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The HAA is dedicated to the study and conservation of African reptiles and amphibians. Membership is open to anyone with an interest in the African herpetofauna. Members receive the Association's journal, African Journal of Herpetology (which publishes review papers, research articles, and short communications – subject to peer review, as well as book reviews) and African Herp News, the Newsletter (which includes short communications, natural history notes, bibliographies, husbandry hints, announcements and news items).

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Articles shall be considered for publication provided that they are original and have not been published elsewhere. Articles will be submitted for peer review at the Editor's discretion. Authors are requested to submit manuscripts by e-mail in MS Word '.doc' or '.docx' format.

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COVER PHOTOGRAPH

Dendroaspis angusticeps
(Captive individual photographed in Cape Point, South Africa)
Image courtesy: Ana-Filipa Domingues

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AHN EDITORIAL

Frustrated out of your brackets?

Well, not quite, but it seemed a catchier title than “The use of punctuation in author citations”. So, what is an author citation? The author citation (also known as the species authority) is the person(s) that first described a species (or subspecies, genus, etc.). And as with nearly every branch of taxonomy, there are rules governing author citations. Why does it matter? Because taxonomy is the basis for nearly every branch of biological science, as without knowing what species we are studying, how can we accurately convey our results?

When I first started off in research, I was included as a co-author on a publication detailing a herpetological survey in which I was involved. Wanting to impress the lead author I carefully worked through the manuscript, and noticing the inconsistent way in which the author citations were presented (sometimes with brackets, sometimes without), I painstakingly standardized them – much to the lead author’s chagrin! And that is how I was introduced to nomenclatural procedures.

So, how should author citations be presented? As mentioned, there is a long list of rules governing taxonomy which are contained in the International Code of Zoological Nomenclature (which is available online at www.iczn.org/the-code/the-code-online). However, luckily for the purposes of A.H.N. there are only a few key rules that are applicable. A.H.N. requires that the species authority be included in the heading of all natural history and geographic distribution notes, and the most common error that we encounter is the incorrect use of brackets. So, when are brackets needed around an author citation?

- If a species is still in the same genus as what it was described in, then brackets are not needed, e.g., *Trachylepis adamastor* Ceríaco, 2015.
- If a species has been moved to a different genus to what it was described in, then the author citation is enclosed in brackets, e.g., *Trachylepis megalura* (Peters, 1878) (*Trachylepis megalura* was originally described as *Euprepes megalurus*, but is now in a different genus).
- It is A.H.N. convention that the species authority is separated from the year of description by a comma.

AHN EDITORIAL

There are many resources to help with the correct presentation of author citations, probably the two most widely used resources being The Reptile Database (http://reptile-database.reptarium.cz) and Amphibian Species of the World (https://amphibiansoftheworld.amnh.org). Although neither of these databases is error-free, they are a great starting point and are regularly updated, and in most instances are correct.

Darren Pietersen
Editor

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ANNOUNCEMENTS

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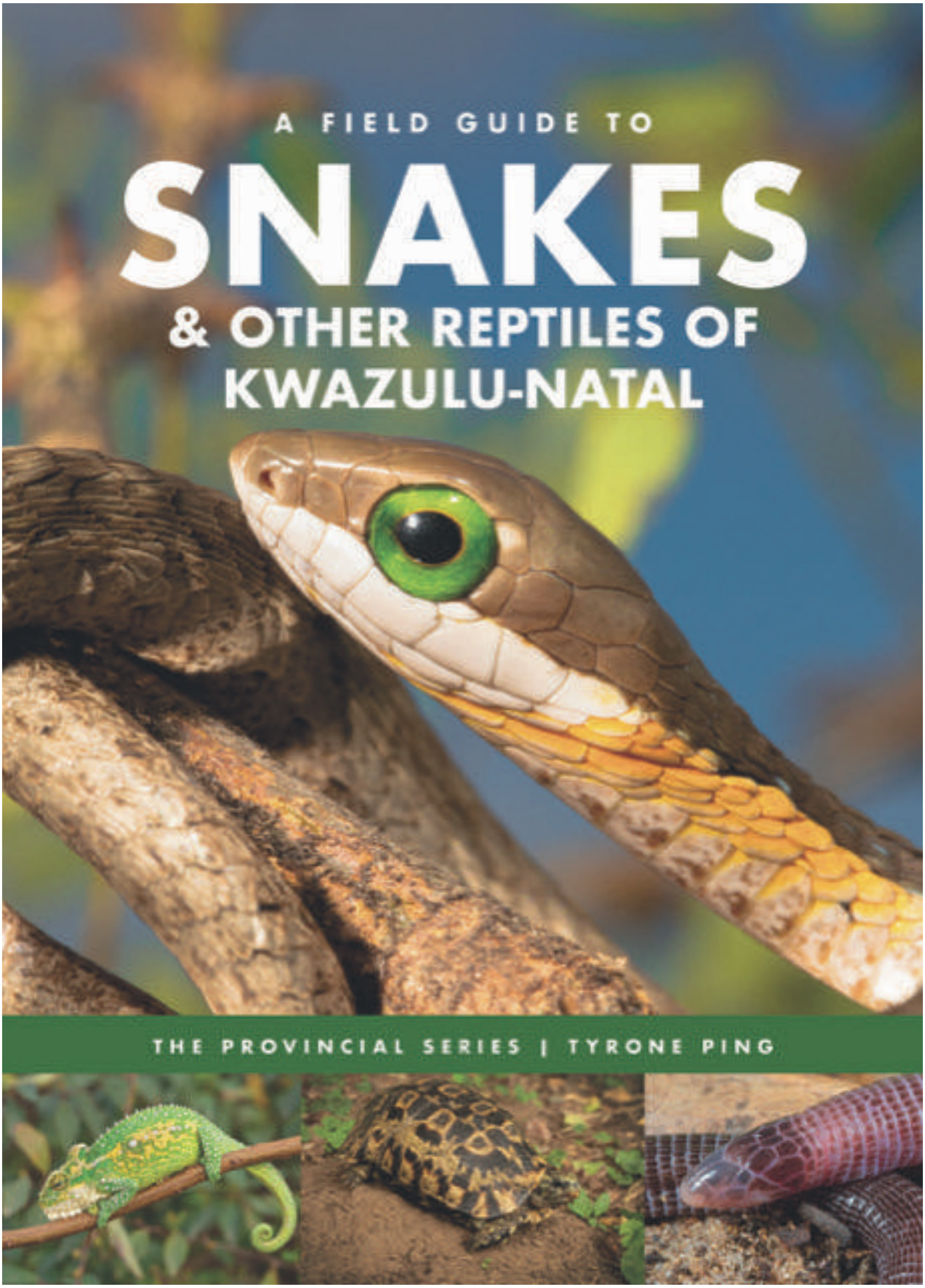
BOOK NOTIFICATION



BOOK NOTIFICATION

A FIELD GUIDE TO SNAKES AND OTHER REPTILES OF KWAZULU-NATAL

TYRONE PING

A first of its kind, this book encompasses the unique herpetofauna of KwaZulu-Natal Province, South Africa. Showcasing a comprehensive collection of reptiles in beautiful detail, including many of the regions' most iconic and feared species, and those shrouded by superstition. From the Black Mamba and Nile Crocodile to the ever-mysterious chameleon, this concisely written guide includes all the reptile species that naturally occur within the province, covering 170 species of snakes, terrapins, turtles, tortoises, chameleons, lizards, monitors and Nile Crocodile. This is a unique field guide and the most up to date guide for KwaZulu-Natal Province, with updated and new field observations, personal accounts and photographs not published in any other field guides. Each species account also has a map showing the species' distribution in the province.

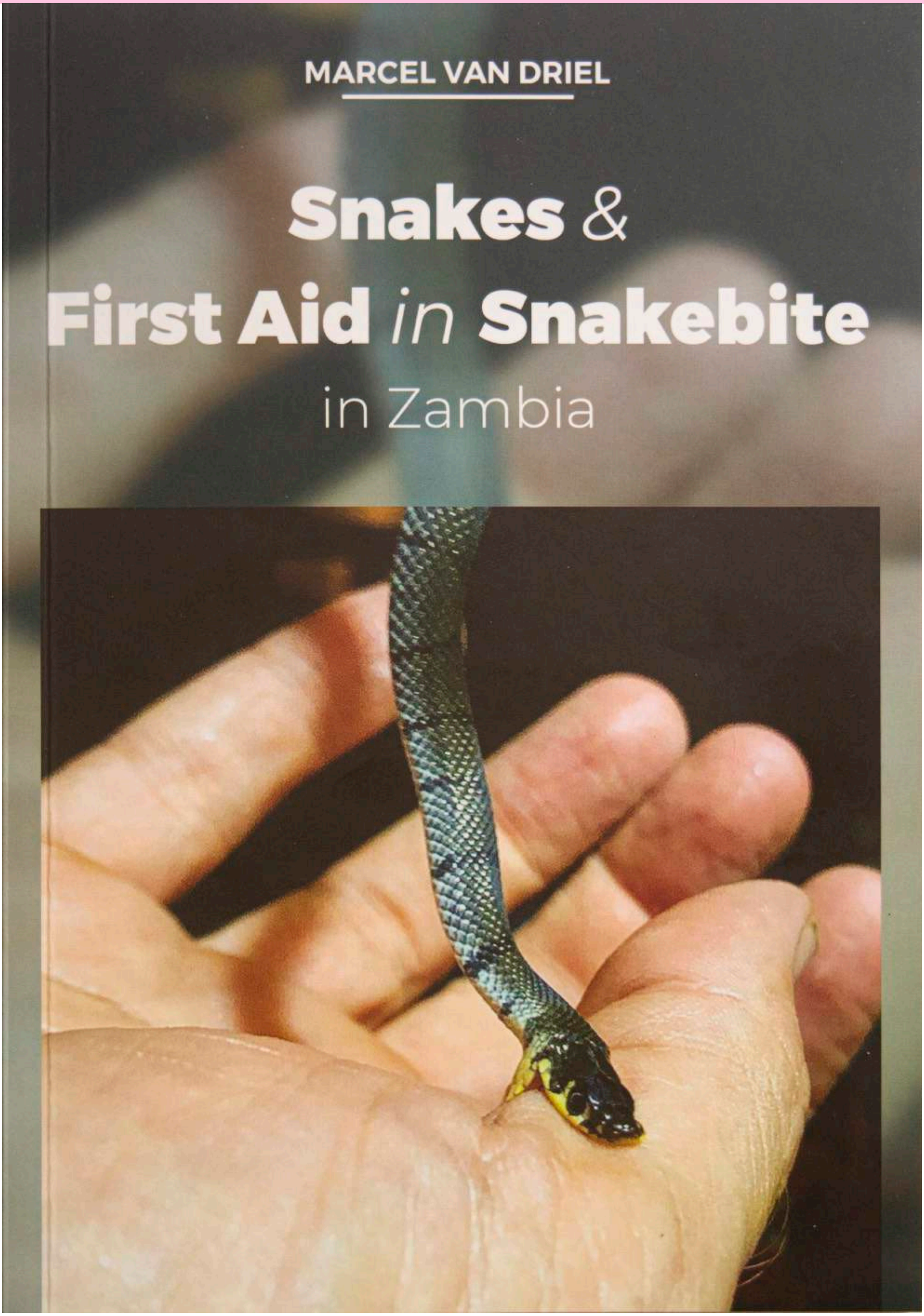
This guide serves as a vital source of reference to the species of snakes and reptiles found in the region, perfect for the novice naturalist while also containing detailed information to answer questions from seasoned herpetologists. Ideal for naturalists, tourists, campers, students and anyone else wanting to learn more about the fascinating diversity of snakes and reptiles in KwaZulu-Natal Province. The author has made a conscious effort to convey the information in an easy-to-follow guide which will aid first-time reptile enthusiasts, children wanting to explore the various species and seasoned herpetologists alike.

Tyrone Ping, a keen field herpetology enthusiast and photographer, has spent the last two decades travelling the length and breadth of KwaZulu-Natal Province collecting data, locating species and photographing some of the scarcest species in order to produce this field guide.

The book is available from https://www.tyroneping.co.za/product/a-field-guide-to-snakes-other-reptiles-of-kwazulu-natal for both local and international purchases. Amazon Kindle purchases can be made at https://www.amazon.com/FIELD-SNAKES-REPTILES-KWAZULU-NATAL-Provincial-ebook/dp/B09MPRXT38.

Suggested Retail Price: R400

BOOK NOTIFICATION



MARCEL VAN DRIEL

Snakes &
First Aid *in* **Snakebite**
in Zambia

BOOK NOTIFICATION

SNAKES AND FIRST AID IN SNAKEBITE IN ZAMBIA

MARCEL VAN DRIEL

There are 101 snake species known to occur in Zambia, but are they all dangerous? And what should one do in case of a snakebite? These questions, and many more, are answered in the recently published "Snakes and First Aid in Snakebite in Zambia". This is the first book addressing the issue of snake safety and snakebite management for Zambia. It is not a field guide for identification of snakes – instead, the common snakes known to cause harmful bites to humans are presented in text and colour photographs.

The book focusses on:

- What makes a snake potentially dangerous or even life-threatening to humans, and how to identify the common dangerous snakes in the country.
- What snake venom is and how it works in the human body.
- How symptoms and signs in a bite victim assist in identifying syndromes.
- Why some first aid measures and medical practices, though widely accepted as effective, are actually harmful and should be avoided.
- What the correct first aid measures are and how they should be applied.

The various first aid measures are explained in detail and are illustrated with colour photographs. Apart from photographs, the book contains illustrations, drawings and charts.

"Snakes and First Aid in Snakebite in Zambia" is a must-have for those in the medical profession, including traditonal healers, and field workers such as wildlife rangers, scouts and game guides, as well as anyone else who works in or regularly visits the bush.

Marcel van Driel is the National Coordinator of the Zambian NGO 'Helping Hands in Snake Safety'. He has lived in Zambia for over 10 years and has been a verbal advocate for improved snakebite management and snake conservation in Zambia for many years. In 2016 he set up the Facebook group "Zambian Snakes and Other Crawlies", which has grown to over 40 000 members, including leading experts on snakes and snakebite in Africa.

In 2019 Marcel was a TEDx speaker about the misconceptions about snakes in Africa. He regularly undertakes awareness activities with communities, institutions and schools, and also gives training in snake awareness, identification, snakebite treatment and snake handling. In addition, he gives snakebite toxicology and first aid training to Zambian doctors and participates in international workshops on snakebite management. Marcel is also a guest lecturer about snakebite management at the University of Zambia.

