate to poor species diagnoses, the cause of which includes a lack of bioacoustics information. Indeed, 14 (36 %) species of *Ischnocnema* still lack description of their vocal repertoire. Among species belonging to the *I. verrucosa* series, *I. abdita*, *I. bolbodactyla*, *I. juipoca*, and *I. penaxavantinho* have known calls (Sazima & Cardoso, 1978; Haddad et al., 1988; Pombal & Cruz, 1999; Giaretta et al., 2007; Bastos et al., 2015; Rocha et al., 2017; Assis et al., 2018). However, *I. octavioi*, *I. surda* and *I. verrucosa* have unknown calls and taxonomic problems. Canedo et al. (2010) did not find a morphological character to differentiate *I. octavioi* from *I. verrucosa*. According to Silva et al. (2013), the specific status between *I. surda* and *I. verrucosa*

needs to be reassessed because the main diagnostic character seems to vary in a clinal manner. Furthermore, Canedo and Haddad (2012) found *I. verrucosa* paraphyletic with respect to *I. octavioi*, reinforcing doubts about the specific limits in this species complex.

The type locality of *I. verrucosa* is the Municipality of Juiz de Fora, State of Minas Gerais, south-eastern Brazil and is also the species' southernmost locality. In addition, *I. verrucosa* has been reported from the western portion of Minas Gerais state (Moura et al., 2012; Silva et al., 2013; Zornosa-Torres et al., 2020), southern and central Espírito Santo state (Tonini et al., 2010; Montesinos et al., 2012; Ferreira et al., 2019b), and southern Bahia state (Orrico, 2010; Freitas et al., 2011; 2019). Herein we describe the advertisement call of *I. verrucosa* for the first time, 160 years after its morphological description, and compare vocal traits across *Ischnocnema* species.

MATERIALS & METHODS

We analysed 49 calls emitted by four males of *Ischnocnema verrucosa* recorded at the Augusto Ruschi Biological Reserve, Municipality of Santa Teresa, State of Espírito Santo, south-eastern Brazil: MBML 11814 recorded after playback stimuli at 09:55 h, 6 July 2019, 19° 53′54″ S, 40° 32′42″ W, air temperature 18 °C; MBML 11685 and two unvouchered specimens recorded without playback stimuli at ca. 07:00 h, 27 September 2019, 19° 54′27″ S, 40° 32′12″ W, air temperature 19 °C.

We recorded using a Tascam DR-40 (with internal microphone) at a sampling rate of 48 kHz and 24 bit resolution. We analysed spectral and temporal parameters using Raven Pro 1.6.1 software from the Cornell Laboratory of Ornithology (Center for Conservation Bioacoustics, 2019). Spectral information was accessed with Fast Fourier Transformation (FFT) size of 512 and overlap of 85.2 %. Sound figures were produced using seewave and tuneR packages in R (R Core Team, 2020): hamming window type, FFT size of 512 and overlap of 90 %. We followed the bioacoustics terminology and the call-centered approach



Figure 1. Spectrogram (top) and oscillogram (bottom) of the advertisement call of *Ischnocnema verrucosa* recorded at the Municipality of Santa Teresa, State of Espírito Santo, south-eastern Brazil - A. Note with pulses not arranged in pulse groups, B. Note arranged in two pulse groups, and C. A recorded male (MBML 11685 / FNJV 59028). Red arrow indicates isolated pulses with lower amplitudes.

from Köhler et al. (2017) (i.e. uninterrupted units are treated as calls whenever they are isolated by long silent intervals). We considered the calls as a single note with pulses arranged in pulse groups when the silence between them was more than twice as long as the pulse duration. Values are presented as minimum–maximum (mean \pm standard deviation).

Our research protocol was approved by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio, Permit Number: 63575–5). Vocal recordings were deposited at the Fonoteca Neotropical Jacques Vielliard (FNJV 59028 and 59029).

RESULTS

The call of *Ischnocnema verrucosa* (Fig. 1) consists of one note with a duration of 0.097–0.319 s (0.19 \pm 0.04; n = 49), 14–62 pulses (34 \pm 9.6; n = 49) arranged in 1–3 pulse groups per note (1.8 \pm 0.6; n = 49) and emitted at a rate 135.5–193.9 pulses/s (171.8 \pm 15.9; n = 49). Calls had a peak frequency of 2583.9–3014.6 Hz (2709.6 \pm 88.8; n = 48), frequency 5 % 2239.4–2497.8 Hz (2338.9 \pm 60.8; n = 45) and frequency 95 % 2928.5–5770.9 Hz (3366.3 \pm 658.8; n = 48). An isolated pulse with lower amplitude was emitted after 0.01–0.12 s (0.07 \pm 0.02; n = 48) in 48 of the 49 analysed calls (Fig. 1).

DISCUSSION

The Municipality of Santa Teresa is ca. 350 km north-east from the type locality (Municipality of Juiz de Fora) of *Ischnocnema verrucosa*. Although the calls herein reported were not recorded from topotype specimens, they belong to the same population sampled to recover the phylogenetic position of *I. verrucosa* by Canedo & Haddad (2012). They included three specimens of *I. verrucosa* to investigate the molecular phylogeny of *Ischnocnema* (same as Taucce et al., 2018) of which two were from our location at Santa Teresa (MNRJ 34899 and 34900) and one from the Municipality of Camacan, State of Bahia (CFBH 23685); therefore, the phylogenetic position of topotypes of *I. verrucosa* has not been tested. Neves et al. (2017) recently reported *I. verrucosa* from five different sites at the type locality. However, after sampling these areas for five years (2006–2011), *I. verrucosa* was not observed calling (Neves & Varela-Rios, pers. comm).

Vocal parameters have been widely used for diagnosing species within Ischnocnema (Taucce et al., 2012; 2018). However, the genus still lacks acoustical evaluation in an evolutionary approach to improve homology criteria. Bioacoustic traits have not been used to diagnose any of the six species series. Rocha et al. (2017) stated that a general bioacoustical pattern for the I. verrucosa series is unclear. However, within the I. verrucosa series, acoustic traits seem to relate to genetic lineages and morphological similarities. The advertisement call of I. verrucosa differs from those of the I. juipoca + I. penaxavantinho lineage by its lower number of notes per call (5-19 notes per call combining vocalisation of I. juipoca and I. penaxavantinho; see Giaretta et al., 2007; Bastos et al., 2015; Assis et al., 2018) and from those of the *I. abdita* + *I. bolbodactyla* lineage by its lower number of pulses per note (2-4 pulses per note combining calls of I. abdita and I. bolbodactyla; see Pombal & Cruz, 1999; Rocha et al., 2017).

Among the other species of *Ischnocnema*, the advertisement call of *I. verrucosa* differs from *I. sambaqui*, *I. manezinho*, *I. randorum*, *I. nigriventris*, *I. bocaina*, *I. lactea*, *I. parnaso*, *I. colibri*, *I. feioi*, *I. garciai*, *I. oea*, *I. gualteri*, *I. guentheri*, *I. henselii*, *I. izecksohni*, and *I. nasuta* by its shorter duration (0.5–41.9 s combined values from these species). The advertisement call of *I. verrucosa* differs from *I. vizottoi* and *I. melanopygia* by its longer duration (0.01–0.072 s combined values from these species). The advertisement call of *I. verrucosa* differs from *I. sambaqui*, *I. manezinho*, *I. nigriventris*, *I. vizottoi*, *I. bocaina*, *I. concolor* and *I. melanopygia* by its pulsed structure (unpulsed structure in these species). The advertisement call of *I. verrucosa* differs from *I. parnaso*, *I. parva* and *I. colibri* by its higher pulse rate (16.55–44.87 pulses/s combined values from these species). Finally, the advertisement call of *I. verrucosa* differs

from *I. sambaqui, I. manezinho, I. randorum, I. nigriventris, I. bocaina, I. feioi, I. garciai, I. oea, I. gualteri, I. guentheri, I. henselii, I. izecksohni* and *I. nasuta* by its lower number of notes (2–170 notes per call in these species). For further information on the advertisement call of these species, see Heyer (1985), Castanho & Haddad (2000), Martins & Haddad (2000), Berneck et al. (2013), Andrade et al. (2017), Silva-Soares et al. (2018), Taucce et al. (2018a;b), Forti et al. (2019), and Taucce et al. (2019).

Among species of the *I. verrucosa* series, only *I. octavioi* and *I. surda* still lack descriptions of their vocalisation. *Ischnocnema octavioi* is the sister taxon of *I. verrucosa* (Canedo & Haddad, 2012; Taucce et al., 2018) and *I. surda* is tentatively closely related to this lineage based on morphological similarities (see Canedo et al., 2010; Dantas & Ferreira, 2010; Silva et al., 2013; Holer et al., 2017). A taxonomic review dealing with these three species is required to access whether they represent distinct valid species.