RUHAN VERSTER

Ruhan cleaning amphibian tissue for isolation of Chytrid Fungus *Batrachochytrium dendrobatidis* during a field trip in the vicinity of Brits, North West Province, South Africa. Photo: Umbuli.com

Amphibians have been under extensive scrutiny since the discovery of the amphibian chytrid fungus, *Batrachochytrium dendrobatidis,* in 1998. This fungus has been associated with the biggest current biodiversity loss of any vertebrate group and has been associated with the decline of 501 amphibian species globally. It has also led to the known extinction of around 90 amphibian species. This fungus has thus become an increasingly important conservation research topic, and the South African landscape offers interesting opportunities for research since declines of amphibians definitively attributed to the amphibian chytrid fungus have been curiously absent from within our borders, despite *B. dendrobatidis* being an invasive alien organism originating from Southeast Asia.

Ruhan Verster is a Ph.D. student at the North-West University, whose focus since his M.Sc. has been dedicated to better understanding the ecology of amphibian chytrid fungus regarding lineage-specific differences in host interactions and environmental tolerances. His Master's project focussed on the spatial patterns and host occupation of *B. dendrobatidis* associated with the Orange River, constituting the largest and most detailed chytrid transect within South Africa to date. That study provided evidence for a previously held prediction that the Orange River and associated agricultural aquatic infrastructure act as refuges for the fungus in an otherwise inhospitable environment. Critically for amphibian conservation, contact zones between *B. dendrobatidis* lineages of variable virulence were also identified during that study.

Figure 1. Fieldwork trip as part of a comprehensive survey for Chytrid Fungus *Batrachochytrium dendrobatidis* around the Drakensberg Mountains on the Lesotho border. Photo: Ruhan Verster.

Figure 2. Chytrid Fungus *Batrachochytrium dendrobatidis* survey conducted in Madagascar with multinational research team. Photo: Ruhan Verster.

In light of the finding that the two lineages of chytrid known to occur in South Africa had overlapping distributions along the Orange River, Ruhan, together with study supervisor Ché Weldon, isolated the first recombinant lineage of amphibian chytrid known for South Africa, and one of only two examples known globally – the other being from Brazil. This led to parallel experimental work that tested the preconceived notions that the hypervirulent lineage of chytrid will also transmit more aggressively. This was found not to be the case, with the less virulent lineage (*Bd*CAPE) able to infect more frogs in a one-on-one challenge experiment than the hypervirulent lineage (*Bd*GPL) responsible for most of the amphibian declines globally. After learning that lineage recombination was occurring, Ruhan set out to determine whether co-infection with both lineages on a single individual amphibian host could occur. This was proven during his Ph.D. study, both experimentally and in the field, using new quantitative polymerase chain reaction (qPCR) tools that not only detect infection but also distinguish the lineage of *B. dendrobatidis* present – the development of which he was also an integral part of through collaboration with U.K.-based mycologists.

Ruhan's Ph.D. was initially planned to focus on screening amphibians, reptiles and fishes in Madagascar for different diseases, but the COVID pandemic unfortunately necessitated the change to a South African-focussed context. Following the publication in 2018 that the origin of chytrid was now thought to be Asia, some rethinking had to be done of the standard working hypothesis that amphibian chytrid was an endemic pathogen, based on the former Out-of-Africa hypothesis. This saw Ruhan form part of a team that identified gaps in research for the African continent which led to an experiment conducted for his Ph.D. that investigated how chytrid lineages alter the behaviour and fitness of frogs.

During his Ph.D. tenure, Ruhan formed part of research teams that further studied the contact zones between different chytrid lineages in South Africa and also used the novel genomic identification tools to model the climates for the different lineages in South Africa, and compared how the different lineages were distributed relative to previous predictive models – work that forms a manuscript-focussed chapter in his Ph.D. thesis. Another chapter in his Ph.D. pertained to an experiment conducted using Common Caco *Cacosternum boettgeri* tadpoles that used sophisticated object tracking software to track the behaviour of tadpoles infected with different lineages of chytrid, compared to non-infected counterparts. Early in the experiments it already became apparent that there were differences between infected and non-infected individuals, and further analysis showed that behavioural differences were also lineage-specific. Thus, in a multilineage chytrid environment such as South Africa, the behaviour of tadpoles can vary depending on the lineage they are infected with. This lineage-specific analysis of behavioural influences is rarely investigated, especially as focus is often placed on the fungal lineage perceived to be a bigger threat to a species, but with these comparative experiments using different lineages, a new view of the influence that chytridiomycosis may have on the survival fitness of frogs was formed.

Figure 3. Sampling of amphibians in the vicinity of Onseepkans, Northern Cape Province, South Africa during the Orange River survey. Photo: Ruhan Verster.

In conclusion, Ruhan's research started with a survey for chytrid in areas where suitable habitat was extremely limited, as well as the field testing of newly developed tools for the identification and quantification of different lineages, finding evidence that both can infect a single frog. Experimental work has always interested him, and transmission experiments have shown that multilineage infection may occur if differently infected populations of amphibians share the same habitat. The precise quantification of changes in the behaviour of tadpoles when infected with *B. dendrobatidis* is also a first for a South African amphibian species, and there is still potential for further development of this experimental model. Although his research in the past has been focused on the South African landscape, Ruhan aims to apply his experience in amphibian conservation research elsewhere in Africa and beyond.

AMPHIBIANS AND REPTILES OF UGALLA RIVER NATIONAL PARK, TANZANIA: PRELIMINARY CHECKLIST WITH RANGE EXTENSIONS FOR 13 SPECIES

J.V. LYAKURWA, A.M. MSIGWA, W.C. KIBASA & G.W. SUMMAY

ABSTRACT

Ugalla River National Park in western Tanzania is among the six recently established national parks in the country. As is the case for most parts of western Tanzania, Ugalla River National Park's herpetofauna are poorly known, making it difficult to appropriately plan for the conservation of the vertebrates in this region. A survey during the middle of the wet season (February) and beginning of the dry season (June) using several standard methods documented 19 species of amphibians and 31 species of reptiles. Of these, 13 species represent range extensions from the previously known ranges with some of the species representing the first records in western Tanzania. Although the area seems to be relatively species rich compared to other localities in the country, none of the species are endemic or threatened. This study supports the existing reports on the scarcity of herpetofaunal data for western Tanzania, and calls for more detailed surveys in the western part of the country.

BACKGROUND

Ugalla River National Park (URNP) is one of the recently established national parks (NP) in Tanzania, covering what used to be Ugalla North Game Reserve and North Ugalla Forest Reserve (URT 2019; TANAPA 2021; Fig. 1). Before its upgrade to national park status, the area was among the most important hunting sites in western Tanzania (Leader-Williams et al. 1993; Baldus and Cauldwell 2004; Wilfred 2012; Wilfred and MacColl 2016). This direct utilization led to dramatic declines of wildlife, which was also aggravated by unprecedented rates of poaching and human encroachment (Wilfred 2012; Wilfred and MacColl 2016; TANAPA 2021), calling for an improved protection status. In 2019, the government of Tanzania decided to upgrade the status of these reserves to national park status, mostly in order to improve conservation of wildlife and in the long run, as a way of improving photographic tourism in western Tanzania (URT 2019). Despite the upgrade, our knowledge on the status of biodiversity in this area is limited. Scarcity of data is even more evident for smaller taxa, which were of little interest in the hunting industry e.g., invertebrates, small mammals and herpetofauna (Wilfred 2012; Wilfred and MacColl 2016). For example, most distribution maps of herpetofauna lack data for western Tanzania, especially for the Tabora region (Spawls et al. 2004, 2018; Channing and Howell 2006; Channing and Rödel 2019). Having updated data on species occurrences and distributions is one of the important steps towards effective conservation of wildlife (Heyer et al. 1994; Rovero et al. 2014; Tolley et al. 2016) and it is important for avoiding undetected extinctions (Pimm et al. 2014). Similarly, this information is crucial in setting conservation

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priorities and to inform a parks' management plans (Rovero et al. 2014; Meng et al. 2016; Tolley et al. 2016).

Ugalla River National Park consists mostly of miombo woodlands and floodplains (Kalumanga 2015; TANAPA 2021) and is part of the Malagarasi Ramsar site (John et al. 2019). Ugalla River National Park also represents two main biomes; the Zambezian region which covers most of the park, and the Somali-Maasai regional centre of endemism in the east of the park (White 1983). It is also adjacent to the Guinea-Congolian transitional zone to the north (White 1983). These mosaics and continuity of biomes and habitats indicate the possibilities of having large numbers of species and/or species of conservation concern. The need to update herpetofauna data in western Tanzania is not only due to changes in the conservation status of the areas but also partly due to the recent taxonomic changes in several genera, which have affected some taxa that are known to occur in these areas. Some of these changes involved splitting of some species into several species, e.g., Large-nosed Reed Frog *Hyperolius nasutus sensu lato* (Channing et al. 2013), Wahlberg's Snake-eyed Skink *Panaspis wahlbergii sensu lato* (Kilunda et al. 2019) and Blue-headed Tree Agama *Acanthocercus atricollis sensu lato* (Wagner et al. 2018), making it difficult to establish which of the newly described or elevated species occur within URNP. Due to these factors, we conducted a snapshot survey in URNP in February and June 2021 with the aim of providing preliminary data for amphibian and reptile species present in the park. The information collected could act as a basis for long-term monitoring in this newly established national park and can highlight the current situation of herpetofauna conservation and management in western Tanzania.

MATERIALS AND METHODS

Data collection was done for a total of 18 days; 13 days during the middle of the rainy season (11–23 February 2021) and five days during the beginning of the dry season (23–27 June 2021) at four sites (Iluma, Lunyeta, Lumbe and along the Ugalla River; Fig. 1, Table 1). We sampled at Iluma, Lunyeta and Lumbe during the wet season as other parts of the reserve were inaccessible due to flooding, but we were able to reach Ugalla River (the 4th site) early in the dry season. Data were collected using several methods to maximize captures. This included bucket pitfall traps with a drift fence, time constrained searching and opportunistic encounters (*sensu* Lyakurwa et al. 2019; Summay et al. 2020) within a 4 km radius of each site.

We established two bucket pitfall trap lines (Howell 2002) at Iluma, Lunyeta and close to the Ugalla River across a range of microhabitats making a total of six trap lines. Each bucket pitfall trap line consisted of a 50 m long transparent drift fence with 11 20-L buckets set in a straight line at 5 m intervals, summing to a total of 66 buckets across 300m of drift fences for the three sites. Trapping was done for 11 nights (four nights at Iluma, three at Lunyeta and four at Ugalla River), making a total of 726 trap nights for the entire trapping period. Trap monitoring was done immediately following sunrise and in the late afternoon.

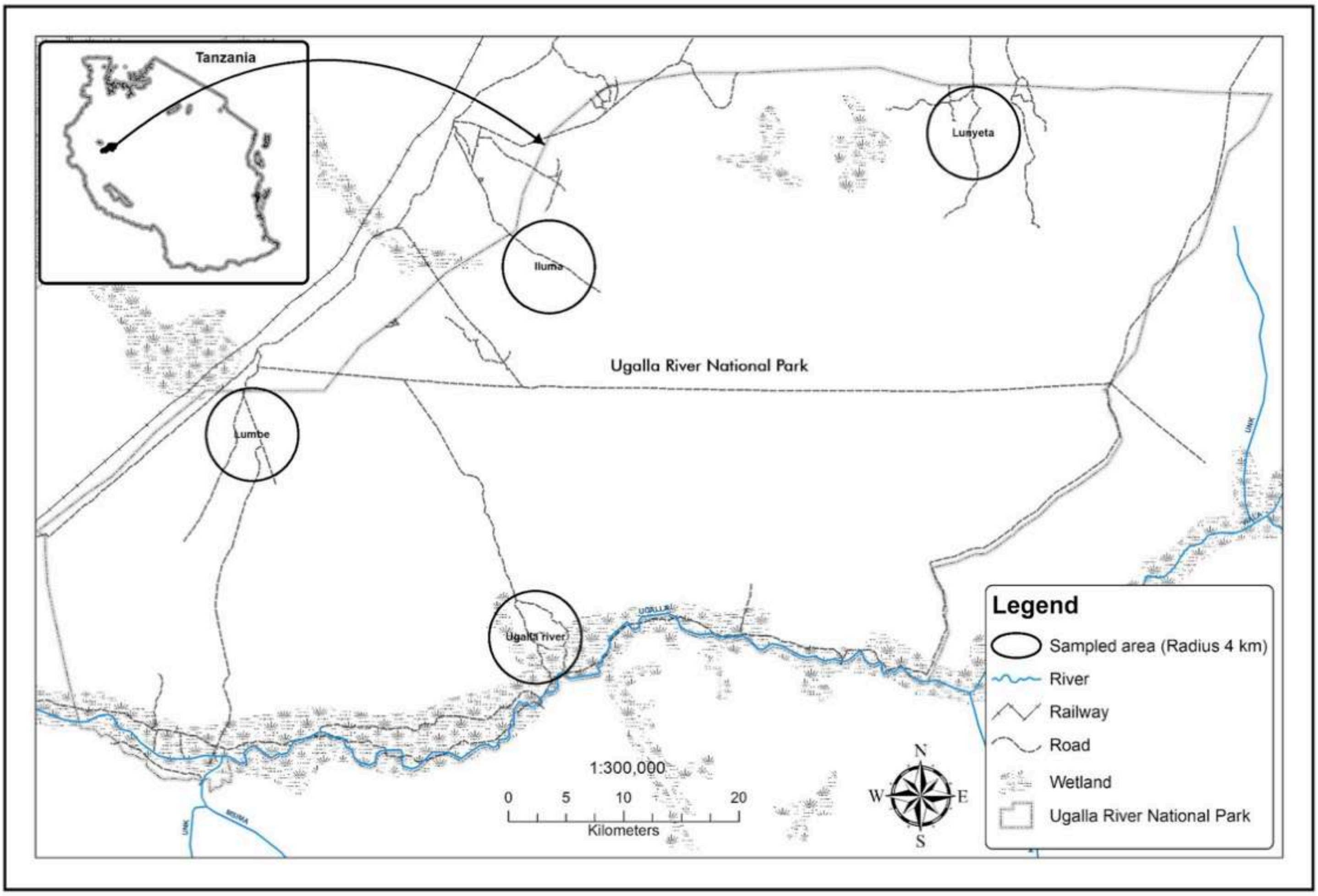

Figure 1. Location of Ugalla River National Park, Tanzania, with the four sampled sites indicated by circles. Sampling was done within a 4 km radius of each site.

Site no.	Site name	Latitude	Longitude
1	Iluma	05° 22’ 08” S	31° 40’ 26” E
2	Lunyeta	05° 18’ 35” S	32° 03’ 41” E
3	Lumbe	05° 30’ 44” S	31° 29’ 56” E
4	Ugalla River	05° 47’ 03” S	31° 42’ 58” E

Table 1. Location of the four herpetofauna sampling sites in Ugalla River National Park, Tanzania.