ACKNOWLEDGEMENTS

We thank the Projeto Bromélias for logistical support sponsored by Rufford Foundation. Instituto Nacional da Mata Atlântica (INMA) and Reserva Biológica Augusto Ruschi for logistical support. APA thanks Coordenação de Aperfeiçoamento de Pessoa de Nível Superior (CAPES), JVAL (380682/2019–2 and 300962/2022-3), CZ (300929/2022-6), and RBF (317799/2021-5) thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for research scholarship.

REFERENCES

- Andrade, F.S., Haga, I.A. & Giaretta, A.A. (2017). Reassessment of the advertisement call of *Ischnocnema parva* (Anura: Brachycephalidae). *North-Western Journal of Zoology*, 13: 271–277.
- Assis, C.L., Guedes, J.J.M., Savignon, G. & Feio, R.N. (2018). New record of the Data Deficient frog *Ischnocnema penaxavantinho* Giaretta, Toffoli and Oliveira, 2007 (Anura: Brachycephalidae) from southeastern Brazil. *Herpetology Notes* 11: 561–563.
- Bastos, R.P., Signorelli, L., Nomura, F. & Morais, A.R. (2015). Geographical distribution extension and notes on vocalizations of *Ischnocnema penaxavantinho* Giaretta, Toffoli & Oliveira, 2007 (Anura: Brachycephalidae). *The Herpetological Bulletin* 132: 22–24.
- Berneck, B.V., Targino, M., & Garcia, P.C.D.A. (2013). Rediscovery and re-description of *Ischnocnema nigriventris* (Lutz, 1925) (Anura: Terrarana: Brachycephalidae). *Zootaxa* 3692: 131–142.
- Canedo, C.B., Pimenta, V.S., Leite, F.S.F. & Caramaschi, U. (2010). New species of *Ischnocnema* (Anura: Brachycephalidae) from the state of Minas Gerais, southeastern Brazil, with comments on the *I. verrucosa* species series. *Copeia* 4: 629–634.
- Canedo, C. & Haddad, C.F.B. (2012). Phylogenetic relationships within anuran clade Terrarana, with emphasis on the placement of Brazilian Atlantic rainforest frogs genus *Ischnocnema* (Anura: Brachycephalidae). *Molecular*

Phylogenetics and Evolution 65: 610–620. Doi: 10.13128/ Acta_Herpetol-18320.

- Caramaschi, U. & Canedo, C. (2006). Reassessment of the taxonomic status of the genera *Ischnocnema* Reinhard and Lütken, 1862 and *Oreobates* Jiménez-de-la-Espada, 1872, with notes on the synonymy of *Leiuperus verrucosus* Reinhardt and Lütken, 1862 (Anura: Leptodactylidae). *Zootaxa* 1116: 43–54.
- Castanho, L.M. & Haddad, C.F. (2000). New species of *Eleutherodactylus* (Amphibia: Leptodactylidae) from Guaraqueçaba, Atlantic Forest of Brazil. *Copeia* 2000: 777–781.
- Center for Conservation Bioacoustics. (2019). Raven Pro: Interactive Sound Analysis Software (Version 1.6.1) [Computer software]. Ithaca, NY: The Cornell Lab of Ornithology. http://www.birds.cornell.edu/raven.
- Comitti, E.J. (2017). Herpetofauna da bacia do Rio Cachoeira, município de Joinville, Santa Catarina, Sul do Brasil. *Acta Biológica Catarinense*, 4: 90–105.
- Dantas, R.B. & Ferreira, R.B. (2010). Geographic distribution: *Ischnocnema octavioi. Herpetological Review* 41: 103–104.
- Ferreira, R.B., Lourenço-de-Moraes, R., Zocca, C., Duca, C., Beard, K.H. & Brodie, E.D. (2019a). Antipredator mechanisms of post-metamorphic anurans: a global database and classification system. *Behavioral Ecology and Sociobiology* 73: 69. https://doi.org/10.1007/s00265-019-2680-1.
- Ferreira, R.B., Mônico, A.T., Silva, E.T., Lirio, F.C.F., Zocca, C., Mageski, M.M., Tonini, J.F.R., Beard, K.H., Duca, C. & Silva-Soares, T. (2019b). Amphibians of Santa Teresa, Brazil: the hotspot further evaluated. *ZooKeys* 857: 139–162. https:// doi.org/10.3897/zookeys.857.30302.
- Fiorillo, B.F., Faria, C.S., Silva, B.R. & Martins, M. (2018). Anurans from preserved and disturbed areas of Atlantic Forest in the region of Etá Farm, municipality of Sete Barras, state of São Paulo, Brazil. *Biota Neotropica* 18: e20170509. http:// dx.doi.org/10.1590/1676-0611-BN-2017-0509.
- Freitas, M.A., Souza, B.H. & Fonseca, P.M. (2011). Ischnocnema verrucosa – geographic distribution. Herpetological Review 42: 385.
- Freitas, M.A, Silva, T.F.S., Fonseca, P.M., Hamdan, B., Filadelfo, T. & Abegg, A.D. (2019). Herpetofauna of Serra do Timbó, an Atlantic Forest remnant in Bahia state, northeastern Brazil. *Herpetology Notes* 12: 245–260.
- Giaretta, A.A., Toffoli, D. & Oliveira, L.E. (2007): A new species of *Ischnocnema* (Anura: Eleutherodactylinae) from open areas of the Cerrado Biome in southeastern Brazil. *Zootaxa* 1666: 43–51.
- Haddad, C.F.B., de Andrade, G.V. & Cardoso, A.J. (1988). Anfíbios anuros no Parque Nacional da Serra da Canastra, estado de Minas Gerais. Brasil Florestal. *Rio de Janeiro* 64: 9–20.
- Hedges, S.B., Duellman, W.E. & Heinicke, M.P. (2008). New World direct-developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. *Zootaxa* 1737: 1–182.
- Heyer, W.R. (1985). New species of frogs from Boracéia, São Paulo, Brazil. Proceedings of the Biological Society of Washington, 98: 657–671.
- Holer, T., Sýkorovský, D. & Hejcmanová, P. (2017). First record of *Ischnocnema octavioi* (Bokermann, 1965) from São Paulo

state, Brazil. Check List 13:2126, 1-5.

- Köhler, J., Jansen, M., Rodríguez, A., Kok, P.J.R., Toledo, L.F., Emmrich, M., Glaw, F., Haddad, C.F.B., Rödel, M.O. & Vences, M. (2017) The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. *Zootaxa*, 4251: 1–124. https://doi. org/10.11646/zootaxa.4251.1.1.
- Lynch, J.D. (1972). Generic partitioning of the South American leptodactyloid frog genus *Eupsophus* Fitzinger, 1843 (*sensu lato*). *Bulletin of the Southern California Academy of Sciences* 71: 2–11.
- Martins, I.A. & Haddad, C.F. (2010). A new species of *Ischnocnema* from highlands of the Atlantic Forest, Southeastern Brazil (Terrarana, Brachycephalidae). *Zootaxa*, 2617: 55–65.
- Mascarenhas, L., Tiso, C., Linares, A.M., Moura, C.F.O., Pezzuti, T.L., Leite, F.S.F. & Eterovick, P.C. (2015). Improved local inventory and regional contextualization for anuran diversity assessment at an endangered habitat in southeastern Brazil. *Journal of Natural History* 50: 1–17. https://doi.org/10.1080 /00222933.2015.1103911.
- Monteiro, J.P.C. & Cremer, M.J. (2021). Herpetofauna na região da Baía Babitonga, nordeste do estado de Santa Catarina: estado atual do conhecimento. Revista CEPSUL - *Biodiversidade e Conservação Marinha* 10: eb2021001. https://doi.org/10.37002/revistacepsul. vol10.691eb2021001.
- Montesinos, R., Peloso, P.L.V., Koski, D.A., Valadares, A.P. & Gasparini, J.L. (2012). Frogs and toads of the Pedra Azul Forno Grande Biodiversity Corridor, southeastern Brazil. *Check List* 8: 102–111. https://doi.org/10.15560/8.1.102.
- Moura, M.R., Motta, A.P., Fernandes, V.D. & Feio, R.N. (2012). Herpetofauna from Serra do Brigadeiro, an Atlantic Forest remain in the state of Minas Gerais, southeastern Brazil. *Biota Neotropic* 12: 209–235. https://doi.org/10.1590/ S1676-06032012000100017.
- Narins, P.M., Feng, A.S., Fay, R.R. & Popper, A.N. (2007). *Hearing* and Sound Communication in Amphibians. New York: Springer.
- Neves, M.O., Ferreira, V.G., Fonseca, E.M., Ceron, K., Varela-Rios, C.H. & Carvalho, R.M.H. (2017). Anurans of Juiz de Fora Municipality, Zona da Mata of Minas Gerais state, Brazil. *Oecologia Australis* 21: 374–384.
- Orrico, V.G.D. (2010). Amphibia, Anura, Brachycephalidae, *Ischnocnema verrucosa* Reinhardt and Lütken, 1862: Distribution extension to northeastern Brazil. *Check List* 6: 246–247.
- Pombal, J.P. & Cruz, C.A.G. (1999). Redescrição de *Eleutherodactylus bolbodactylus* (A. Lutz, 1925) e a posição taxonômica de *E. gehrti* (Miranda-Ribeiro, 1926) (Anura: Leptodactylidae). *Boletim do Museu Nacional. Nova Serie, Zoologia* 404: 1–10.
- R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
- Rocha, P.C., Lacerda, J.V.A., Magalhães, R.F., Canedo, C., Pimenta, B.V.S., Heitor, R.C. & Garcia, P.C.A. (2017). Call variation and vocalizations of the stealthy litter frog *Ischnocnema abdita* (Anura: Brachycephalidae). *Acta Herpetologica* 12: 37–48. Doi: 10.13128/Acta_Herpetol-18320.