Since bucket pitfall traps alone cannot adequately sample all herpetofauna species (Heyer et al. 1994; McDiarmid et al. 2012), this method was supplemented with time-constrained searching (Howell 2002) and opportunistic encounters (McDiarmid et al. 2012). Time-constrained searching involved five people searching for herpetofauna in possible hiding/basking sites e.g., in/under rotting logs, under stones, around termite mounds and along/around waterbodies during the day and night for at least two hours, resulting in a total of 230 person hours (120 hours during the day and 110 hours at night) spent searching during the entire survey.

Animals that were found outside of the above sampling procedures but within the study area were recorded as opportunistic encounters. Interviews with four villagers (who worked/ practiced beekeeping in the area in the past) were also conducted. They were asked (assisted with photographs) about the occurrence of some species, especially those likely to occur in the area based on Spawls et al. (2018) and Channing and Rödel (2019). We also extracted data from the literature, especially Wilfred (2012) and Wilfred and MacColl (2016), which contained data mostly on wildlife hunted in the area. In addition, we queried the VertNet database (http://vertnet.org) using the search terms "Ugalla", "Reptilia" and "Amphibia" to compile a list of species known to occur in the area.

Species were identified using Spawls et al. (2018) for reptiles and Channing and Rödel (2019) for amphibians. More recent information regarding the species (e.g., nomenclature) was also retrieved from The Reptile Database (Uetz et al. 2021) and amphibian species of the world (Frost 2021). Some specimens were collected (formalin-fixed in the field and transferred to 70% ethanol for long-term storage) and stored at the Department of Zoology and Wildlife Conservation of the University of Dar es Salaam (Table 2). Photographs of most species were taken and uploaded to iNaturalist (Table 2).

RESULTS AND DISCUSSION

We recorded 19 amphibian species across 11 families, and 31 reptile species across 15 families (Table 2). Ten species were single observations: Great Plated Lizard *Broadleysaurus major*, Black Mamba *Dendroaspis polylepis*, Boomslang *Dispholidus typus*, Cape Wolf Snake *Lycophidion capense*, Black-necked Spitting Cobra *Naja nigricollis*, Boulenger's Scrub Lizard *Nucras boulengeri*, Slender Green Snake *Philothamnus heterolepidotus*, Olive Sand Snake *Psammophis mossambicus*, Southern Striped Skaapsteker *Psammophylax tritaeniatus* and Sand Frog *Tomopterna* sp.; three species were recorded on two occasions i.e., Eastern Tree Agama *Acanthocercus gregorii*, Zambezi Giant Blind Snake *Afrotyphlops mucruso* and Smooth Chamaeleon *Chamaeleo laevigatus*; with the rest being recorded on at least three occasions. None of the species are endemic or threatened. Most of the species are widely distributed, occurring in various ecological zones/biomes, with only a few predominantly Somali-Maasai (e.g., Nyika Gecko *Hemidactylus squamulatus*) or Guinea-Congolian transition (e.g., Chevron-throated Dwarf Gecko

Lygodactylus gutturalis) species.

All species that were recorded through interviews with the local villagers and literature searches were confirmed during this survey except Helmeted Terrapins *Pelomedusa* sp., Leopard Tortoise *Stigmochelys pardalis*, Hinged Tortoises *Kinixys* sp. and Southern African Rock Python *Python natalensis* (Table 2), probably due to the short sampling period and/or our inability to cover much of the park due to low accessibility. Thirteen species represent an extension in distribution from the current known ranges, some of them being recorded in western Tanzania for the first time e.g., Common Ornate Frog *Hildebrandtia ornata* and Rwanda Reed Frog *Hyperolius rwandae* (Table 2). The species rarefaction curves have not reached asymptote (Figure 2), indicating that additional species will likely still be recorded from URNP and even at the four sites that we visited.

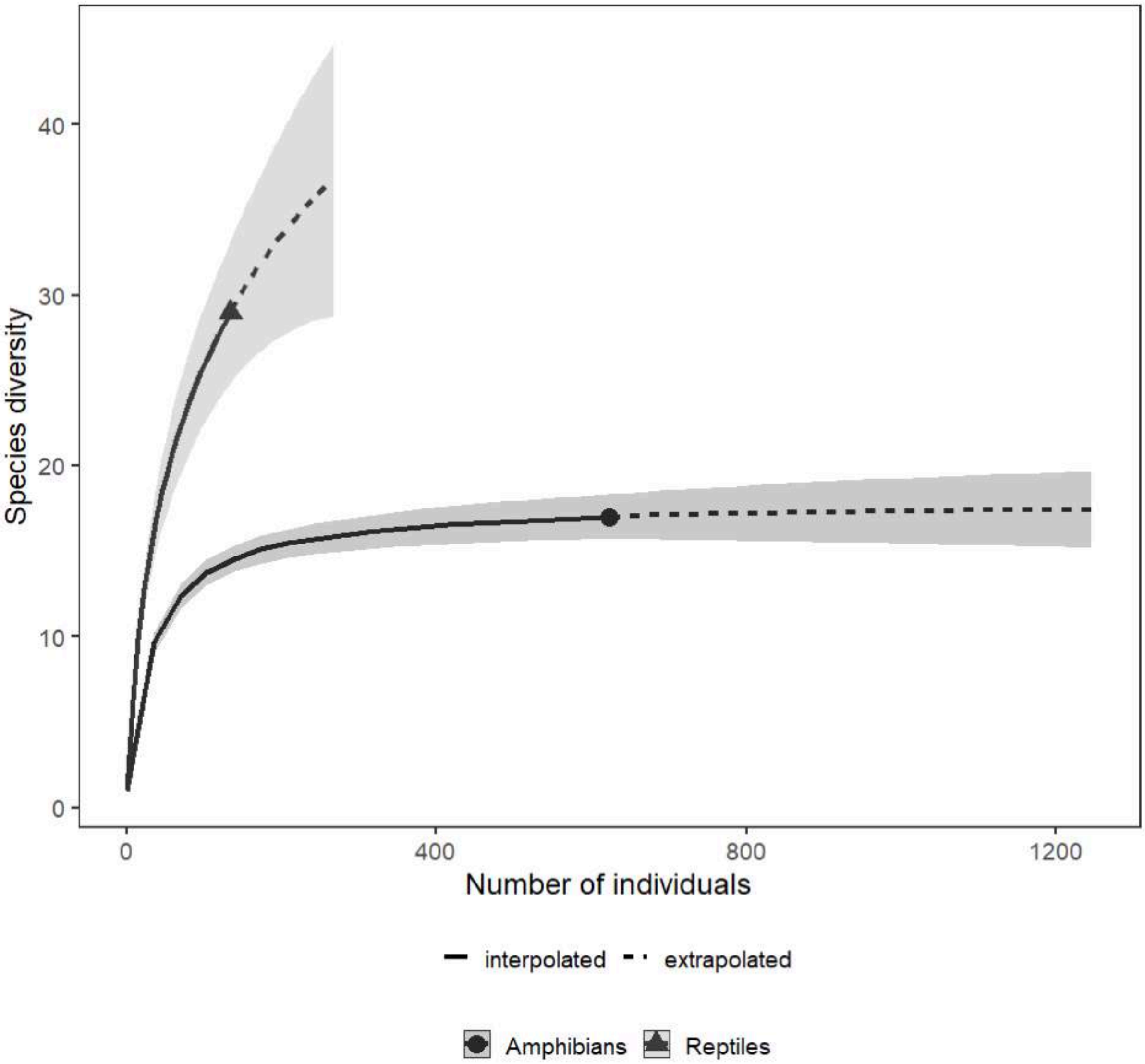

Figure 2. Species rarefaction curves for reptiles (top) and amphibians (bottom) sampled in Ugalla River National Park, Tanzania, in February and June 2021. The shaded area indicates 95% confidence levels. These curves have not reached asymptote, suggesting the likelihood of recording additional species with more surveys.

Despite the short sampling period and our inability to access large portions of the park, the area seems to contain a relatively high number of herpetofauna. For example, the number of reptile species per person hours recorded during this short time period is almost the same as what was recorded in Katavi National Park (Caro et al. 2011) and those of amphibians exceeds that of Mkomazi National Park (Summay et al. 2019). Data from these other parks were collected for longer periods covering the whole parks and even included seasonality factors. Similarly, the number of species recorded during this survey exceeds those recorded in some Eastern Arc Mountain forests (EAM; Burgess et al. 2007), although the Ugalla herpetofauna consists mainly of widely distributed species while those of the EAM are mostly endemic forest specialists (Burgess et al. 2007; Spawls et al. 2018). Ugalla and most parts of Western Tanzania are still largely unexplored from a herpetological perspective (K. Howell, pers. comm.) and this is supported by the range extensions recorded during this study. More new records, including new species, are expected to be found in these areas given long-term data collection and coverage of large areas. Having large numbers of singleton species might be due to the rarity or secretive nature of most herpetofauna (Heyer et al. 1994; Spawls et al. 2004; Meng et al. 2016). From this study, most singletons were snakes, a group which is highly secretive and usually escapes before being detected (Spawls et al. 2018). Three to five years of consecutive sampling (McDiarmid et al. 2012) across various seasons (Stanley et al. 1998; Howell 2002) has been recommended to record rare and secretive species, and this means that for the URNP data to reach asymptote, this process of documenting species should be continuous.

Additional surveys will improve our understanding of the herpetofauna of not only URNP or western Tanzania, but of open country as well, since most of the current herpetofaunal surveys in Tanzania are from forest habitats, especially from the EAM and along the coast (Meng et al. 2016). Distribution data for most amphibians and reptiles is missing for the Tabora region (Spawls et al. 2018 for reptiles), and this is mostly due to a lack of information and survey data. Tanzanian open areas hold potential for the conservation of herpetofauna (Menegon et al. 2006; Meng et al. 2016) and we are yet to fully uncover this potential. These open areas are not only understudied, but are facing an immediate threat from being converted to plantations, especially pine and *Eucalyptus* plantations (Meng et al. 2016). We also recommend more surveys in URNP and other parts of western Tanzania at the beginning of the rainy season, the time at which herpetofaunal activity is at its peak and most areas are accessible.

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Table 2. Preliminary list of amphibians and reptiles of Ugalla River National Park, Tanzania, recorded in February and June 2021, with some notes on their distribution. Asterisks denote species that are included based on the literature review or interviews with local villagers, but which were not observed during the current surveys. S1 = Illuma; S2 = Lunyeta; S3 = Lumbe; S4 = Ugalla River; JVL = John V. Lyakurwa field numbers

Species	S1	S2	S3	S4	Notes, field numbers and iNaturalist link
AMPHIBIANS					
Arthroleptidae					
Long-fingered Squeaker *Arthroleptis stenodactylus* Pfeffer, 1893	x	x	x		Several individuals were found in bucket pitfall traps at Lunyeta and Iluma and a few were recorded during day searches at Lumbe. A widely distributed species but first record around Ugalla. Closest records ~150 km south of URNP. https://www.inaturalist.org/observations/70931395
Bufonidae					
Taita Forest Toad *Mertensophryne taitana* (Peters, 1878)		x	x		One Individual was caught during a day search at Lumbe, and several in bucket pitfall traps at Lunyeta. A widely distributed species. https://www.inaturalist.org/observations/70938543
Guttural Toad *Sclerophrys gutturalis* (Power, 1927)	x	x	x	x	Found at all sites, in bucket pitfall traps and during night searches. A widely distributed species. https://www.inaturalist.org/observations/85224010
Dicroglossidae					
African Tiger Frog *Hoplobatrachus occipitalis* (Günther, 1858)	x	x		x	Found at all sites except Lumbe (no night survey was done at Lumbe). https://www.inaturalist.org/observations/70929750

Hemisotidae					
Marbled Piglet Frog *Hemisus marmoratus* (Peters, 1854)	x	x	x	x	Found at all sites. A widely distributed species. Highly variable morphs were recorded at Lunyeta - the species needs to be investigated further. https://www.inaturalist.org/observations/70994409
Hyperoliidae					
Rwanda Reed Frog *Hyperolius rwandae* Dehling, Sinsch, Rödel and Channing, 2013	x	x		x	Found during night and day searches at Iluma, Lunyeta, Ugalla River and Lumbe. It is part of the *Hyperolius nasutus* complex which has been recently split. *Hyperolius rwandae* was previously thought to be endemic to Rwanda, reaching the Rwanda-Tanzania border ~350 km north-east of URNP. JVL 0030–32. https://www.inaturalist.org/observations/70993317, https://www.inaturalist.org/observations/70938752
Common Reed Frog *Hyperolius viridiflavus goetzei* (Duméril and Bibron, 1841)	x	x	x	x	More than 100 individuals were recorded in swamps at Iluma, Lunyeta, Lumbe and along the Ugalla River. A widely distributed species. https://www.inaturalist.org/observations/70934458, https://www.inaturalist.org/observations/70930664
Variable Reed Frog *Hyperolius pictus* Ahl, 1931				x	Several juveniles were recorded along the Ugalla River, representing an extension in the distribution range for this species of ~50 km. JVL 0034–35. https://www.inaturalist.org/observations/85215973
Senegal Running Frog *Kassina senegalensis* (Duméril and Bibron, 1841)	x	x			Many adults were heard calling at Lumbe and Lunyeta during night surveys, but none were captured. Several juveniles (still with their tails) were spotted in some ponds during the night.
Microhylidae					
Banded Rubber Frog *Phrynomantis bifasciatus* (Smith, 1847)	x				Several individuals were recorded during night searches in a big swamp at Iluma. https://www.inaturalist.org/observations/70933473

Phrynobatrachidae					
East African Puddle Frog *Phrynobatrachus acridoides* (Cope, 1867)	x	x	x	x	A widely distributed species in Eastern Tanzania which was known to reach ~50 km east of URNP. Individuals were collected at all sites in bucket pitfall traps and during night searches. https://www.inaturalist.org/observations/85227257
Natal Puddle Frog *Phrynobatrachus natalensis* (Smith, 1849)	x	x	x	x	Probably the most abundant herp in URNP. Few were caught during night searches, but more than 150 individuals were found in the bucket pitfall traps. Widely distributed. https://www.inaturalist.org/observations/70938446
Pipidae					
Lake Victoria Clawed Frog *Xenopus victorianus* Ahl, 1924	x				Several individuals were seen in ponds at Iluma. A widely distributed species.
Ptychadenidae					
Common Ornate Frog *Hildebrandtia ornata* (Peters, 1878)		x			Several individuals recorded at Lunyeta. A common species in eastern Tanzania, but no known records in the western part of the country. This record extends the known range ~500 km west. https://www.inaturalist.org/observations/70934894
Anchieta's Grass Frog *Ptychadena anchietae* (Bocage, 1868)	x	x	x	x	A widely distributed species. https://www.inaturalist.org/observations/85226164
Nile Grass Frog *Ptychadena nilotica* (Seetzen, 1855)	x	x	x	x	This species was recently split from *P. mascareniensis*. It is widely distributed. https://www.inaturalist.org/observations/85234177
Schilluk Grass Frog *Ptychadena schillukorum* (Werner, 1908)	x		x	x	A widely distributed species. https://www.inaturalist.org/observations/85221388, https://www.inaturalist.org/observations/70933934