- Santos-Pereira, M., Milani, D., Barata-Bittencourt, L.F., Iapp, T.M. & Rocha, C.F.D. (2016). Anuran species of the Salto Morato Nature Reserve in Paraná, southern Brazil: Review of the species list. *Check List* 12: 1–11. https://doi. org/10.15560/12.3.1907.
- Sazima, I. & Cardoso, A.J. (1978). Uma espécie nova de *Eleutherodactylus* do sudeste Brasileiro (Amphibia: Anura: Leptodactylidae). *Revista Brasileira de Biologia* 38: 921–925.
- Silva, E., Heitor, R., Santos, P., Viana, R., Coelho, H. & Garcia, P. (2013). New records of *Ischnocnema verrucosa* Reinhart and Lütken, 1862 and *I. surda* Canedo, Pimenta, Leite and Caramaschi, 2010 (Anura: Brachycephalidae) in Minas Gerais state, Brazil. *Check List* 9: 1062–1066. https://doi. org/10.15560/9.5.1062.
- Silva-Soares, T., Malagoli, L.R., Cruz, C.A.G. & Caramaschi, U. (2018). On the taxonomy and natural history of the secretive *Ischnocnema lactea* (Miranda-Ribeiro, 1923) (Anura: Brachycephaloidea: Brachycephalidae). *Zootaxa*, 4444, 137–153.
- Starnberger, I., Preininger, D. & Hödl, W. (2014). The anuran vocal sac: a tool formultimodal signalling. *Animal Behaviour* 97, 281–288. http://dx.doi.org/10.1016/j. anbehav.2014.07.027.
- Taucce, P.P., Leite, F.S., Santos, P.S., Feio, R.N. & Garcia, P.C.A. (2012). The advertisement call, color patterns and distribution of *Ischnocnema izecksohni* (Caramaschi and Kisteumacher, 1989) (Anura: Brachycephalidae). *Papéis Avulsos de Zoologia* 52: 111–119.
- Taucce, P.P.G., Canedo, C., Parreiras, J.S., Drummond, L.O., Nogueira-Costa, P. & Haddad, C.F.B. (2018a). Molecular phylogeny of *Ischnocnema* (Anura: Brachycephalidae) with the redefinition of its series and the description of two new species. *Molecular Phylogenetics and Evolution* 128: 123– 146. https://doi.org/10.1016/j.ympev.2018.06.042.
- Taucce, P.P., Canedo, C. & Haddad, C.F. (2018b). Two new species of *Ischnocnema* (Anura: Brachycephalidae) from southeastern Brazil and their phylogenetic position within the *I. guentheri* series. *Herpetological Monographs* 32: 1–21.
- Taucce, P.P., Zaidan, B.F., Zaher, H. & Garcia, P.C. (2019). A new species of *Ischnocnema* Reinhardt and Lütken, 1862 (Anura: Brachycephalidae) of the *I. lactea* species series from southeastern Brazil. *Zootaxa* 4706: 531–545.
- Toledo, L.F., Martins, I.A., Bruschi, D.P., Passos, M.A., Alexandre, C. & Haddad, C.F.B. (2015). The anuran calling repertoire in the light of social context. *Acta Ethologica* 18: 87–99. https://doi.org/10.1007/s10211-014-0194-4.
- Tonini, J.F.R., Carão, L.M., Pinto, I.S, Gasparini, J.L., Leite, Y.L.R. & Costa, L.P. (2010). Non-volant tetrapods from Reserva Biológica de Duas Bocas, State of Espírito Santo, Southeastern Brazil. *Biota Neotropica* 10: 339–351. https://doi.org/10.1590/S1676-06032010000300032.
- Zornosa-Torres, C., Augusto-Alves, G., Lyra, M.L., Silva Júnior, J.C., Garcia, P.C.A., Leite, F., Verdade, V., Rodrigues, M.T., Gasparini, J.L., Haddad, C.F.B. & Toledo, L.F. (2020). Anurans of the Caparaó National Park and surroundings, southeast Brazil. *Biota Neotropica* 20: e20190882. https:// doi.org/10.1590/1676-0611-BN-2019-0882.
- Accepted: 5 November 2022

Pelvic spur use during courtship and mating in the red-tailed boa Boa constrictor

RAFAEL KENJI ANZAI^{1,2}, NICOLAS FONTANA ELEUTERIO³, TIAGO DE OLIVEIRA LIMA³, RAFAEL HADDAD MANFIO⁴ & SELMA MARIA DE ALMEIDA SANTOS^{1*}

¹Laboratório de Ecologia e Evolução, Instituto Butantan, Avenida Vital Brazil, 1500, Butantã, 05503-900, São Paulo, SP, Brazil ²Instituto de Biociências da Universidade de São Paulo, Rua do Matão, travessa 14, 321, Cidade Universitária, 05508-090, São Paulo, SP, Brazil

³Criatório Jiboias Brasil, Rua Contagem, 20B, Parque Industrial de Betim, 32670-402, Betim, MG, Brazil ⁴Criadouro Reptiliano, Avenida São Paulo, 707, Centro, 86300-000, Cornélio Procópio, PR, Brazil

*Corresponding author e-mail: selma.santos@butantan.gov.br

Some phylogenetically basal snake species have pelvic girdles and vestigial hind limbs that are seen externally as pelvic spurs, which are probably a plesiomorphic character in the Alethinophidia (Stickel & Stickel, 1946; Palci et al., 2020; Senter, 2022). These pelvic spurs are generally larger in males than in females (Hoge, 1947; Slip & Shine, 1988; Shine & Slip, 1990; Hoefer et al., 2021). Moreover, pelvic spurs have musculature, innervation, and vascularisation and can move autonomously (Hoge, 1947; Bellairs, 1950; Carpenter et al., 1978; 1979). The pelvic spurs of boids and pythonids are known to be used by males during combat, courtship, and mating (Carpenter et al., 1978; Barker et al., 1979; Slip & Shine, 1988; Walsh & Murphy, 2003) and such use has been suggested as an ancestral character (Senter et al., 2014; Senter, 2022).

The red-tailed boa *Boa constrictor* Boidae, is a large viviparous snake (with a female-biased sexual size dimorphism), which inhabits areas of Mexico, Central and South America (Pizzatto & Marques, 2007; Nogueira et al., 2019). In Brazilian populations, vitellogenesis occurs in spring and summer, testicular growth in autumn, and courtship and mating in autumn and winter (Pizzatto & Marques, 2007; Garcia & Almeida-Santos, 2021). Here, we provide the first report of the use of pelvic spurs during courtship and mating in the red-tailed boa.

Our observations were made in two conservation breeding facilities in Brazil, one located in the municipality of Betim (state of Minas Gerais, south-eastern Brazil) and the other in the municipality of Cornélio Procópio (state of Paraná, southern Brazil). In both facilities, snakes were kept individually in enclosures at room temperature and under natural photoperiod. Water was provided ad libitum, and heaters were used when temperatures dropped below 15 °C. During the mating season, one adult female and one to two adult males were placed in the same enclosure (140 \times 70 \times 70 cm). To stimulate mating behaviour, freshly shed skins of other males were occasionally placed within the enclosure. To minimise stress, the snakes were monitored for only one hour at irregular intervals during the day when the behaviours occurred. Breeding pairs were left together for 3-21 days unless they showed intense courtship and mating activity;



Figure 1. Pelvic spur (red arrow) use by a captive male red-tailed boa *Boa constrictor* during courtship in a breeding facility in the municipality of Cornélio Procópio, state of Paraná, southern Brazil

in these cases, they were left together longer. The first set of observations was made between May and August 2019 at the Betim breeding facility, where six males and four females were paired. The second set of observations was made from April to September 2021 at the Cornélio Procópio facility, where five males and three females were paired weekly from early autumn (30 March 2021).