Pyxicephalidae					
Sand Frog *Tomopterna* sp.	x				A complex of highly cryptic species. Further examination is required in this group. https://www.inaturalist.org/observations/70931217
Rhacophoridae					
Peters' Foam-nest Frog *Chiromantis petersii* Boulenger, 1882	x	x			A widely distributed species. Several individuals were recorded at Iluma and Lunyeta, but likely to be found throughout the park. https://www.inaturalist.org/observations/71016970
REPTILES					
Crocodylidae					
Nile Crocodile *Crocodylus niloticus* Laurenti, 1768				x	Several adults and young were observed during night surveys and some while basking during the day, along the Ugalla River. A widely distributed species. https://www.inaturalist.org/observations/85449686
Pelomedusidae					
Helmeted Terrapin *Pelomedusa* sp.*					
Testudinidae					
Leopard Tortoise *Stigmochelys pardalis* (Bell, 1828)*					
Hinged Tortoise *Kinixys* sp.*					
Agamidae					
Eastern Tree Agama *Acanthocercus gregorii* (Günther, 1894)	x			x	One adult was found sleeping on branches at Iluma during a night search and a juvenile was seen along the Ugalla River during a day search. Widely distributed. https://www.inaturalist.org/observations/70926911

Chamaeleonidae					
Flap-necked Chameleon *Chamaeleo dilepis* Leach, 1819		x		x	A widely distributed species. A hatchling and adult were recorded at Lunyeta and several adults were recorded along the Ugalla River. https://www.inaturalist.org/observations/85226773
Smooth Chameleon *Chamaeleo laevigatus* Gray, 1863				x	Known to occur along Lake Tanganyika and into Uganda. Two individuals were observed along the Ugalla River. https://www.inaturalist.org/observations/85223466
Gerrhosauridae					
Great Plated Lizard *Broadleysaurus major* (Duméril, 1851)				x	One individual was seen on a termite mound close to the Ugalla River. Before this study, the nearest recorded locations were Lake Victoria and south of Lake Tanganyika (both ~300 km from URNP). This species is widely distributed in eastern Tanzania.
Gekkonidae					
Tuberculate Thick-Toed Gecko *Elasmodactylus tuberculosus* Boulenger, 1895	x	x			A widely distributed species, with several individuals seen around the buildings at Lunyeta and Iluma. https://www.inaturalist.org/observations/70940210
Nyika Gecko *Hemidactylus squamulatus* Tornier, 1896	x	x	x		Very common at Lumbe, Iluma and Lunyeta, underneath dead logs. First record from Ugalla, but widely distributed in north-eastern Tanzania (closest recorded location before this study ~180 km north-east of Ugalla). https://www.inaturalist.org/observations/70940323, https://www.inaturalist.org/observations/70927476
Cape Dwarf Gecko *Lygodactylus capensis* (Smith, 1849)	x	x		x	Widely distributed across the country. https://www.inaturalist.org/observations/85235191
Chevron-throated Dwarf Gecko *Lygodactylus gutturalis*	x	x	x	x	Common in north-western Tanzania ~50 km north-west of Ugalla, but a new record around Tabora. Very common across the park (in the surveyed areas). https://www.inaturalist.org/

Lacertidae					
Boulenger's Scrub Lizard *Nucras boulengeri* Neumann, 1900		x			Only one juvenile was found at Lunyeta while setting bucket pitfall traps. The species is widely distributed in north-eastern Tanzania, but the closest recorded location to URNP is ~130 km away. https://www.inaturalist.org/observations/70934799
Scincidae					
Sundevall's Writhing Skink *Mochlus sundevalli* (Smith, 1849)	x	x			A widely distributed species. Several individuals were found under dead logs at Lumbe and Lunyeta. https://www.inaturalist.org/observations/70933607
Snake-eyed Skink *Panaspis* cf. *wahlbergii*	x	x	x	x	Very common in eastern Tanzania. Recorded in all the areas visited, in bucket pitfall traps and during day searches. This species has recently been split into several separate species and the taxonomic status of the populations in Tanzania remains to be verified as most Tanzanian populations were not included in the analysis. JVL 0033. https://www.inaturalist.org/observations/70933530
Speckle-lipped Skink *Trachylepis maculilabris* (Gray, 1845)				x	This species was common along the Ugalla River but was not recorded at the other sites. Common in eastern Tanzania and close to Lakes Tanganyika and Malawi, stretching narrowly northward to the border of Tanzania and reaching the western side of URNP. https://www.inaturalist.org/observations/85449943
Tree Skink *Trachylepis planifrons* (Peters, 1878)	x	x		x	These records represent an extension in distribution range. This species is common in eastern Tanzania and ~120 km south of Ugalla, close to Lake Tanganyika. Current distribution maps indicate only two localities in western Tanzania - close to Lake Rukwa and Lake Tanganyika. https://www.inaturalist.org/observations/70936614, https://www.inaturalist.org/observations/70936033

Striped Skink *Trachylepis striata* (Peters, 1844)	x	x			A widely distributed species. Recorded at Iluma and Lunyeta during this survey. https://www.inaturalist.org/observations/70931030
Variable Skink *Trachylepis varia* (Peters, 1867)	x	x			A widely distributed species. Populations in URNP may be referable to the unnamed Clade C of Weinell and Bauer (2018), but this requires confirmation. https://www.inaturalist.org/observations/70929819
Varanidae					
Nile Monitor *Varanus niloticus* (Linnaeus, 1766)				x	A widely distributed species. Recorded along the Ugalla River. https://www.inaturalist.org/observations/85449686
Colubridae					
White-lipped Snake *Crotaphopeltis hotamboeia* (Laurenti, 1768)	x				A widely distributed species. Three individuals (one adult and two juveniles) were found under dead logs during day searches at Iluma. https://www.inaturalist.org/observations/95748770
Boomslang *Dispholidus typus* (Smith, 1828)			x		A widely distributed species. One juvenile was found on a low branch during a day search at Lumbe. https://www.inaturalist.org/observations/70926736
Slender Green Snake *Philothamnus heterolepidotus* (Günther, 1863)				x	Range extension. Previous closest recorded locality ~150 km north-west of Ugalla. One juvenile was found under a dead log close to the Ugalla River. https://www.inaturalist.org/observations/95749235
Elapidae					
Black Mamba *Dendroaspis polylepis* Günther, 1864		x			A widely distributed species. One individual was recorded at Lunyeta, which retreated into termite holes and was spotted again in the following days at the same area.
Black-necked Spitting Cobra *Naja nigricollis* Reinhardt, 1843		x			A widely distributed species. One individual was found under a dead log at Lunyeta during a day search. https://www.inaturalist.org/observations/70926811

Lamprophiidae				
Cape Wolf Snake *Lycophidion capense* (Smith, 1831)		x		A widely distributed species. One individual was found under a dead log during a day search at Lunyeta. https://www.inaturalist.org/observations/70926779
Olive Sand Snake *Psammophis mossambicus* Peters, 1882			x	One Individual was found at Repeater area which is near Ugalla River during a day search and escaped into the grass. A widely distributed species.
Southern Striped Skaapsteker *Psammophylax tritaeniatus* (Günther, 1868)	x			One individual was found coiled on grass during a night search in a swamp at Iluma on the border of the park. Another range extension, previously known to occur ~50 km south-west of URNP, close to Lakes Rukwa and Tanganyika, and in southern Tanzania.
Pythonidae				
Southern African Rock Python *Python natalensis* Smith, 1840*				
Typhlopidae				
Lineolate Blind Snake *Afrotyphlops lineolatus* (Jan, 1864)	x	x		A widely distributed species. Several individuals were found under dead logs at Iluma and Lunyeta. https://www.inaturalist.org/observations/70933649
Zambezi Giant Blind Snake *Afrotyphlops mucruso* (Peters, 1854)	x	x		A widely distributed species. Several individuals were found under dead logs at Iluma and Lunyeta. https://www.inaturalist.org/observations/70929840

NOTES ON THE REPRODUCTION OF *TRACHYLEPIS* SKINKS IN NAMIBIA

G. KOPIJ & B. BUISWALELO

INTRODUCTION

Of the approximately 11 690 reptile species in 1 226 genera and 92 families, 7 144 are lizards, and among the lizards, 1 742 are skinks (Scincidae; Uetz et al. 2021). It is, therefore, the largest reptile family, and *Trachylepis* is one of the largest genera within the family with 87 species, most of which (83 species) occur in Africa (Uetz et al. 2021).

Most skinks are oviparous, while 45% are viviparous to some extent, and few are ovoviviparous (Branch 1998; Alexander and Marais 2007; Blackburn and Flemming 2010). In ovoviviparous species, young develop lecithotrophically in eggs that hatch inside the female's reproductive tract, emerging as live young (Metallinou et al. 2016). Regular lecithotrophy is characteristic of the Striped Skink *T. striata* and Cape Skink *T. capensis*, while the Damara Variable Skink *T. damarana* and Western Three-striped Skink *T. occidentalis* are oviparous or viviparous (Vitt and Blackburn 1983; Branch 1998; Alexander and Marais 2007; Weinell and Bauer 2018). Weinell et al. (2019) provide insight into *Trachylepis* reproductive mode evolution based on a species-level phylogeny.

There is a paucity of reproductive data for many *Trachylepis* skink species in Africa. The Kalahari Tree Skink *T. spilogaster* is the only well-studied species - Pianka (1986) studied 74 individuals, while Goldberg (2006) analysed 29 specimens. Other species that have been investigated are *T. capensis* (Flemming 1994), *T. striata* (Simbotwe 1980; Patterson 1990), Rainbow Skink *T. margaritifer* (Visser 1975; Simbotwe 1980) and Red-sided Skink *T. homalocephala* (Visser 1975). Here we provide data on timing of reproduction, mode of reproduction and clutch/brood size of 10 skink species from Namibia.

MATERIAL AND METHODS

For this study, we used specimens that are housed in the reptile collection of the National Museum in Windhoek, Namibia, and which were collected in different vegetation types in Namibia (Figs. 1–3) and in different seasons (Table 1). The specimens were measured in the laboratory, with two morphological characters being measured to the nearest 0.1 mm with the aid of a Vernier calliper: 1) snout-vent length (SVL), measured from the anterior end of the snout to the anterior edge of the vent; and 2) tail length (TL), measured from the anterior edge of the vent to the end of the tail. Tail length was not measured in specimens with freshly autotomized tails.

Each specimen was dissected and their reproductive organs closely examined for sexing and ageing with the help of a stereo microscope. Individuals were sexed by assessing the presence of gonads (testes in males and ovaries in females). Specimens

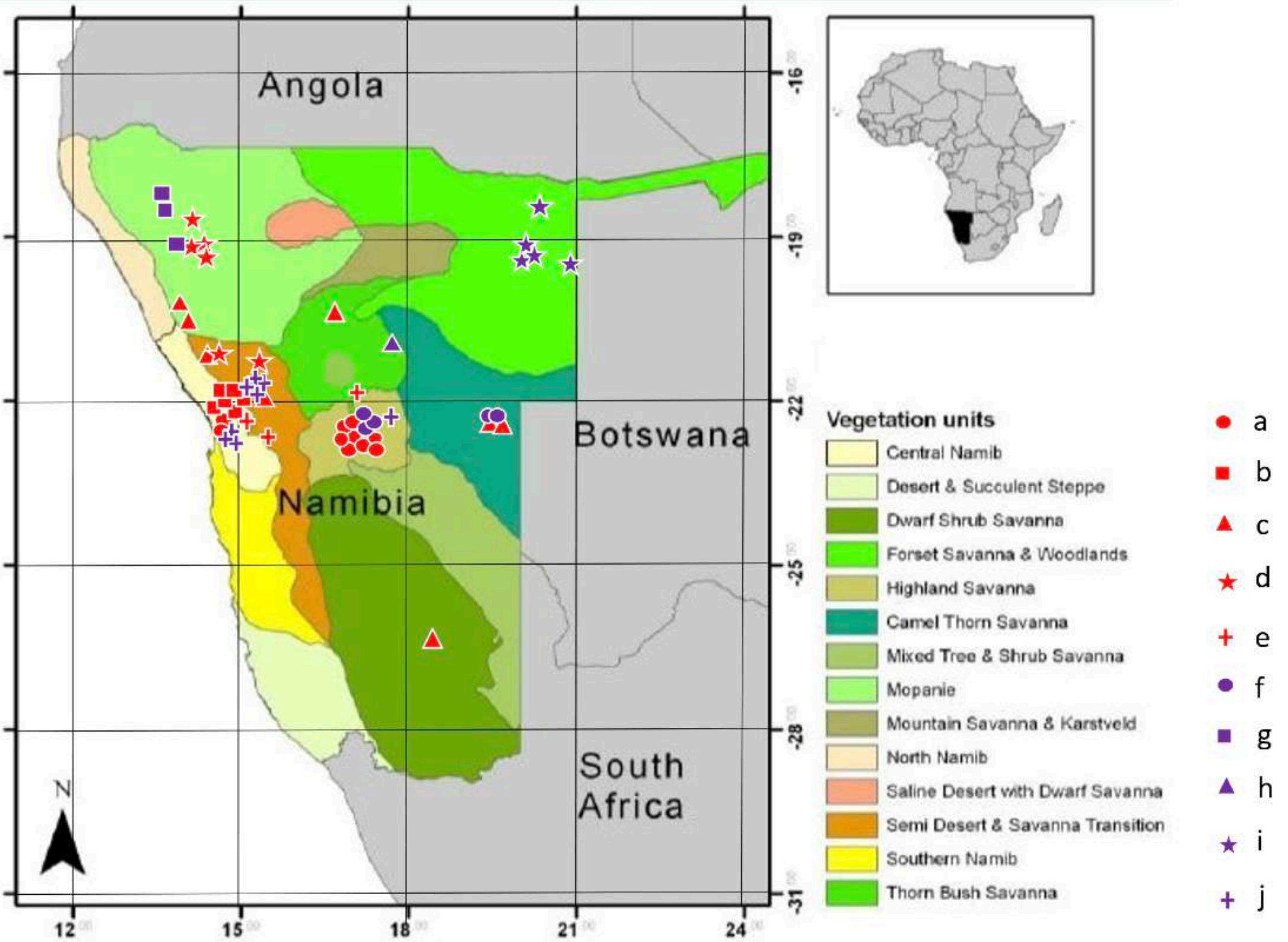

Figure 1. Sampling localities of the *Trachylepis* specimens examined during this study. a = Western Rock Skink *T. sulcata*, b = Hoesch's Skink *T. hoeschi*, c = Western Three-striped Skink *T. occidentalis*, d = Wedge-snouted Skink *T. acutilabris*, e = Kalahari Tree Skink *T. spilogaster*, f = Cape Skink *T. capensis,* g = Ovambo Tree Skink *T. binotata,* h = Wahlberg's Skink *T. wahlbergii*, i = Damara Variable Skink *T. damarana,* j = Speckled Sand Skink *T. punctulata.*

Figure 2. Ovambo Tree Skink *Trachylepis binotata* in Ogongo area, Omusati Region, Namibia. Photo: Grzegorz Kopij.

Figure 3. Dry savanna (semi-desert and savanna transition) near Omaruru, Omaruru region, Namibia. Photo: Grzegorz Kopij.

were classified as adults (well-developed gonads) or juveniles (under-developed gonads). The reproductive status of each female was determined using the following scale: inactive follicles, enlarged follicles, oviductal eggs or neonates. Oviductal eggs and neonates, when present, were counted.

RESULTS AND DISCUSSION

Most specimens originated from places in Namibia where there are two distinct seasons, viz. dry (May–October) and wet (November–April) seasons (Figs. 1 & 3). Overall, there is no clear pattern in the timing of breeding in *Trachylepis* species collected in these places. Most species bred in both the dry and wet seasons, and there was a slight peak at the end of the dry and the beginning of the wet season in some species (Table 1). This is probably because their main diet, i.e., beetles, ants and termites, are available throughout the year, with an emergence of ant and termite alates taking place at the onset of the wet season (Bauer et al. 1990; G. Kopij, pers. obs.).

No Namibian *Trachylepis* species are truly viviparous in the sense that they provide mostly maternal nutrition (matrotrophy; Metallinou et al. 2016). If females can breed throughout the year, or at least more than once per year, then we expect to find full-term eggs or neonates in females collected at the same site at different times of the year. Similarly, the only way to infer that both oviparity and ovoviviparity are present in a single species at a site based on museum material is to demonstrate that both shelled eggs and full-term embryos are present in that species. Among three Western Rock Skink (*T. sulcata*) specimens investigated, two were oviparous (shelled eggs were present) and one was ovoviviparous (neonates were present). Branch (1998) states that *T. sulcata* is ovoviviparous and mentions unconfirmed reports of oviparity. This presented record is therefore the first confirmed case of oviparity in *T. sulcata*. Similarly, both oviparous and ovoviviparous *T. capensis* were recorded in this study. According to Branch (1998) this species is usually ovoviviparous, but in some regions it can be oviparous. These records suggest that both *T. sulcata* and *T. capensis* use both oviparity and ovoviviparity in Namibia.

The clutch/brood size in most species ranged from 3–7 (Table 2). Only one *T. sulcata* contained two neonates. A case of exceptionally large brood size (n = 12 neonates) was recorded in *T. capensis*, and exceptionally large clutch sizes in *T. occidentalis* (n = 12 eggs) and Wahlberg's Skink *T. wahlbergii* (n = 11 eggs). Such large clutch/brood sizes have not been previously recorded (Visser 1975; Vitt and Blackburn 1983; Pianka 1986; Goldberg 2006).

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Table 1. Seasonal distribution of samples (reproductive status and number of specimens analysed). Blue – wet season, orange – dry season. Symbols: + = inactive, A = enlarged follicles, E = oviductal eggs, N = fully developed neonates. Numbers refer to the number (>1) of specimens examined (e.g., 2A means two specimens with enlarged follicles).

Month→ Species↓	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Number of specimens examined**
T. acutilabris	+		2E							2A		+	6
T. binotata									2	+			3
T. capensis			+				A					A ; 2E	5
T. damarana									3+ ; 2A				5
T. hoeschi			A				2			3A			6
T. occidentalis							+			+ ; E			3
T. punctulata								+ ; E	A	E ; N	3E		8
T. spilogaster			+				+		A				3
T. sulcata	E		3+ ; N		+ ; 2A						E	N	10
T. wahlbergii												E	1
Total:	**2**	**0**	**9**	**0**	**3**	**0**	**5**	**2**	**9**	**10**	**4**	**6**	**50**

Table 2. Clutch/brood size in *Trachylepis* species recorded in various habitats and seasons in Namibia. Each entry refers to a single examined specimen. Clutch/brood sizes from Branch (1998) are listed with the most common reproductive mode listed first. SVL = Snout-vent length; TL = Tail length.

Species	Parity mode	Habitat	SVL + TL (mm)	Site	Date	Clutch size (this study)	Clutch size (Branch 1998)
T. acutilabris	Oviparous	Dry savannah	55.8 + 82.9	Kohero, Omaruru District	1965/03/11	5 eggs	—
		Semi-desert	55.5 + 32.7	Uis, Damaraland	1966/03/03	4 eggs	
T. capensis	Oviparous / Ovoviviparous	Dry savannah	116.1 + 79.6	Eava, near Gobabis	1983/12/13	12 neonates	5–18 neonates / eggs
		Dry savannah	120.2 + 91.4	Eava, near Gobabis	1983/12/13	7 eggs	
T. damarana	Oviparous?	Kalahari Woodland	56.0 + 30.6	Kaudum, Kavango	Unknown	10 eggs	4–12 neonates / eggs**
T. occidentalis	Oviparous / Ovoviviparous	Dry savannah	96.5 + 14.6	Hughes, Gobabis District	1963/10/13	12 eggs	5 – 7 eggs / neonates
T. punctulata	Ovoviviparous	Semi-desert	52.9 + 68.2	Karibib District	1972/11/03	3 eggs	2–4 neonates
		Semi-desert	53.8 + 80.8	Karibib District	1972/11/03	4 eggs	
		Semi-desert	49.3 + 9.4	Karibib District	1972/11/03	3 eggs	
		Namib Desert	53.8 + 10.8	Swakopmund District	1973/08/31	3 eggs	
T. sulcata	Ovoviviparous	Namib Desert	76.5 + 125.4	Swakopmund District	1974/03/28	2 neonates	3–5 neonates (unconfirmed oviparity)
		Highland savanna	81.6 + 130.5	Avis Dam, Windhoek	1984/01/27	7 eggs	
		Highland savanna	60.6 + 115.8	Windhoek District	1984/11/30	3 eggs	
T. wahlbergii	Oviparous?	Dry savannah	80.1 + 109.0	Okakarara, Hereroland	1988/12/13	11 eggs	— *

* Branch (1998) only provided data for "southern populations", presumably referring to what are now *T. striata* and *T. punctatissima*.

**There is uncertainty regarding the reproductive mode given that this taxon was recently realised to represent a species complex (Weinell & Bauer 2018).

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EFFECTS OF WEATHER ON THE MOVEMENTS AND BEHAVIOUR OF CAPE DWARF CHAMELEONS *BRADYPODION PUMILUM* IN A SUBURBAN GARDEN

A.D. REBELO

Abstract

Chameleons are cryptic and hard to find, making behavioural observations challenging. Basic information regarding chameleon behaviour, such as movement patterns and habitat use, remain unknown or scarce. Repeat observations of Cape Dwarf Chameleons *Bradypodion pumilum* were made in the morning, midday and night in a suburban garden to provide insights into these behaviours over a 2-month period. The time period and weather condition, such as temperature, wind speed and rainfall, were used to test for differences in perch height and position adjustments using mixed effects models and the Akaike Information Criterion. Chameleons were found to be mostly inactive at night compared to during the day and were most frequently active during warmer or windier conditions. Chameleons perched highest at night, often descending slightly before being observed in the morning and then ascending again during the course of the day. In general, perches were higher in warmer conditions and lower in windier conditions. The positions of sleeping individuals did not differ from their respective diurnal perches in the horizontal plane. Individual chameleons generally remained within a specific section of the garden over the study period, with the exception of the few adult chameleons which roamed more extensively. Here, suburban chameleons are shown to alter their behaviour according to the time period and the prevailing weather conditions. Thermoregulation, thermal preferences and avoidance of discomfort are discussed as the most plausible explanations for these findings.

Introduction

Chameleon surveys are often done at night when chameleons are easier to spot (Randrianantoandro et al. 2007; da Silva and Tolley 2013; Measey et al. 2013; da Silva et al. 2014; O'Donoghue et al. 2020), and this is also the most convenient time to record habitat utilisation, such as perch height and vegetation preferences. Other tracking techniques, such as radio telemetry, facilitate unbiased data collection at any time period but are costly and still require considerable effort (see Rebelo et al. 2022). Whether perch sites that are used by chameleons to sleep (roosts) are representative of the perch sites used by chameleons for their daily activities, remains unanswered. Measey et al. (2013) state that “roosting most likely evolved in the chameleon ancestor to reduce predation by nocturnal ground-dwelling predators”. It seems plausible then that modern-day arboreal chameleons still choose safe roosting sites that are structurally distinct from their diurnal perches, and it might therefore be erroneous to use roost sites as a proxy for diurnal perch choice.

Diurnal activities of chameleons revolve around thermoregulation, foraging, active

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predator avoidance and conspecific interactions. Arboreal forest chameleons have a daily routine of sleeping low down in the trees, foraging higher up from morning until midday, thereafter using denser foliage to avoid direct sunlight before continuing to forage in the afternoon and descending back down to their roosting height (Akani et al. 2001). The Cape Dwarf Chameleon's *Bradypodion pumilum* foraging behaviour is characterised by spending a large proportion of its time moving, although moving infrequently relative to typical 'active foragers' (Butler 2005). Dietary data concerning evasive and sedentary prey types within the genus *Bradypodion* are incongruent (Measey et al. 2011; Carne and Measey 2013), although it is evident that both evasive and sedentary prey are consumed.

It seems possible that the large amount of time spent moving could be a result of multiple behaviours, such as 'cruise-foraging' (Butler 2005), slowly moving into tongue range of prey items identified from a distance (von Frisch 1962), or simply foraging opportunistically while moving to optimise thermoregulation. Foraging chameleons are expected to change their positions over the course of the day, favouring sites that have a high prey abundance (Parcher 1974) or which become suitable for thermoregulation. Chameleons that perch on the periphery of bushes may be more visible to avian predators, and indeed Cuadrado et al. (2001) noted that larger individuals of the Mediterranean Chameleon *Chamaeleo chamaeleon* prefer the inner/denser parts of vegetation, which reduces their conspicuousness to predators. Communication with conspecifics may also influence perch height, as Rebelo et al. (2022) found that male *B. pumilum* perched higher than females and these authors hypothesised that this was to increase their field of view.

Chameleons actively thermoregulate and will orientate their body to alter the surface area exposed to sunlight, as well as move between exposed and shaded parts of bushes (Bennett 2004; Andrews 2008). Chameleons living in open-canopy habitat, such as *B. pumilum* in some suburban gardens, are more exposed to solar radiation (Measey et al. 2013) and must use the sparse vegetation effectively to prevent overheating. Burrage (1973) observed *B. pumilum in situ* for a year and noted that individuals selected a high roosting site in the evening and hypothesised that this was in order to capture the first rays of morning sunlight. Some Malagasy chameleons are shown to adjust their roost or perch site according to the prevailing weather conditions such as wind, rain and temperature (Raselimanana and Rakotomalala 2003; Raholdina 2012, as cited in Measey et al. 2013). Therefore, there appears to be important motivations for chameleon perch choice and movement during diurnal activities, but night-time perch choice may also have consequences for survival.

Reptiles are more vulnerable to predation when they are asleep (Libourel and Herrel 2016). Chameleons can, to some degree, mitigate against being detectable to nocturnal predators by selecting specific roosting sites. Chameleons of the genus *Brookesia* are active on the leaf-litter of the forest floor during the day, but specifically ascend low vegetation to roost (Carpenter 2003; Randrianantoandro et al. 2007), while other chameleon species roost at the very ends of branches and stems (Burrage 1973; Carpenter 2003). Roosting off the ground protects chameleons from terrestrial predators and roosting at the tips of vegetation may further reduce predation from predators that are proficient climbers, such as snakes or mammals. Roosts that are long and thin may be too small to support the weight of the predator and also act as an alert system when a predator begins climbing, sending tactile cues that are particularly noticeable at the tips of vegetation, warning chameleons and allowing time for evasive action such as falling to the undergrowth (Parcher 1974; Measey et al. 2013). Similar roost selection and nocturnal behaviour is well documented in other arboreal lizards (Chandler and Tolson 1990; Vitt et al. 2002; Bors et al. 2020). There are, however, other factors that may influence roost site selection, such as exposure to strong winds, heavy rain and low temperatures that disturb, cause discomfort to or injure sleeping chameleons.

In the current study, individual chameleons were marked and repeatedly located during periods in the day and night to measure the height and spatial position of their perches. These data were used to test for differences in behaviour between the time periods and weather conditions. I hypothesise that chameleons perch higher at night than during the day. Furthermore, I hypothesise that chameleon activity and perch height differ according to prevailing weather conditions such as wind, temperature and rain.

Methods

Study area and preparation

This study was conducted in a suburban garden in Bergvliet, Cape Town, Western Cape Province, South Africa (34° 03' 12" S, 18° 27' 23" E) between 30 March and 14 June 2020. The study area consisted of planted Fynbos vegetation (~10 x 4 m), bordered by mowed lawns to the north and east, trees to the west and a swimming pool to the south. The trees were excluded from the searches as they are structurally different and challenging to search thoroughly. *Bradypodion pumilum* have been present in the garden for more than 20 years and are believed to have originated from the area. Chameleons that were located within the study area were marked with a unique number on their ventrum using a felt-tipped pen.

Chameleon snout-vent length (SVL) and tail length (TL) were measured to the nearest 5 mm using a ruler, and sex was determined by the presence of a hemipenal bulge. Individuals with a SVL of 70–80 mm and a TL of 80–105 mm were regarded as adults, those with a SVL of 55–65 mm and a TL of 60–70 mm were categorised as subadults, while those with a SVL of 50 mm and a TL of 45 mm were categorised as juveniles.

Data collection

All the marked chameleons were located by visually searching the study area. The last known location of each chameleon was used as the starting point from which to launch the next sampling period's search, but individuals could not always be located if they had moved to a concealed position. Searches were conducted three times per day: during the morning (07h00–09h00), midday (11h00–14h00) and night (21h00–00h00). For each sighting, the chameleon's perch height above ground level was measured to the nearest 50 mm using a measuring tape, and the specific bush that it was on was noted. Chameleon perch adjustment was defined as any movement since the last observation period, and this was scored based on horizontal (such as a change in bush), or vertical (such as a change in perch height) movements exceeding 300 mm. Although data were collected as often as possible, there were some days when no data were collected and any perch adjustment data for the subsequent sampling period were excluded from the analyses to prevent inferring erroneous movement measures.