In general, as soon as the males detected females in the enclosure they remained motionless and increased tongue flicking frequency. Then, males and females started moving through the enclosure. Males then climbed on the females' backs and aligned their bodies to those of the females. Next, the males began to rub their spurs gently on the side of the females' bodies, moving in a posterior to anterior direction, this is shown for boas in the Cornélio Procópio breeding facility in Figure 1 and for the Bentim facility in a video (BHS video, 2023). The spurs repeatedly moved from a resting to an erect state. The movement and touch of the spurs may stimulate females to contract their bodies and change position, thus facilitating cloacal apposition and hemipenis intromission. Spur use may be particularly relevant for smaller males because they may not have enough strength to move the body of large females.

The timing of our observations coincides with that of previous reports on courtship and mating (Pizzatto &

Marques, 2007; Garcia & Almeida-Santos, 2021). Moreover, three mated females from the Cornélio Procópio breeding facility gave birth to a total of 51 offspring in the summer, similar to that reported in the literature (Garcia & Almeida-Santos, 2021). These results contrast with those of Gadd (1983), who reported unsuccessful parturition after courtship and mating with little use of spurs. Our data would appear to reinforce the critical role of pelvic spurs for successful courtship and mating in red-tailed boas.

ACKNOWLEDGEMENTS

We thank Henrique Braz for the English revision and suggestions and FAPESP for the financial support to R.K. Anzai (2020/01467-3).

REFERENCES

- Barker, D.G., Murphy, J.B. & Smith, K.W. (1979). Social behavior in a captive group of Indian pythons, *Python molurus* (Serpentes, Boidae) with formation of a linear social hierarchy. *Copeia* 1979(3): 466–471.
- Bellairs, A.D'A. (1950). The limbs of snakes with special reference to the hind limb rudiments of *Trachyboa boulengeri*. *The Herpetological Journal* 4: 73–83.
- BHS video (2023). Male red-tailed boa *Boa constrictor* using pelvic spur during courtship in a breeding facility in Minas Gerais, Brazil. Filmed by Rafael Haddad Manfio. https:// youtu.be/hXizrINuSIo.
- Carpenter, C.C., Murphy, J.B. & Mitchel, L.A. (1978). Combat bouts with spur use in the Madagascar boa (*Sanzinia madascariensis*). *Herpetologica* 34: 207–212.
- Gadd, J.P. (1983). Observations on the sexual behavior of the boa constrictor, *Constrictor*, in captivity, with notes on an unsuccessful parturition. *The Herpetological Bulletin* 6: 39–41.
- Garcia, V.C. & Almeida-Santos, S.M. (2021). Reproductive cycles of neotropical boid snakes evaluated by ultrasound. *Zoo Biology* 41: 74–83.

- Hoefer, S., Robinson, N.J. & Pinou, T. (2021). Size matters: sexual dimorphism in the pelvic spurs of the Bahamian boa (*Chilabothrus strigilatus strigilatus*). *Herpetology Notes* 14: 201–203.
- Hoge, A. (1947). Dimorfismo sexual nos boídeos. *Memórias do Instituto Butantan* 20: 181–188.
- Nogueira, C.C., Argôlo, A.J.S., Arzamendia, V., Azevedo, J.A., Barbo, F.E., Bérnils R.S., et al. (2019). Atlas of Brazilian snakes: verified point-locality maps to mitigate the Wallacean shortfall in a megadiverse snake fauna. *South American Journal of Herpetology* 14(Special Issue 1): 1–274.
- Palci, A., Hutchinson, M.N., Caldwell, M.W., Smith, K.T. & Lee, M.S.Y. (2020). The homologies and evolutionary reduction of the pelvis and hindlimbs in snakes, with the first report of ossified pelvic vestiges in an anomalepidid (*Liotyphlopsbeui*). *Zoological Journal of the Linnean Society* 188: 630–652.
- Pizzatto, L. & Marques, O.A.V. (2007). Reproductive ecology of boinae snakes with emphasis on Brazilian species and a comparison to pythons. *South American Journal of Herpetology* 2(2): 107–122.
- Senter, P. (2022). Phylogeny of courtship and male-male combat behavior in snakes: an updated analysis. *Current Herpetology* 41(1): 35–81.
- Senter, P., Harris, S.M. & Kent, D.L. (2014). Phylogeny of courtship and male-male combat behavior in snakes. *PLoS ONE* 9(9): 1–10, e107528.
- Shine, R. & Slip, D.J. (1990). Biological aspects of the adaptative radiation of Australasian pythons (Serpentes: Boidae). *Herpetologica* 46(3): 283–290.
- Slip, D.J. & Shine, R. (1988). The reproductive biology and mating system of diamond pythons, *Morelia spilota* (Serpentes: Boidae). *Herpetologica* 44(4): 396–404.
- Stickel, W.H. & Stickel, L.F. (1946). Sexual dimorphism in the pelvic spurs of *Enygrus*. *Copeia* 1946(1): 10–12.

Accepted: 20 September 2022

First record of the Indian smooth snake Wallophis brachyura from Karnataka, India

D. DEEPAK, S. BABU^{*}, H.N. KUMARA & R.S. NAVEEN

Sálim Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore, Tamil Nadu, India

^{*}Corresponding author e-mail: sanbabs@gmail.com

.....

he Indian Smooth Snake Wallophis brachyura Günther, 1866, is a non-venomous, slender, crepuscular snake endemic to India (Whitaker & Captain, 2004; Parmar, 2019). Despite the snake being rare, it has been listed as 'Least Concerned' (IUCN, 2021) due to its wide ranging distribution. The species has been recorded across a variety of habitats in central India such as arid scrub, dry deciduous forests, semi-evergreen forests, small hillocks, farmlands, and human settlements. It is an agile and non-aggressive snake that has displayed burrowing behaviour and has been found on open ground, on trees, and under piles of rocks. It feeds on juveniles of geckos, skinks, and garden lizards, and kills its prey by constricting them (Whitaker & Captain, 2004). It is a species that is active throughout the year, but most active between February and September (Parmar, 2019; Ghadage et al., 2013; Jadhav et al., 2018).

The snake was described by Günther in 1866 from the present-day Pune district in Maharashtra and since then has been reported from four states namely Maharashtra, Gujarat, Madhya Pradesh, and Chhattisgarh (Table 1S, see Supplementary Material), with most records from Gujarat and Maharashtra. This species was reported from many localities in 12 districts of Maharashtra since 1866, and from Ahmedabad, Surat, and Tapi districts of Gujarat since 2006 (Patel et al., 2015; Parmar, 2019). It has been recorded once



Figure 1. Indian Smooth Snake *Wallophis brachyura* in Siruguppa taluk of Bellary district in Karnataka



Figure 1. Published and verified distribution records of the *Wallophis* brachyura in India

from both Bhopal and Ujjain districts in Madhya Pradesh (Ingle & Sarsavan, 2011; Patel et al., 2015), and once from Rajnandgaon district in Chhattisgarh (Parmar, 2019). The species has been described as endemic to central and western India, as it was believed that its range is restricted only to the four states in which it had been recorded in the past.

Herein, we report the first record of this species from the southern Indian state of Karnataka. The current record of this species is from Siruguppa taluk of Bellary district, and it marks the southernmost record of the species in the country. Siruguppa taluk lies in the north-eastern part of the Bellary district, covering an area of 1,034 km² situated between 14° 51' and 15° 50' latitude and between 76° 21' and 77° 09' longitude. Siruguppa has a vast expanse of flat agricultural landscapes containing mostly black cotton soil, with red soil being present in the south-western parts of the taluk. The tree density in the landscape is very low, so the entire area is almost open, except for the few small hillocks present in the

mid-western parts of the taluk. The average annual rainfall in the area is 683 mm (District Census Handbook, 2011).

On 14 November 2020 at 07:50 h, a snake was sighted in the north-eastern part of Siruguppa taluk (at an altitude of 370 m a.s.l. at 22 °C). It was crossing a dirt path that was bordered by an agricultural area with black soil and cotton crops. It was photographed without being disturbed. The individual measured ~1 m in length. The snake was later identified from the photograph to be an individual of the species *W. brachyura* (Fig. 1.).

The Extent of Occurrence (EOO) derived by using all the past distribution records is ~370,000 km². The new sight record extends the EOO further south and increases the area by ~100,000 km². As of now, our current observation is the southernmost distribution limit of the species.

ACKNOWLEDGEMENTS

We thank the Karnataka Forest Department for the necessary funding and permission to conduct this study. We also thank the Director, SACON for the timely facility being provided to the investigator while executing this study.

REFERENCES

- District Census Handbook: Bellary (2011). Census of India 2011 (Karnataka). Series 30, Part XII A.
- Ghadage, M.K., Theurkar, S.V., Madan, S.S., Bhor, G.L. & Patil, S.B. (2013). Distribution of *Calliophis melanueus*, *Boiga trigonata*, *Coluber grascilis* and *Coronella brachyera* in Western region of Khed Tahsil, MS, India. *Research Journal of Recent Sciences* 2: 24–25.