The sunlight reached the study area around 08h00 during March and by 09h00 in June (Azimuth = 12.11°). The local weather conditions, including rain, temperature, cloud-cover and wind, were roughly scored for each observation period. Quantitative weather data for the Cape Town International Airport weather station (16 km away) were obtained from the South African Weather Services (SAWS) for the period of the study using the R package *noaa* (Chamberlain 2021). Daily rainfall data were assigned to the binary categories of true or false due to the spatial variability in localised rainfall events. Wind speed and temperature data were obtained for hourly intervals and the median conditions for each study period were calculated by subsampling the readings from 06h00–08h00 (morning), 10h00–14h00 (midday) and 20h00–00h00 (night) for each day. The weather station data generally corroborated the local conditions recorded at the study site, and the former were therefore used in the analyses.

Data analysis

Perch height and perch adjustment data were analysed separately. A generalised linear mixed effect model with a binomial family was used to analyse the perch adjustment data, while a linear mixed effect model was used to analyse the perch height data using the *lme4* package (Bates et al. 2015) implemented in the R environment (R Core Team 2021). Both analyses use random effects to account for the repeated measures of chameleon identity and included fixed effect combinations for the median hourly temperature and wind speed, total daily rainfall, and diel time period. Sex and SVL were excluded as explanatory variables from the models due to the small sample sizes, which resulted in model convergence issues. It is acknowledged that these variables have an effect on perch height and movement (Rebelo et al. 2022), however the repeated sampling of the same individuals lends itself to testing labile covariates (such as weather) and this is what this study focussed on. The Akaike Information Criterion (AIC) was used to compare models to identify which combination of parameters best explained the data. Predicted values and 95% confidence intervals were calculated for the best fitting model using the *effects* package (Fox and Weisberg 2019) in R.

RESULTS

A total of 10 chameleons were marked within the study area, consisting of four adults, five subadults and one juvenile. Only two 'resident' mature adults occupied the fynbos patch, while another two 'vagrant' adults occasionally moved through and were only marked once they entered the study area from another part of the garden.

I gathered 543 data points from the 10 marked individuals over the 73-day study period. Two chameleon mortalities occurred during the study: the vagrant adult female was predated (presumably by a Fiscal Shrike *Lanius collaris*) and the resident adult male whose health deteriorated towards the end of the study and which was eventually found dead. One unmarked subadult chameleon was occasionally observed in the study area and at least three neonates were also present but were not marked or studied.

Chameleon perch height was best explained by a linear mixed effect model that included all the considered fixed effects: observation period (morning, midday and night), temperature, wind speed and rainfall (Table 1). Chameleons were predicted to perch marginally lower at midday (0.78 m; 95% CI 0.60–0.96 m) than at night (1.00 m; 0.83–1.17 m) or during the morning (0.90 m; 0.73–1.08 m). They also perched lower during stronger winds, colder temperatures, and on rainy days (Fig. 1A–C). The predicted perch height averaged 0.90 m (0.73–1.08 m), 0.78 m (0.60–0.96 m) and 1.00 m (0.83–1.17 m) for the morning, midday and night observation periods, respectively (Fig. 1C). The predicted perch height averaged 0.83 m (0.65–1.00 m) and 1.21 m (1.02–1.40 m) in temperatures of 13°C and 28°C, respectively (Fig. 1A). The predicted perch height averaged 0.96 m (0.78–1.13 m) and 0.80 m (0.62–0.98 m) in wind speeds of 0.5 m/s and 10.0 m/s, respectively (Fig. 1B). The predicted perch height averaged 0.91 m (0.74–1.08 m) for days with no rain and 0.82 m (0.64–1.00 m) for days with rain (Fig. 1D). Visual inspection of the data suggests that during hot temperatures (above 24°C), perch height decreased slightly (Fig. 1A), and this trend persisted when only midday perch data were considered.

Chameleon perch adjustment, defined as the change in position from the previous sighting, was best explained by a linear mixed effect model that included the observation period (morning, midday and night), temperature and wind speed as fixed effects (Table 1). Temperature was included in the top two best-fitting models and rainfall was included in the second best-fitting model only (ΔAIC = 1.05). Thus, the effect of rainfall on chameleon movement was inconclusive. Chameleons made fewer perch adjustments on days with cold minimum temperatures (Fig. 2A) and more perch adjustments on days with stronger winds (Fig. 2B). The predicted chance of adjusting perches averaged 0.44 (0.37–0.52) and 0.60 (0.46–0.72) in temperatures of 13°C and 28°C, respectively. The predicted chance of adjusting perches averaged 0.33 (0.26–0.40) and 0.76 (0.68–0.83) in winds of 0.5 m/s and 10 m/s, respectively. The predicted chance of adjusting perches between midday and night was 0.78 (0.71–0.83), between morning and midday was 0.46 (0.38–0.55) and between night and morning was 0.23 (0.17–0.29). Chameleons made the most horizontal and vertical adjustments during the period between midday and night (43% horizontal and 84% vertical adjustments), followed by between

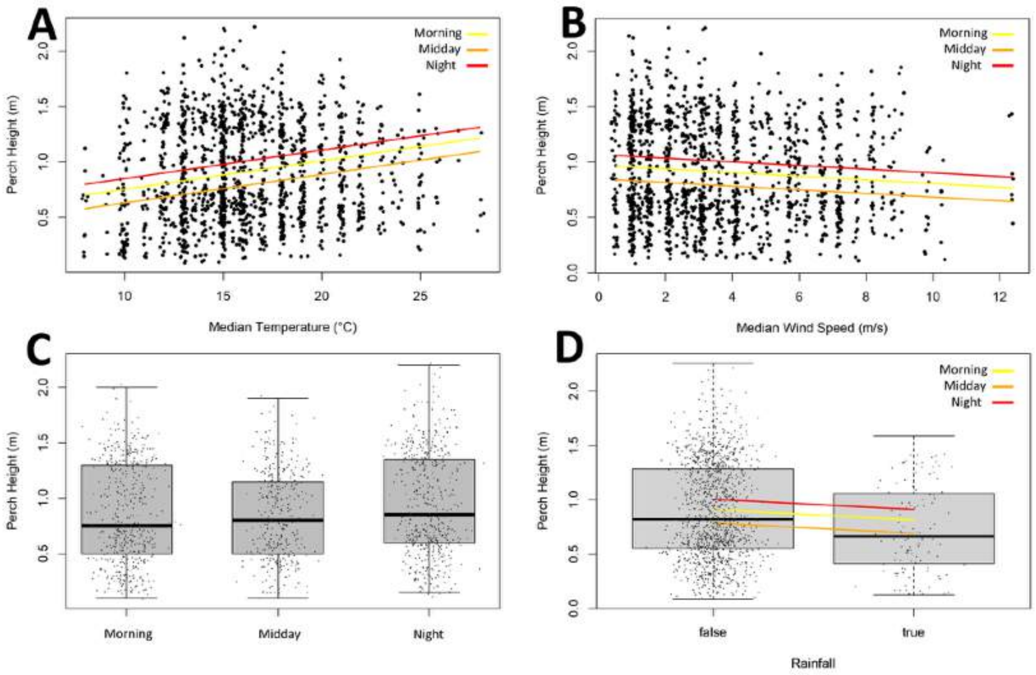

Figure 1. Perch height as a function of the predictor variables: (A) median temperature, (B) median wind speed, (C) period of day and (D) whether it had rained that day. The lines indicate the best-fitting model prediction for each observation period (morning, midday and night). Note that the point data has been randomly shifted by a small amount in both the x and y direction for enhanced visualisation.

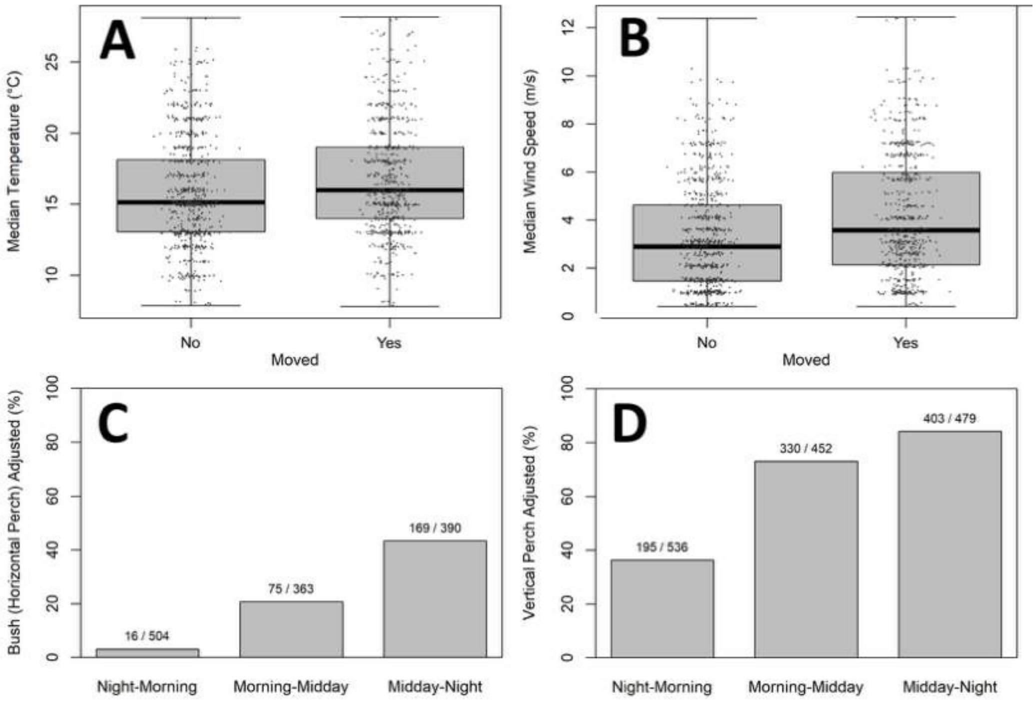

Figure 2. Perch adjustment as a function of weather conditions and observation period: (A) median temperature, and (B) median wind speed; (C) proportion of horizontal perch adjustments and (D) vertical perch adjustment between each observation period. The line indicates the best-fitting model prediction for the midday period only. Note that the point data has been randomly shifted by a small amount in both the x and y direction for enhanced visualisation in A & B.

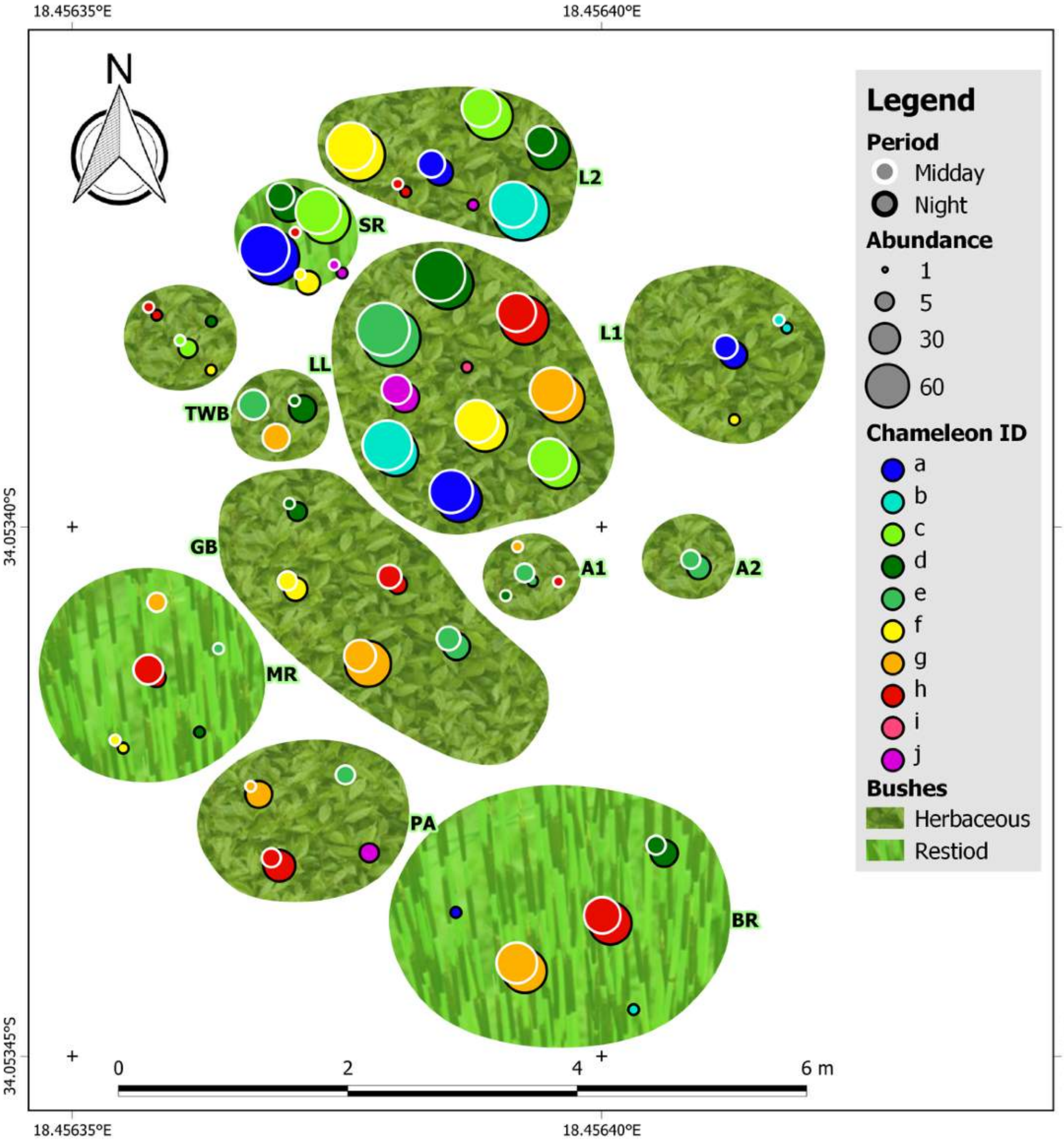

Figure 3. Abundance and presence of individual chameleons across bushes present in the study area for midday and night periods. Note that the size and position of bushes have been slightly altered to improve visualisation of the data. Bushes: *Euryops virginius* (A1), daisy (Asteraceae) (A2), Large Thatching Reed *Thamnochortus spicigerus* (BR), Rusty Sage *Salvia lanceolata* (GB), Common Sunshine Conebush *Leucadendron salignum* (L1 & L2), Wild Dagga *Leonotis leonurus* (LE), Cape Flats Conebush *Leucadendron levisanus* (LL), Albertinia Thatching Reed *Thamnochortus insignis* (MR), Gonna Bush *Passerina corymbosa* (P), Broom Thatchreed *Thamnochortus fruticosus* (SR) and Saffron Bush *Gnidia squarrosa* (TWB).

morning and midday (21% horizontal and 73% vertical adjustments) and lastly, with notably few horizontal adjustments, between night and morning (3% horizontal and 36% vertical adjustments; Fig. 2C & D).

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Discussion

Repeat observations of chameleons in a suburban environment reveal that perch height and perch adjustments differ between day and night and appear to be associated with prevailing weather conditions. Chameleons perch slightly higher at night than during the day, possibly mitigating the risk of predation by nocturnal predators or attempting to maintain their preferred body temperature by positioning themselves to absorb late/early solar radiation. During warmer days, chameleons perched higher on average and were more likely to adjust their perch site. On windy days, chameleons perched lower but adjusted their perch more often than they did on non-windy days. Chameleons were more active on warmer days and foraged throughout the vegetation, whereas on cold or windy days they remained close to the ground, appearing to prefer the centre of bushes, possibly to protect themselves from easy predation or the cold and being dislodged or injured by moving branches.

Roosting sites

It is not surprising that most of the perch adjustments took place between the morning and evening observation periods, given that chameleons are diurnal. The requirements of sleep and diurnal activity are quite different and pose unique challenges, especially for thermoregulation and predator avoidance. Sleep requires the partial shutdown of the brain, and chameleons cannot actively evade predators as they do during the day (Stuart-Fox 2013) but must become alerted to a predator before they can act. In the current study, chameleon roosts were higher than their diurnal perch sites, which could give two advantages against nocturnal predators: first, predators cannot reach the chameleon if they cannot climb or support their weight on that substrate. Second, the tips of thin branches transmit more noticeable tactile cues to sleeping chameleons when climbed by predators (Measey et al. 2013). Once alerted, some chameleons are known to avoid predators by releasing their perch and dropping to the ground (Parcher 1974; Stuart-Fox 2013).

An alternative explanation for high roosting sites is offered by thermoregulation, where chameleons seek out parts of vegetation that remain in sunlight towards the end of the day and inevitably find themselves on the outer and upper branches of bushes as the sun sets. Burrage (1973) hypothesised that *B. pumilum* pre-emptively perch high in vegetation in the evening to enhance early morning thermoregulation. This is unlikely to be the case as during this study chameleons were often found facing downwards and at a lower height in the early morning but on the same perch that they occupied the previous night, suggesting that they had adjusted their position slightly either during the night or very early in the morning before the first observation period. This adjustment might be made to avoid cold or windy conditions during the night. Chameleons that are caught out in exposed positions in the morning, such as the tips of branches, may be too cold to make adjustments and may become especially susceptible to predation by avian predators. Once the temperature had risen by midday, chameleons were generally found higher in the vegetation than in the early morning. The upper parts of the vegetation likely presented better exposure to sunlight for thermoregulation, and possibly better foraging for flying insects resting on the tips of branches. Parcher (1974) found that Malagasy chameleons would often perch near the terminal stems of vegetation to intercept insect pollinators.

Temperature

Temperature showed a strong positive relationship with chameleon perch height and a relatively weak positive relationship with perch adjustment. The performance of traits such as speed, grip strength and bite force in *B. pumilum* is dependent on body temperature, and speed performance steadily improves with higher temperatures up to the critical threshold (Segall et al. 2013). *In situ* activity has been shown to decrease in *Anolis* lizards when body temperature becomes lower or higher than the preferred temperature range (Gunderson and Leal 2015). Ectotherms, by definition, are dependent on external sources of heat in the environment to adjust their body temperature. Warmer weather allows chameleons to reach their preferred temperatures earlier in the morning and become active earlier, as observed at dawn by Burrage (1973) and the current study where some chameleons were observed feeding and moving in such conditions. Cold chameleons thermoregulate by positioning themselves in full sunlight, which is usually at the top of the canopy, and adjusting their body orientation to maximise the receiving surface area (Bennett 2004; Andrews 2008).

Although Anderson and Deban (2010) demonstrate that chameleon tongue projection is not affected by low environmental temperatures, perch adjustment data for *B. pumilum* shows that they do not actively move about to forage on cold days (Butler 2005). This likely explains why chameleons adjust their perches more frequently and perch higher on warmer days. In addition to the modelling results, scrutiny of the data indicated that perch height decreased slightly during very hot conditions. Various terrestrial lizards avoid the midday heat by staying in the shade of bushes or going underground (Milstead 1957), and chameleons may be doing the same by moving into the lower, shadier parts of vegetation (Bennett 2004). This behaviour would also help to explain why chameleons were notably harder to find on warm late-mornings in the current study. Interestingly, the preferred temperature of *B. pumilum* is 29.30 ± 1.30°C (Segall et al. 2013), which is hotter than the temperature observed in the current study at which chameleons began to perch lower in the vegetation. However, this could either be due to the effectiveness of chameleon thermoregulation or an effect of the distance between the site and the weather station.

On cold (and usually overcast) days, chameleons were inactive and perched low down at the base of vegetation in the early morning and would remain there for extended cold spells. In contrast, Burrage (1973) remarked that *B. pumilum* in Stellenbosch remained active “even on rainy winter days”, although the examples that are given appear anecdotal, being selected from ‘fair’ weather conditions during early mornings, whereas the summary data shows that a higher proportion of chameleons are in the state of 'retreat' at lower body temperatures (<12°C). Because cold spells often extend over several days, it is difficult to assess whether chameleons are choosing to perch lower down to avoid the associated effects of the cold weather (wind or rain) or stay low down because they have not resumed their normal behaviour higher in the vegetation. During the current study, as the season began to transition to winter with more frequent colder weather, chameleons perched lower and were less active. Chameleons cannot maintain their optimal body temperatures throughout the year in Mediterranean climates (Andrews 2008) and this may explain why chameleons are observed less frequently in winter than other seasons (Katz et al. 2013; Measey et al. 2013) because chameleons perch in the denser foliage close to the base of the vegetation, making them difficult to observe.

Wind

Chameleons were more active and perched lower in vegetation on windier days. Winds cause vegetation to sway to and fro, and the longer and more flexible the stem, the greater the displacement and velocity. The tips of branches are thus subject to violent collisions with other vegetation and any chameleon perching at this position is in danger of being dislodged or injured. *Bradypodion pumilum* have occasionally been found lying dead under trees in the aftermath of a storm, with no visible injuries (pers. obs.) and I hypothesise that these mortalities result from internal injuries sustained during strong winds.

Chameleons can mitigate the effects of wind by moving from the tips to the base of vegetation where the stems are sturdier and more sheltered from the wind. Alternatively, they might move to a more stable bush. Cold winds have a convective cooling effect (Porter and Gates 1969) which can rapidly reduce body temperature and affect the activity of ectotherms (Maia-Carneiro et al. 2012). Chameleons may attempt to avoid these effects by sheltering from cold winds, or foraging may be more productive in sheltered areas where flying insects also take refuge from wind (Burrage 1973). An additional factor to consider is that chameleons use the movement of vegetation caused by wind to disguise their own movements (Parcher 1974; pers. obs.). Chameleons may thus feel less conspicuous on windier days, and thus move more frequently during these conditions.

Rain

Although rainfall explained some variation in perch height, it did not appear to affect whether chameleons adjusted their perches. These results are difficult to interpret because rain was infrequent, variable, and usually heralded by cold weather and wind, which might explain why it had poor predictive power in the models. Rain can rapidly cool surfaces that it comes into contact with and heavy rain and/or hail probably cause discomfort to chameleons. Burrage (1973) noted that *B. pumilum* retreated to dense vegetation for shelter during prolonged periods of rain, but that they were still active. During the present study, chameleons generally took refuge low down near the base of bushes during prolonged rainy periods until warmer weather prevailed. Whether this was solely due to the wind, cold or rain remains unclear – perhaps getting cold and wet is inevitable. Bennett (2004) noted that the Mt Kenya Side-striped Chameleon *Trioceros schubotzi* made immediate behavioural adjustments at the first signs of rain. Finer temporal resolution data or experimentation that also accounts for the type of precipitation is required to test this in *B. pumilum*.

Movement and spatial arrangement

Most chameleons moved very little over the study period and remained on a single or close cluster of bushes. The exception being a pair of adults that would rotate around the garden from the trees in the west, and while a predator ate the female early on, the male continued to occasionally visit the study area. Some level of bush fidelity was observed, with each individual exhibiting a unique distribution across the study site. Some chameleons were observed using exactly the same perch site multiple times, as noted in captive *B. pumilum* (von Frisch 1962), but this was not the case in general. The bush most favoured by chameleons was the large central Cape Flats Conebush *Leucadendron levisanus*, followed by the low but dense Common Sunshine Conebush *L. salignum* to the north. Chameleons were frequently found in the same bush, with up to five individuals occasionally being present simultaneously. The bushes to the south were only occasionally visited, and mostly by the adult chameleons. In general, the location of each chameleon's night roost was similar to that individual's perch location during midday. These observations are unlikely to be representative of the behaviour of this species in general, however, as studies conducted in their natural environment indicate that this species occupies larger areas (Katz et al. 2013; Rebelo et al. 2022).

Additional observations

A pair of 'vagrant' adult chameleons entered the study site midway through the study. Two days later, one of these chameleons was found partially eaten under the central bush, presumably by a Fiscal Shrike (which was seen in that bush the previous day). Conflict between the newcomers and the resident adult chameleons may have made the former more noticeable to the shrike, although no conflict was observed during the study. The remaining newcomer male continued to alternate between the study area and a flowering elder *Nuxia* tree to the west of the study site (~5 m away). The two resident adults were more mobile than the subadults and perched in various different bushes. They were often observed within the same bush, but at times they did separate, and it is possible that the frequent movements were an attempt by the female to avoid harassment from the male (Rebelo et al. 2022).

The density of resident chameleons in the study site was exceptionally high (~2 250 individuals/ha, excluding neonates) in comparison with wild populations which usually do not exceed 100 individuals/ha (Measey et al. 2013) and appears to be greater than the density observed in the same garden in previous years. This is likely due to a combination of factors, including the study site being a very small area with a concentrated population of chameleons, the habitat being in an artificial setting and receiving less shade than the rest of the garden, and the study site being surrounded by mowed grass on three sides, which limits dispersal opportunities and concentrates prey activity, such as flying insects. This abnormally high density may also be the result of the timing of this study – the high number of subadults that were resident in the study site may have all originated from the same litter, and as they would all be siblings this may have made them more tolerant of one another. It is expected that as these subadults mature, that the resident adult pair would evict them from the area.

Limitations

Chameleons may have been disturbed while measuring perch height, increasing the likelihood of them moving to another perch site. However, chameleons were often found at the same perch site between subsequent measurements, suggesting that they were not disturbed, and the time between measurements (~3 hours) allowed ample time for them to return to a preferred perch. Not all chameleons could be found during every search, with individuals being overlooked 4.3%, 15.7% and 2.2% of the time during the morning, midday and night, respectively. The inflated value for midday is due to chameleons changing perches during daily activities and perching lower down, but fortunately these chameleons could often be observed again during the night. Therefore, it can be expected that the observed perch heights during midday may be biased towards more exposed sites, and that the true mean perch height was probably lower than recorded. In addition, weather data were obtained from Cape Town International Airport which is approximately 16 km from the study site, and is therefore not expected to accurately represent local weather conditions, especially for wind and rainfall.

Lastly, the study took place in the Austral autumn and winter, and has limited insight to behaviours during the hotter and drier summer period. The interpretation of these data should consider these limitations, as well as the studied population being in a suburban environment.

CONCLUSION

Chameleon behaviour and movement within a suburban garden environment differed according to the prevailing weather conditions and period of the day. It seems likely that these behavioural differences are due to thermoregulation, suitable conditions for activity and possibly the avoidance of harm or discomfort. Although nocturnal roost sites were generally situated higher in the vegetation than diurnal perch sites, these observed differences were relatively minor (6–12%), and no discernible differences in the use of bushes was noted between these periods. Therefore, in a suburban population of *B. pumilum*, roost sites appear to be a reasonable proxy for the position and height of perch sites used by chameleons during the day.

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Table 1. Model comparisons for height (linear mixed effects) and perch adjustments (generalised linear mixed effects) for the nine best-fitting models and the null model. The models within two AIC of the best-fitting model are in bold. K = number of model parameters; AIC = Akaike Information Criterion; ΔAIC = difference in AIC from the best-fitting model; wi = AIC weight; LogL = log-likelihood; period = diel period of the observation; temp = median temperature (°C); wind = median wind speed (m/s); rain = binary field of whether it rained that day or not.

Parameters	K	AIC	ΔAIC	wi	LogL
Perch Height					
period+temp+wind+rain	8	964.6	**0.00**	0.94	-474.3
period+temp+wind	7	970.1	5.48	0.06	-478.0
period+temp+rain	7	979.9	15.29	0.00	-482.9
period+temp	6	990.1	25.50	0.00	-489.0
period+wind+rain	7	1015.6	50.97	0.00	-500.8
temp+wind+rain	6	1017.6	53.05	0.00	-502.8
period+rain	6	1019.6	55.03	0.00	-503.8
temp+wind	5	1030.3	65.74	0.00	-510.2
wind+rain	5	1031.5	66.96	0.00	-510.8
temp+rain	5	1035.2	70.58	0.00	-512.6
period+wind	6	1038.4	73.80	0.00	-513.2
rain	4	1039.5	74.89	0.00	-515.7
period	5	1045.5	80.94	0.00	-517.8
wind	4	1053.8	89.24	0.00	-522.9
temp	4	1055.4	90.86	0.00	-523.7
null	3	1065.4	100.77	0.00	-529.7
Perch Adjustment					
period+temp+wind	6	1670.4	**0.00**	0.47	-829.2
period+temp+wind+rain	7	1671.5	**1.05**	0.28	-828.7
period+wind	5	1672.3	**1.87**	0.18	-831.1
period+wind+rain	6	1674.2	3.76	0.07	-831.1
period+temp+rain	6	1723.6	53.15	0.00	-855.8
period+temp	5	1726.1	55.64	0.00	-858.0
period	4	1730.9	60.50	0.00	-861.5
period+rain	5	1731.4	60.95	0.00	-860.7
wind	3	1965.8	295.34	0.00	-979.9
temp+wind	4	1966.2	295.77	0.00	-979.1
temp+wind+rain	5	1967.4	297.02	0.00	-978.7
wind+rain	4	1967.5	297.10	0.00	-979.8
temp+rain	4	2006.1	335.65	0.00	-999.0
temp	3	2008.7	338.29	0.00	-1001.4
null	2	2018.8	348.34	0.00	-1007.4
rain	3	2019.0	348.59	0.00	-1006.5

ARE *PACHYDACTYLUS TIGRINUS* VAN DAM, 1921 AND *PACHYDACTYLUS PUNCTATUS* PETERS, 1854 BATESIAN MIMICS OF THICK-TAIL SCORPIONS *PARABUTHUS* SPP?