- Günther, A. (1866). Fifth account of new species of snakes in the collection of the British Museum. *Annals and Magazine of Natural History* 3(18): 24–29.
- Ingle, M. & Sarsavan, A. (2011). A new locality record of *Coronella brachyura* (Günther, 1866) (Serpentes, Colubridae, Colubrinae) from Madhya Pradesh, India, with notes on its distribution and natural history. *Sauria* 33(2): 59–61.
- IUCN (2021). The IUCN Red List of Threatened Species. Version 2021-2. www.iucnredlist.org.
- Jadhav, P.L., Chavan, S.P. & Trimukhe, H.S. (2018). Snake species diversity and their distribution in and around Nanded city, Maharashtra, India. *Journal of Entomology and Zoology Studies* 6(4): 1855–1860.
- Parmar, D.S. (2019). Description of head scalation variation, hemipenis, reproduction, and behavior of the Indian Smooth Snake, *Coronella brachyura* (Günther, 1866). *Amphibian & Reptile Conservation* 13(1): 78–89 (e164).
- Patel, H., Vyas, R. & Tank, S.K. (2015). On the distribution, taxonomy, and natural history of the Indian Smooth Snake, *Coronella brachyura* (Günther, 1866). *Amphibian* & *Reptile Conservation* 9(2) [General Section]: 120–125.
- Whitaker, R. & Captain, A. (2004). *Snakes of India, the Field Guide*. Draco Books, Chennai, India, 495 pp.

Accepted: 29 October 2022

Please note that the Supplementary Material for this article is available online via the Herpetological Bulletin website: https://thebhs.org/publications/the-herpetological-bulletin/issue-number-163-spring-2023

Common wall lizards *Podarcis muralis* at a new site in England registered by a citizen science reporting tool

WILL JOHANSON^{*} & JENNY TSE-LEON

The Froglife Trust, Brightfield Business Hub, Bakewell Road, Peterborough, PE2 6XU, UK

*Corresponding author e-mail: william.johanson@froglife.org

.....

The common wall lizard *Podarcis muralis* Laurenti, 1768, is a small lizard species that is widely distributed across southern and western Europe (Böhme et al., 2009). It has colonised areas outside this native range successfully, including Britain, where the Wall Lizard Project estimates 20,500 animals to be living (Langham, 2019). Here, we report an observation of *P. muralis* at Faversham, a town in south-east England. This has been identified from a sighting submitted to Froglife's Dragon Finder App, a free digital recording tool that was developed with the aim of increasing recording of amphibians and reptiles by members of the public in Great Britain and Northern Ireland.

The wall lizard sighting was submitted to a Microsoft Access database through the Dragon Finder App on 9 April 2022, as a photo of a pair of lizards basking on a brick wall (Fig. 1). These were reported using the species selection tool built into the app as viviparous lizards Zootoca vivipara. However, during verification by trained Froglife staff members and volunteers (using photos and distributional records), the two lizards were identified as P. muralis, probably an adult male and female. Through information accompanying the submission, we learned that the sighting was from a private garden of a property built three years earlier. From the location of the sighting and follow-up correspondence with the app user, it was inferred that the house is part of a larger residential development, bordered by mixed land uses (improved grassland, built-up areas and arable fields) (Kent Habitat Survey, 2012). The approximate location of the sighting was 51.309° N, 0.88° E (Fig. 2). In further correspondence with the app user, we received photographs taken in spring 2020 of a juvenile *P. muralis* basking on the same brick wall (Fig. 3). The user had observed lizards basking on the garden walls, believed to be the same population of *P. muralis*, regularly in the spring and summer since 2020.

The only other verified reports of *P. muralis* in the Faversham area come from the nearby site of Ospringe Church (location: 51.30684° N, 0.86835° E), first recorded and verified by Kent Reptile and Amphibian Group in July 2020. At the time of writing, the origin of this population had not been identified. This population is located <1 km south-west of the Faversham sighting, separated mostly by a mixture of arable fields and improved grassland (Kent Habitat Survey, 2012).

Williams (2019) notes that introduced *P. muralis* populations in Britain display a preference for dense and scattered scrub, bare ground, introduced and dry



Figure 1. A pair of *Podarcis muralis* in Faversham, submitted to the Dragon Finder App in April 2022



Figure 2. Map depicting the locations of the *Podarcis muralis* observations in Faversham (blue circle, right) and the Ospringe Church (blue star, far left) (Courtesy ESRI Satellite (ArcGIS/World Imagery))

dwarf shrub and hard cliff, but also favour anthropogenic features including roads, rail tracks, quarries and residential gardens. In fact, Williams (2019) found a lower probability of occurrence at increased distances from roads, rail tracks



Figure 3. A juvenile $\ensuremath{\textit{Podarcis}}\xspace$ muralis taken in 2020 at the same location as Figure 1

and buildings. Because the land-use between the Ospringe and Faversham is dominated by arable fields and improved grassland, it is unlikely that *P. muralis* would be encountered in these habitats as part of a contiguous population. However, the proximity of the two observation sites (<1 km) suggests the populations have a common origin; it seems likely that fragments of suitable habitat may have acted as 'stepping stones' for the dispersal of *P. muralis* (Williams, 2019). Also the similar 'brown' morphology observed amongst individuals in the Ospringe population (Phillips, 2020) and in Faversham (Figs. 1&3) supports a common origin. Alternatively humanmediated, or 'jump' dispersal could provide a possible explanation for the presence of both populations; Michaelides et al. (2015) found that 11 of 23 British P. muralis populations studied likely originated from non-native wild populations in England, citing deliberate, 'secondary introductions' as likely explanations for this. It should be noted that a plant nursery borders west of the residential area from which the sighting was reported to us; Michaelides et al. (2013) report that "some introductions (of *P. muralis*) may be mediated via the nursery trade".

Finally, the identification of *P. muralis* at a previously unrecorded site in Faversham through the Dragon Finder App helps to showcase some of the benefits associated with citizen science projects, and particularly public species recording tools. They allow for the detection of non-native species (Howard et al., 2022) and provide data over broad geographical scales - "allowing ecologists to move from local inference to inference at the scale of species ranges and ecosystems" (Dickinson et al., 2010); particularly relevant in the context of a non-native species such as *P. muralis* as it expands its distribution and population. Of all *P. muralis* observations submitted through the Dragon Finder App from 2016–2021, we estimate that two further sightings, both in Devon, would warrant further investigation as potential unrecorded populations, highlighting this value further.

ACKNOWLEDGEMENTS

We would like to thank all that have contributed, and continually contribute, their reptile and amphibian observations to the Dragon Finder App. We also extend our thanks to Kent Reptile and Amphibian Group for providing us with existing *P. muralis* records upon our request. We thank Kay Mind for allowing us to use the photos in Figures 1 and 3.

REFERENCES

- Böhme, W., Pérez-Mellado, V., Cheylan, M., Nettmann, H.K., Krecsák, L., Sterijovski, B., ... & Avci, A. (2009). *Podarcis muralis*. IUCN Red List Threat. Species. https://dx.doi. org/10.2305/IUCN.UK.2009.RLTS.T61550A12514105.en. Accessed on 23 October 2022.
- Dickinson, J.L., Zuckerberg, B. & Bonter, D.N. (2010). Citizen science as an ecological research tool: challenges and benefits. *Annual review of ecology, evolution, and systematics* 41: 149–172.
- Howard, L., van Rees, C.B., Dahlquist, Z., Luikart, G. & Hand, B.K. (2022). A review of invasive species reporting apps for citizen science and opportunities for innovation. *NeoBiota* 71: 165–188.
- Kent Habitat Survey. (2012). Broad Habitats (database). Assessing Regional Habitat Change (ARCH). https:// webapps.kent.gov.uk/KCC.KLIS.Web.Sites.Public/ ViewMap.aspx.
- Langham, S. (2019). The Wall Lizard Project. Surrey Amphibian and Reptile Group. http://surrey-arg.org.uk/SARGWEB. php?app=PmSitePicker. Accessed on 23 October 2022.
- Michaelides, S., While, G.M., Bell, C. & Uller, T. (2013). Human introductions create opportunities for intra-specific hybridization in an alien lizard. *Biological Invasions* 15: 1101–1112.
- Michaelides, S.N., While, G.M., Zajac, N. & Uller, T. (2015). Widespread primary, but geographically restricted secondary, human introductions of wall lizards, *Podarcis muralis*. *Molecular Ecology* 24(11): 2702–2714.
- Phillips, N. (2020, 4th October). Wall lizards and stoats, a day on the North Downs. UK Wildlife. http://www.uk-wildlife. co.uk/wall-lizards-and-stoats-a-day-on-the-northdowns/. Accessed on 23 October 2022.
- Williams, R.J. (2019). The Invasion Ecology of Common Wall Lizard (*Podarcis Muralis*): Population Dynamics, Interactions and Adaptations. Doctoral dissertation, University of Leeds. https://etheses.whiterose. ac.uk/25978/. Accessed on 23 October 2022.

Accepted: 2 November 2022

The first record of a viviparous lizard Zootoca vivipara predating a blue-tailed damselfly Ischnura elegans

JOSHUA DARKIN

Faculty of Science and Engineering, University of Wolverhampton, Wulfruna Street, Wolverhampton, West Midlands WV1 1LY, UK

Author e-mail: joshuadarkin0@gmail.com

.....

The viviparous lizard *Zootoca vivipara* eats invertebrates, mainly spiders, bugs, flies, and isopods (Beebee & Griffiths, 2000). The blue-tailed damselfly *lschnura elegans* is a small (27–35mm) dark damselfly, widely distributed across Europe and Asia, with a similar range to *Z. vivipara*. It is commonly found in mesotrophic (moderate levels of dissolved nutrients) to eutrophic (rich levels of dissolved nutrients) wet habitats, with a preference for lakes and ponds with some tolerance to brackish water; it flies from around mid-April to September (Bouton et al., 2011; Dudaniec et al., 2018). Hitherto, there have been no records of any damselfly being predated by *Z. vivipara*, although there is a record of a yellow-winged darter *Sympetrum flaveolum* being predated by *Z. vivipara* in northern Spain (Flechoso et al., 2015).

On 13 July 2022, I visited Foulshaw Moss Nature Reserve, Cumbria, England (54° 14'39" N, 2° 50'03" W). This reserve is a raised peat bog habitat, situated on the southern tip of the English Lake District covering an area of 3.5 km². It is an ideal habitat for *Z. vivipara* and the northern viper *Vipera berus*. At 12:07 h, when the weather was partly cloudy with an approximate air temperature of 17 °C, a male *Z. vivipara* was observed basking on the edge of the Foulshaw Moss boardwalk close to the peat moss and near a peat pool. It was here the damselfly alighted only to be grasped by the lizard (Fig. 1). I recorded the lizard taking approximately one minute to ingest the damselfly, during which time the lizard shook the



Figure 1. The male viviparous lizard *Zootoca vivipara* capturing the blue-tailed damselfly *Ischnura elegans*

damselfly from side to side, dragging it backwards across a portion of the boardwalk to force it into its mouth, eventually swallowing the entire damselfly (BHS video, 2023).

Following ingestion, the lizard resumed basking with its mouth agape. The Foulshaw Moss Nature Reserve has an abundance of both damselflies and dragonflies, including the endangered white-faced darter *Leucorrhina dubia*, as well as a diverse array of other invertebrate prey for *Z. vivipara*.

ACKNOWLEDGEMENTS

I would like to thank my father, Glenn Darkin, for driving me to and from Foulshaw Moss Nature Reserve. I would also like to thank Prof. Mark O'Shea MBE and Dr. Simon Maddock for spending their time reading through various drafts and providing valuable suggestions to help improve the final result. Finally, I would like to thank the British Dragonfly Society for the identification of the damselfly.

REFERENCES

- Beebee, T. & Griffiths, R.A. (2000). *Amphibians and Reptiles: A Natural History of the British Herpetofauna*. London, HarperCollins. 270 pp.
- BHS video (2023). The first video footage of a viviparous lizard *Zootoca vivipara* capturing and consuming a blue-tailed damselfly *Ischnura elegans*. Filmed by Darkin, J. https:// youtu.be/ZmOJOpV4m_A.
- Bouton, N., Iserbyt, A. & Van Gossum, H. (2011). Thermal plasticity in life-history traits in the polymorphic bluetailed damselfly, *Ischnura elegans*: No differences between female morphs. *Journal of Insect Science* 11(1): 112.
- Dudaniec, R.Y., Yong, C.J., Lancaster, L.T., Svensson, E.I. & Hansson, B. (2018). Signatures of local adaptation along environmental gradients in a range-expanding damselfly (*Ischnura elegans*). *Molecular Ecology* 27(11): 2576–2593.
- Flechoso, M.F., Morales, J., Lizana, M. & González, M.I. (2015). Taking advantage of the massive emergence of the odonate Sympetrum flaveolum as a trophic resource for Zootoca vivipara. Boletim de la Asociación Herpetológica Española 26(1): 23–26.

Accepted: 1 September 2022

Aestivation of the spectacled caiman Caiman crocodilus in Colombia

EDISON D. BONILLA-LIBERATO^{1*}, NIDIA FÁRFAN-ARDILA² & SERGIO A. BALAGUERA-REINA³

¹Environmental Biology Programme, University of Ibagué, Carrera 22 Calle 67 B, Av. Ambalá, Ibagué, Colombia ²NaturalSIG Corporation,Calle 24a #2–27, El Prado, Santa Marta, Colombia ³Department of Wildlife Ecology and Conservation, Fort Lauderdale Research and Education Center, University of Florida, Fort Lauderdale, FL, USA

*Corresponding author e-mail: edisondanielbl@hotmail.com

n response to high temperatures and dry weather, some ectotherms may enter a period of inactivity, termed aestivation, where they slow their metabolism to conserve energy (Ganslosser, 2008). The precise behaviour shown may vary according to geographical location and prevailing conditions. For example, in Venezuela, it has been observed that some individuals of C. crocodilus restrict their movements and bury themselves in the mud when prevailing temperatures are high (Staton & Dixon, 1975). Whereas Medem (1981) stated that generally C. crocodilus usually either aestivate buried in mud or on the surface under leaf litter, bushes, and/or stubble during the day, or disperse to the nearest body of water on the Caribbean coast of Colombia. However, there is no specific information relating to how and when this process occurs and whether spectacled caiman stick with one of the strategies across the season (either aestivation or dispersal) or vary it depending on weather conditions. Herein, we report and detail the behaviour of a spectacled caiman aestivating in the Tayrona National Natural Park (TNNP), Department of Magdalena, on the Colombian Caribbean coast. The TNNP is characterised by low rainfall between December-April and July-August due to the north-easterly trade winds, making these the driest seasons (Parque Nacional Natural Tayrona, 2006).

This study was carried out under research endorsement ORFEO 2020200002463 dated 26 March 2020 granted by the Colombian National Natural Park Agency.

Observations were made in the Cañaveral area of the TNNP (11° 18'37.5" N, 73° 56'03.2" W). During July 2021 through January 2022, the movements and home range of 5 individuals of C. crocodilus were monitored using VHF radio telemetry across the TNNP (Bonilla-Liberato, 2022). One of the animals tracked was a female (132 cm total length) that was tracked until January 2022. Between November and January, rainfall was low, so the water body where the individual was found was reduced, and with it, the movements of the animal. From 28 December 2021 onwards, this individual restricted its activity, being observed in the same place during the three daily surveys until 9 January 2022. The female was slightly submerged in the mud at the edge of the water body, where the top of her head and nostrils were uncovered, making it difficult to locate her visually due to the colour of the water and the amount of mud in the area (Fig. 1). Through this time we noticed a change in her behaviour, with a notable reduction



Figure 1. An aestivating female *Caiman crocodilus* in the Cañaveral sector of TNNP - **A.** During the day, **B.** At night photographed by camera trap

in wariness and aggressiveness to human presence and any other kind of disturbances generated (i.e. noise created by breaking branches and walking) but still responding when researchers mimicked hatchling distress calls. Prior to this period, the behaviour of this individual whenever researchers approached had been highly wary and aggressive.

To understand more in-depth this change in behaviour we deployed a camera trap (HC-001B trail hunting trap) for a period of three days. The camera trap revealed that the individual was actually more active during the night, moving around the remnant of the body of water. This was corroborated in morning inspections of the area where we found tracks of those movements across the surroundings of the remnant body of water, even though the individual otherwise remained inactive. After 9 January, we were unable to make any new records of this individual. However, no traces were found to suggest that the animal had been predated in the area, so it was inferred that the individual had undertaken an exploratory movement in search of water bodies and food. Similarly, Medem (1981) reported that not all spectacled caimans aestivate, some of them may also migrate in search of rivers and streams, so the studied individual may have presented a compound behavioural pattern during the dry season (aestivation and dispersal). Our data provide confirmation of *C. crocodilus* aestivation for the Colombian Caribbean coast, as well as offering a preliminary insight into the behaviour that may occur in spectacled caimans during times of aestivation.

REFERENCES

Bonilla-Liberato, E.D. (2022). Ecología espacial de los crocodylianos en el sector oriental del Parque Nacional Natural Tayrona, caribe colombiano durante el segundo semestre del 2021 (Trabajo de grado). Universidad de Ibagué, Colombia. 65 pp. https://hdl.handle. net/20.500.12313/2958.

- Ganslosser, U. (2008). Thermoregulation in Animals. In *Encyclopedia of Ecology*, 3550–3557 pp. Jorgensen S.E. & Fath B.D. (Eds.). Elsevier, London.
- Medem, F. (1981). Los Crocodylia de Sur América. Los Crocodylia de Colombia. Editorial Carrera 7 Ltda. Santa Fe de Bogotá. 354 pp.
- Parque Nacional Natural Tayona. (2006). Plan De Manejo Parque Nacional Natural Tayrona. Parques Nacionales Naturales de Colombia, 202. https:// www.parquesnacionales.gov.co/portal/wp-content/ uploads/2018/07/PMPNNTayrona.pdf.
- Staton, M.A. & Dixon, J.R. (1975). Studies on the dry season biology of *Caiman crocodilus crocodilus* from the Venezuelan Llanos. *Memoria de la Sociedad de Ciencias Naturales La Salle* 35(101): 237–265.

Accepted: 14 September 2022

Predation by a smooth snake *Coronella austriaca* of an aspic viper *Vipera aspis* in Spain

ENEKO I. ESCALANTE¹, PRZEMYSŁAW ZDUNEK^{2,3*} & ALEKSANDRA KOLANEK^{3,4}

¹Calle el Álamo 3, 3°B, 09240 Briviesca, Spain
 ²Association du Refuge des Tortues, 2920 Route de Paulhac, 31660 Bessières, France
 ³NATRIX Herpetological Association, ul. Opolska 41/1, 52–010 Wrocław, Poland
 ⁴University of Wroclaw, Institute of Geography and Regional Development, Department of Geoinformatics and Cartography, pl. Uniwersytecki 1, 50–137 Wrocław, Poland

*Corresponding author e-mail: zdunek.komodo@gmail.com

The smooth snake *Coronella austriaca* Laurenti, 1768, is a medium-sized colubrid snake with a total length rarely up to 90 cm (Muratet, 2015). It is distributed across most of Europe, from Portugal in the west to the Ural Mountains in the east, and northwards to southern Scandinavia. It reaches the Balkan, Iberian and Italian Peninsulas, and also some Mediterranean islands (Speybroeck et al., 2016; Di Nicola et al., 2020). The diet of the smooth snake consists mainly of lacertid lizards, shrews, and small rodents, less often young snakes and slow-worms (Goddard, 1984; Rugiero et al., 1995; Reading & Jofré, 2013; Kolanek et al. 2020; Kolanek & Bury, 2020). Snakes represent part of the diet of *C. austriaca* (Rugiero et al., 1995; Reading & Jofré, 2013). Genus *Vipera* was previously documented in the diet of this species (Rugiero et al., 1995; Luiselli et al., 1996; Reading & Jofré, 2013; Groen, 2018). To the best of our knowledge, ours is the first direct observation of predation by a smooth snake on *Vipera aspis* (L. 1758) in Spain and beyond the borders of Italy (Rugiero et al., 1995; Di Nicola et al., 2020).



Figure 1. Predation by an adult smooth snake *Coronella austriaca* on a juvenile aspic viper *Vipera aspis*, yellow arrows indicate where the smooth snake has grasped the aspic viper with its mouth

On 13 June 2022, at 13:42 h about 30 kilometers east of Burgos, Spain (42.36709° N, -3.317816° W, WGS 84), while on the hiking circuit Presa de Alba, we saw an adult smooth snake and a juvenile aspic viper close together. The area around the observed scene was very humid due to the nearby dam and the Embalse de Alba river flowing alongside. The surrounding environment was densely overgrown with brush and low vegetation, but the observation took place on a concrete road and we made a video recording of it (BHS Video, 2023). It was a sunny warm day with a cloudless sky and no wind. At the start of the observation, it seemed as if the snakes would ignore each other and go their own way, but they did not (Fig. 1A). The smooth snake initiated an attack by grabbing the aspic viper near its tail (Fig. 1B). In defence, the viper bit its opponent a few times (Fig. 1C), which caused the smooth snake to wrap around the viper, initiating a struggle (Fig. 1C&D). The aspic viper bit two more times and then gave up the defence. Continuing the constriction, the smooth snake moved to grab the victim by its head (Fig. 1E), and then begun to swallow it whole (Fig. 1F).

The account of predation presented here increases the knowledge of the Spanish herpetofauna and adds details to the known behaviour of *C. austriaca* preying upon *V. aspis* already recorded in Italy (Rugiero et al., 1995; Di Nicola et al., 2020). It is noteworthy that initially the viper tried to avoid a confrontation by moving its body back from the smooth snake and only bit the smooth snake once it had been attacked. It would appear that it did not perceive the other snake as a predator until it was attacked.

ACKNOWLEDGEMENTS

We would like to give a special thanks to Miguel el de la Miel for being a nature lover and being in the right place at the right time and Matthieu Berroneau for helpful suggestions to improve this manuscript.

REFERENCES

BHS Video (2023). Predation by a smooth snake *Coronella austriaca* of aspic viper *Vipera aspis* in Spain. Recorded by Miguel el de la Miel. https://youtu.be/d-HIXSG7I-E.

- Di Nicola, M.R., Zecchin, L., D'Amico, M. & Faraone, F.P. (2020). Ophiophagy in *Coronella austriaca*: first case of predation on *Hierophis viridiflavus* and first direct observations of predation on *Vipera aspis*. *Herpetology Notes* 13: 1107– 1110.
- Goddard, P. (1984). Morphology, growth, food habits and population characteristics of the Smooth snake *Coronella austriaca* in southern Britain. *Journal of Zoology* 204: 241–257.
- Groen, J. (2018). It's a snake-eat-snake world: Predation on an adder (*Vipera berus*) by a smooth snake (*Coronella austriaca*) in a nature reserve in the north of the Netherlands. *Herpetology Notes* 11: 729–731.
- Kolanek, A. & Bury, S. (2020). Natural History Notes. Coronella austriaca (Smooth Snake). Diet/Cannibalism. Herpetological Review 51(3): 612.
- Kolanek, A., Pastrykiewicz, M., Borawski, W. & Bury, S. (2020). Coronella austriaca (smooth snake) - mortality after prey ingestion. The Herpetological Bulletin 152: 32–33.
- Luiselli, L., Capula, M. & Shine, R. (1996). Reproductive output, costs of reproduction, and ecology of the smooth snake, *Coronella austriaca*, in the eastern Italian Alps. *Oecologia* 106: 100–110.
- Muratet, J. (2015). *Identifier les Reptiles de France Métropolitaine*. France: Edition Ecodiv, 530 pp.
- Reading, C. & Jofré, G. (2013). Diet composition changes correlated with body size in the smooth snake, *Coronella austriaca*, inhabiting lowland heath in southern England. *Amphibia-Reptilia* 34: 463–470.
- Rugiero, L., Capula, M., Filippi, E. & Luiselli, L. (1995). Food habits of Mediterranean populations of the smooth snake (*Coronella austriaca*). *The Herpetological Journal* 5: 316–318.
- Speybroeck, J., Beukema, W., Bok, B. & Van Der Voort, J. (2016). Field Guide to the Amphibians & Reptiles of Britain and Europe. London, United Kingdom: Bloomsbury Publishing Plc. 432 pp.

Accepted: 20 October 2022

Death-feigning in the lizard Leposoma scincoides

CÁSSIO ZOCCA^{1,2*}, JOÃO PEDRO KLOSS-DEGEN¹ & RICARDO LOURENÇO-DE-MORAES³

¹National Institute of the Atlantic Forest (INMA), 29650–000, Santa Teresa, ES, Brazil

²Projeto Bromélias, Instituto de Ensino, Pesquisa e Preservação Ambiental Marcos Daniel (IMD), 29090-160, Vitória, ES, Brazil
³Programa de Pós-graduação em Ecologia e Monitoramento Ambiental (PPGEMA), Universidade Federal da Paraíba, 58297-000, Rio Tinto, PB, Brazil

*Corresponding author e-mail: zoccabio@hotmail.com

izards use antipredator mechanisms, including **L**colouration and postural displays to avoid attacks by predators (Martins, 1996). Thanatosis or death-feigning is one particular postural display that is frequently used after physical contact with a predator (Humphreys & Ruxton, 2018) and has been reported in several species belonging to lizard families that include the Crotaphytidae (Gluesing, 1983), Liolaemidae (Santos et al., 2010), Scincidae (Patel et al., 2016), Tropiduridae (Bertoluci et al., 2006), and Gymnophthalmidae (Machado-Filho et al., 2018). Here we provide the first record of thanatosis in Leposoma scincoides (Gymnophthalmidae), a small lizard endemic to south-eastern Brazil found mainly in the litter of the Atlantic Forest, from Teresópolis (Rio de Janeiro) to Salvador (Bahia) (Rodrigues, 1997).

On 9 November 2019, two individuals of *Leposoma scincoides* were captured in leaf litter during sampling in the municipality of Santa Teresa, Espírito Santo, south-eastern Brazil (19° 52'16.38" S, 40° 33'43.34" W; 822 m a.s.l.). When handled, the subjects (SVL = 114 mm and 106 mm) immediately turned onto their backs, placing themselves in a simulated death posture with their eyes closed (Fig. 1A); after about four minutes they were touched by the researcher and their posture returned to normal (Fig. 1B).

Leposoma scincoides may use thanatosis when camouflage or escape attempts have failed. This strategy may work when predators wish to avoid dead prey so as not to be poisoned by toxins from bacterial decomposition; are unable to identify prey due to lack of movement; and/or where ingestion is hindered by the physical position of the prey (Humphreys & Ruxton, 2018). It has been suggested that this thanatosis evolved to counter visually orientated predators such as birds (Humphreys & Ruxton, 2018). The death-feigning posture reported here for *Leposoma scincoides* is similar to that described previously for other gymnophthalmids, *Iphisa elegans* (Machado-Filho et al., 2018), *Micrablepharus atticolus* (Mesquista et al., 2018) and *Placosoma glabellum* (Muscat et al., 2016).

ACKNOWLEDGEMENTS

We thank National Institute of the Atlantic Forest (INMA) and Projeto Bromélias for field and logistical support. CZZ (300929/2022-6) thanks National Council for Scientific and



Figure 1. Leposoma scincoides (SVL = 114 mm) - A. Displaying death-feigning, and B. Normal position

Technological Development (CNPq, Programa de Capacitação Institucional – PCI/INMA). RLM thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES for providing fellowships.

REFERENCES

- Bertoluci, J., Cassimiro, J. & Rodrigues, M.T. (2006). Tropiduridae (Tropidurid lizards). Death feigning. *Herpetological Review* 37: 472–473.
- Costa, H.C. & Bérnils, R.S. (2021). Répteis do Brasil e suas Unidades Federativas: lista de espécies. *Herpetologia Brasileira* 10(3): 110–279.
- Gluesing, E.A. (1983). Collared lizard predation: the effects of conspicuous morphology and movement. *Copeia* 1983: 835–837.
- Humphreys, R.K. & Ruxton, G.D. (2018). A review of thanatosis (death feigning) as an anti-predator behaviour. *Behavioral Ecology and Sociobiology* 72, Article 22.
- Machado-Filho, P.R., Moya, G.M. & Maffei, F. (2018). Death-feigning behaviour in *Iphisa elegans*: the second reported case in the Family Gymnophthalmidae (Reptilia: Squamata). *Acta Amazonica* 48(2): 151–153.
- Martins, M. (1996). Defensive tactics in lizards and snakes: the potential contribution of the Neotropical fauna. In *Anais do XIV Encontro Anual de Etologia*, 185–199 pp.

Del Claro, K. (Ed.). Sociedade Brasileira de Etologia, Universidade Federal de Uberlandia, Brasil.

- Mesquita, G.S., Ferraz, D., Ramalho, W.P., Machado, I.F. & Vaz-Silva, W. (2018). Death-feigning as defensive behaviour in blue-tailed microteiid lizard *Micrablepharus atticolus* Rodrigues, 1996. *Herpetology Notes* 11: 1065–1067.
- Muscat, E., Entiauspe-Neto, O.M. & Loebmann, D. (2016). Defensive behavior and predation on *Placosoma glabellum* (Peters, 1870) (Squamata: Gymnophthalmidae). *Herpetologia Brasileira* 2: 51–52.
- Patel, H., Naik, V. & Tank, S.K. (2016). Death-feigning behavior in two species of *Lygosoma* (Squamata: Scincidae) from India. *Phyllomedusa* 15(2): 191–194.

- Rodrigues, M.T. (1997). A new species of *Leposoma* (Squamata: Gymnophthalmidae) from the Atlantic forest of Brazil. *Herpetologica* 53(3): 383–389.
- Santos, M.B., Oliveira, M.C.L.M., Verrastro, L. & Tozetti, A.M. (2010). Playing dead to stay alive: thanatosis in *Liolaemus* occipitalis (Squamata: Liolaemidae). *Biota Neotropica* 10: 361–364.

Accepted: 25 October 2022

HERPETOLOGICAL BULLETIN REPORT 2022

There were 117 manuscripts submitted in 2022, almost the same number as in 2021 (Table 1). The overall acceptance rate for articles has remained at 52 % and all four issues in 2022 have been the full 48 pages. Of the published articles, 11 % have been illustrated with an accompanying video and consequently had full public access from the time of release. Reports and book reviews have also benefitted from immediate public access.

 Table 1. Submission and acceptance rates for manuscripts received in 2022 (2021)

	No. submitted	No. accepted	% accepted
Full Papers	17 (21)	10 (15)	59 (71)
Short Notes	19 (9)	8 (6)	42 (67)
Short Communications & Natural History Notes	81 (88)	43 (40)	53 (46)
Totals	117 (118)	61 (61)	52 (52)

In 2022, all four online issues of The Bulletin were uploaded to the BHS website on time - on 1st March, 1st June, 1st September and 1st December. In each case, The Bulletin hard copy was dispatched by post to subscribers roughly two weeks later although some delays were experienced with the December issue due to postal strikes.

The Bulletin receives submissions for across the world and in 2022 they came from 21 countries. The pie chart below shows the continental spread of submissions as well as the extent of studies on non-native species in captivity. The major contributors were Europe and South America/Caribbean with a significant contribution from South Asia. All the captive studies on non-native species were from Europe. Manuscripts were accepted covering all the major groups of reptiles and amphibian and with the split between them roughly 60/40 %.



The BHS is very grateful to the following people who gave their time and expertise reviewing manuscripts for The Bulletin in 2022: Roger Avery, Sebastian Barrionuevo, Ashok Captain, Giovanni Chaves-Portilla, Roger Downie, Ariavaldo Giaretta, Xavier Glaudas, Tandora Grant, Richard Griffiths, Thais Guedes, Joanna Hedley, Rick Hodges, Todd Lewis, Ben Limburn, Robert Jadin, Angela Julian, Leo Malagoli, Chris Michaels, Dimitris Margaritoulis, Konrad Mebert, Aurelien Miralles, Chucho Ortega, Larissa Pelegrini, Luis Vera Perez, Chris Reading, Marluci Rebalato, Sean Roviot, Rodolfo Santos, Christine Tilley, Ben Tapely, Romulus Whitaker, Mark Wilkinson, and Wolfgang Wüster.

Rick Hodges Scientific Editor

BRITISH HERPETOLOGICAL SOCIETY COUNCIL 2021/2022 Society address: c/o Zoological Society of London, Regent's Park, London, NW1 4RY Website: www.thebhs.org

President	Dr. Gerado Garcia	president@thebhs.org
Chairman:	Mr. Mark Hollowell (co-opted)	chair@thebhs.org
Treasurer:	Mr. Michael Wise (co-opted)	treasurer@thebhs.org
Secretary:	Mr. T. Rose (co-opted)	secretary@thebhs.org
Finance Officer:	Ms. Jennie Shea	jennieshea215@gmail.com
The Herpetological Journal		
Scientific Editor:	Dr. Marcio R. Pie	bhsherpetologicaljournal@gmail.com
The Herpetological Bulletin		
Scientific Editor:	Prof. Rick Hodges	herpbulletineditor@gmail.com
The NatterJack		
Editor:	Mrs. Suzanne Simpson	suziesimpson0@gmail.com
Librarian:	Mr. David Bird	drbird.herp1@talktalk.net
Development Officer:	Mr. Mark Hollowell	mark22@btinternet.com
Website and Communications Officer:	Mr. Anthony Plettenberg Laing	avonplettenberglaing@gmail.com
Conservation Officer:	Mrs. Jan Clemons	clemons@btinternet.com
Trade Officer:	Dr. Jonathan Bielby	tradeofficer@thebhs.org
Meetings Organiser:	Mr. Paul Eversfield	paul.eversfield@btinternet.com
Captive Breeding Committee		
Chair:	Dr. Simon Townson	s.townson@imperial.ac.uk
Education Committee		
Chair:	Ms. Kim Le Breuilly	education@thebhs.com
Research Committee		
Chair:	Dr. Chris Gleed-Owen	chris@cgoecology.com

Ordinary Members

Mr. Stephen Copley Mr. Steven Allain stephenccopley@btinternet.com (2nd year) steveallain@live.co.uk (3rd year)

Fellows of the British Herpetological Society

Prof. T.J.C. Beebee, Mr. D. Bird, Prof. J.E. Cooper, Mr. J. Coote, Prof. R.A. Griffiths, Mr. T. A. Rose, Mr. V. F. Taylor, Dr. S. Townson, Mr. R. Meek

Past Presidents (retiring date)

Dr. M. A. Smith (1956), Dr. J.F.D. Frazer (1981), The Earl of Cranbrook (1990), Prof. J.L. Cloudsley-Thompson (1996), Dr. R. Avery (1997), Dr. H. Robert Bustard (2005), Prof. T.J.C. Beebee (2013), Prof. R. A. Griffiths (2018)