R.I. STANDER

INTRODUCTION

Mimicry is widespread in the animal kingdom and is known from various reptile taxa around the world (Schmidt 2004; Mattison 2005; Phelps 2010). Despite this, it remains a controversial subject, particularly because of the anecdotal nature of reported mimetic relationships and a lack of experimental studies of the behaviour (Carr 1968; Mattison 2005). Mimicry is a complex system (Brandao and Motta 2005) defined by Vane-Wright (1980) as: "an organism (the mimic) which simulates signal properties of a second living organism (the model) which are perceived as signals of interest by a third living organism (the operator), such that the mimic gains in fitness as a result of the operator identifying it as an example of the model." In this definition, we note three fundamental components of a mimetic relationship: the model, the mimic and the operator (also referred to as the receiver, predator or deceived species interchangeably).

There are several criteria requiring fulfilment to diagnose a mimetic relationship. First, the mimic and model must occur sympatrically — not only geographically but also syntopically. Second, the mimic and model must mirror one another, yet a high level of morphological resemblance is not required. The necessary level of precision depends on the receiver's cognitive ability to perceive the stimulus, and a motivation to respond to it. These factors imply a capacity to remember or innately respond to a sign stimulus on the part of the receiver (Wickler 1975; Vane-Wright 1976; Kikuchi and Pfennig 2010; Cota and Krebs 2015). Third, behavioural similarity should exist between mimic and model, and lastly the receiver must react similarly to signals of both the model and the mimic. In classic Batesian mimicry (a harmless species mimicking a harmful or unpalatable species), the receiver benefits by avoiding the model and, in turn, the mimic benefits by also being avoided (Wickler 1975).

Batesian mimicry may be colourative, behavioural (adapted morphology), or a combination of both (Werner and Frankenberg 1982). Among reptiles, examples of combined morphological-behavioural mimicry include egg-eating snakes *Dasypeltis* spp. mimicking saw-scaled vipers *Echis* spp. in colour, accompanied by stridulation and flattening of the head to achieve morphological resemblance (Gans 1961; Phelps 2010; Spawls and Branch 2020). Similarly, juvenile Bushveld Lizards *Heliobolus lugubris* mimic ground beetles/"oogpisters" *Anthia* spp. in colouration and behaviourally by performing a conspicuous walk with extended legs and a hunched back (Schmidt 2004).

Vane-Wright (1976) explicitly distinguishes between mimicry and diversion as predator avoidance strategies, and the two should not be confused. Diversion entails drawing a predator's attention to a less-vulnerable body part, such as the tail, in an effort to increase the chances of surviving an attack, while mimicry aims at entirely avoiding an attack. Mimetic behaviour may be constantly employed and not necessarily in response to predator-stimulus (Schmidt 2004), while diversion is generally only seen in response to such stimuli (Johnson and Brodie 1974; Autumn and Han 1989). Diversion also works on a wide range of predators while mimicry is typically highly predator-specific (Cota and Krebs 2015).

Diversion as a defensive behaviour has been reported in gekkonids and other reptiles around the world. Snakes such as Gerard's Burrowing Snake *Chilorhinophis gerardi* and Common Purple-glossed Snakes *Amblyodipsas polylepis polylepis* both hide the head and lift the tail in a very deliberate fashion in an attempt to fool predators (Branch 1998; Marais 2004; Maritz et al. 2015). Discussions on Western Banded Geckos *Coleonyx variegatus* indicate the possibility of both diversion and mimicry being at play, and initial observations of Turpan Wonder Geckos *Teratoscincus roborowskii* also suggest this possibility (Autumn and Han 1989; Mattison 2005). Johnson and Brodie (1974) showed that tail-raising is used as a diversion in the North American *C. variegatus* when in the presence of a snake*.* The gecko raises the tail, which may additionally be undulated (a phenomenon also observed in the defensive behaviour of *T. roborowskii*; Autumn and Han 1989), making it more likely that the snake will strike at the tail and not a more vulnerable body part. In an attack, the gecko allows the snake to secure a firm grip on the tail before performing an autotomy (Vitt and Caldwell 2014). Branch (1998) mentions that Common Rough Geckos *Pachydactylus rugosus,* Barnard's Rough Geckos *P. barnardi* and Southern Rough Geckos *P. formosus* raise the (arched) tail over the back when molested, but does not suggest that this entails either mimicry or diversion. FitzSimons and Brain (1958), however, speculate that tail-raising may be a case of scorpion mimicry in the Giant Ground Gecko *Chondrodactylus angulifer* although they express doubt in this regard*.* This tail-raising behaviour has led to widespread anecdotal mention (much of it informally) of scorpion mimicry in all of the above-mentioned *Pachydactylus* species as well as the Namaqua Mountain Gecko *P. montanus.* Brandao and Motta's (2005) observations provide very strong circumstantial evidence that Batesian scorpion mimicry is employed by the sphaerodactylid Goias Gecko *Coleodactylus brachystoma*, although problems with the classification of this behaviour within traditional mimetic models are identified.

There are numerous anecdotal reports of Batesian scorpion mimicry in the defensive behaviour of African gekkonids. Species of thick-toed geckos *Pachydactylus*, giant geckos *Chondrodactylus* and other taxa globally reportedly mimic scorpions (e.g., FitzSimons and Brain 1958; Autumn and Han 1989; Mahnkopf nd.; Brandao and Motta 2005), yet the behaviour has not been well-documented nor studied in much detail. In the absence of evidence demonstrating the successful deception of at least some potential predators (FitzSimons and Brain 1958), the notion that geckos mimic scorpions is difficult to verify.

Aspects of behaviour that might suggest mimicry must therefore be examined in light of available circumstantial evidence.

Here I discuss Tiger Geckos *Pachydactylus tigrinus* and Speckled Geckos *P. punctatus* to assess whether these tail-raising species employ Batesian mimicry or simple diversion as a predator-defence mechanism. A description of their defensive behaviour is presented, followed by a critical discussion of whether the behaviour is a valid example of Batesian mimicry or not.

METHODS

To test the hypothesis that scorpion-mimicking geckos would have a lower incidence of tail regeneration (since mimicry would be expected to ward off predators), *P. tigrinus* and *P. punctatus* specimens in the Ditsong National Museum of Natural History, Pretoria, South Africa, as well as photographs in an online citizen science database (ReptileMAP, available at vmus.adu.org.za) were examined. Conversely, geckos that use the tail for diversion would be expected to display a higher incidence of tail regeneration since the tail would likely be lost during predator encounters. Conceding with Glaudas et al. (2017) regarding specific biases that may be associated with museum specimens, only those specimens with fully regenerated tails, or tails in the process of regeneration, were considered, since handling and captivity resulted in inadvertent autotomy in many cases (evidenced by freshly autotomised tails preserved alongside the specimens). Records of Transvaal Geckos *P. affinis* and Van Son's Geckos *P. vansoni* were examined as controls. Both of these taxa are similar in size and habit to *P. tigrinus* and *P. punctatus* but are not known for lifting their tails. *Pachydactylus affinis* is also syntopic with both *P. tigrinus* and *P. punctatus* in parts of its range. Additional observations were made *in-situ* in the Soutpansberg mountains in northern Limpopo Province, and these observations were used to provide behavioural insights and supplement the museum records.

RESULTS

The following observations of *P. punctatus* are based on numerous field encounters during all seasons, in the Soutpansberg, Blouberg and Limpopo basin regions of Limpopo Province, South Africa, between 2016 and 2021. *Pachydactylus punctatus* is a common and widespread nocturnal gecko in the northern regions of Limpopo Province. It is frequently encountered crossing open areas (in terrestrial and rupicolous settings) and when doing this, the animal is usually moving at considerable speed with the body raised well off the substrate, and with the tail raised and arched slightly over the back. The tail is generally not raised when the gecko is undisturbed and stationary or moving slowly (pers. obs.). When *P. punctatus* is disturbed, the elevated tail is arched in the same fashion as described above (Fig. 1), but if not raised, may also be slowly undulated nearer to the ground.

In South Africa, the nocturnal and strictly rupicolous *P. tigrinus* is restricted to the Limpopo basin and northern foothills of the Soutpansberg in northern Limpopo Province. The following description is based on observations of five *P. tigrinus* (ranging from hatchlings to adults) in the wild, between 2019 and 2021. All subadults (n =

1) and adults (n = 3) displayed tail-raising behaviour, which has been observed in two populations of *P. tigrinus* in the north-eastern region of Limpopo Province.

Figure 1. Defensive display of a Speckled Gecko *Pachydactylus punctatus*. Photo: R. Stander.

It was observed in a subadult and two adults in winter and was also seen in an adult in summer. Only the hatchling did not display tail-raising behaviour. Tail-raising was only observed in *P. tigrinus* once an animal had been disturbed by handling (per. obs.). *Pachydactylus tigrinus* displays some of the most elaborate defensive behaviour: when individuals move, the tail is lifted and arched overhead while the body is raised high off the ground by extending the limbs (Fig. 2). When the animal is stationary – that is, when it is threatened and holding its ground instead of fleeing, or its course of motion is suddenly blocked by a hand for example (after being disturbed initially) – the behaviour takes on a more conspicuous form. Here, the head is rested on the ground (gular surface usually in contact with the substrate) while the forelimbs maintain a bend of 45° or less, the hind limbs are fully extended and the tail is lifted completely upright and arched in any direction – even backwards (Fig. 3), but usually forward or to the side. The lower back may also be slightly hunched during this display (Fig. 2) and the gecko may turn away from the perceived threat, presenting the tail.

Only nine of 23 (39%) *P. vansoni* examined in the ReptileMAP Virtual Museum have regenerated tails, while 20 of the 29 (69%) *P. affinis* have regenerated tails. Only seven of 33 (21%) *P. punctatus* records examined in the ReptileMAP Virtual Museum have regenerated tails. By contrast, 21 of the 26 (81%) *P. tigrinus* specimens in the Ditsong National Museum of Natural History, ReptileMAP Virtual Museum and live animals observed in the field had re-generated tails.

Figure 2. A Tiger Gecko *Pachydactylus tigrinus* holding its tail up while moving. Photo: R. Stander.

DISCUSSION

If both *P. tigrinus* and *P. punctatus* (tail-lifting taxa) had low incidences of tail regeneration, we could surmise that they were mimicking scorpions and were thus avoided by predators. If both had high incidences of regeneration, it could be conjectured that they were employing diversion. However, the fact that two tail-lifting taxa (*P. tigrinus* and *P. punctatus*) exhibit tail regeneration frequencies at opposite ends of the spectrum, both of which are comparable to two non-tail-lifting taxa (*P. affinis* and *P. vansoni*), shows that tail autotomy rates vary interspecifically. Thus, these results do not allow us to attribute any differences in the frequency of autotomy to either mimicry or diversion.

In order to be considered Batesian mimics, potential mimics need to meet four criteria: they need to be syntopic with the model; the mimic needs to resemble the model morphologically; the mimic and model need to display similar behaviour; and the mimic and model need to elicit a similar response from a potential predator (Wickler 1975; Vane-Wright 1976; Kikuchi and Pfennig 2010; Cota and Krebs 2015). In order to assess whether the two *Pachydactylus* species under discussion here meet these criteria, each of these criteria will be evaluated separately.

Are *P. tigrinus* and *P. punctatus* syntopic with a potential model?

Despite Leeming's (2019) mention that Rock Scorpions (*Hadogenes* spp.) prey on small vertebrates, Jacobsen (1989) reports that *P. tigrinus* frequently shares crevices with large *Hadogenes*, suggesting that these co-exist harmoniously. *Hadogenes* scorpions have extremely weak venom and are thus not suitable models. Four highly venomous scorpion taxa occur within the ranges of both gecko species, where they are common to locally abundant. These are the Transvaal Thick-tail Scorpion *Parabuthus transvaalicus* (Fig. 4), Mozambique Thick-tail Scorpion *Par. mossambicensis* (Fig. 5), Granulated Thick-tail Scorpion *Par. granulatus* (Fig. 6) and Eastern Nomad Scorpion *Hottentotta trilineatus* (Fig. 7). The above-mentioned scorpion taxa share the same broad habitat with the two gecko species and are therefore not just sympatric, but also syntopic. Both *Pachydactylus* species therefore meet the requirement of being syntopic with a potential model species.

Figure 3. Defensive display of a Tiger Gecko *Pachydactylus tigrinus* after being disturbed. Photo: M. Burger.

Figure 4. Threat display of a Transvaal Thick-tail Scorpion *Parabuthus transvaalicus*. Photo: R. Stander.

Figure 5. Threat display of a Mozambique Thick-tail Scorpion *Parabuthus mossambicensis*. Photo: R. Stander.

Figure 6. Threat display of a Granulated Thick-tail Scorpion *Parabuthus granulatus*. Photo: R. Stander.

Figure 7. Threat display of an Eastern Nomad Scorpion *Hottentotta trilineatus*. Photo: R. Stander.

Do *P. tigrinus* and *P. punctatus* morphologically resemble *Parabuthus* scorpions?

Pachydactylus punctatus would presumably be a mimic of *Par. mossambicensis* and *H. trilineatus*, since the scorpions display a similar colouration to the gecko and are of comparable size. Leeming (2019) reports a maximum total length of 80 mm for *Par. mossambicensis* and 60 mm for *H. trilineatus*, while the maximum snout-vent length (SVL) for *P. punctatus* is 38 mm (Branch 1998) and the tail length 43 mm (Pienaar et al. 1983), giving a total length of 81 mm. Similarly, *P. tigrinus* potentially mimics *Par. transvaalicus* and *Par. granulatus*, with maximum lengths of 150 and 160 mm, respectively (Leeming 2019), while the maximum SVL for *P. tigrinus* is 53 mm (Branch 1998) and the regenerated tail length 40 mm (Pienaar et al. 1983), for a total length of 93 mm. *Pachydactylus tigrinus* and both of the scorpion species that it potentially mimics are dark brown to black in colour, although the scorpions lack the pale transverse bands seen in the gecko. *Hadogenes* spp. are further disqualified as potential models due to their extremely long and thin tails and proportionally massive pedipalps. Morphological similarity between the geckos and scorpions is thus rather broad, with the overall basic body structure being similar, while colour is closely matched. The geckos are therefore deemed to meet the criteria of resembling the model.

Do *P. tigrinus* and *P. punctatus* behave similarly to *Parabuthus* scorpions?

It could be argued that some level of behavioural similarity exists between *P. punctatus* and its supposed models, but less so in *P. tigrinus* and its presumed models. This is because the *Parabuthus* species mentioned here generally walk and run with the tail raised and curled over the mesosoma (pers. obs.). As previously noted, *P. punctatus* is known to assume a similar posture when running and also when threatened. On the contrary, *P. tigrinus* only assumes such a posture when it is threatened, at which time the overall appearance with the head lowered, posterior raised well off the ground and tail overhead bears a somewhat surprising similarity to the threat display of a *Parabuthus* scorpion. However, *P. tigrinus* has been observed to turn away from the aggressor – a behaviour not at all typical of the threat display of *Parabuthus* scorpions (pers. obs.). In Johnson and Brodie's (1974) experiments with *C. variegatus,* geckos would often turn away from the snake and face the opposite direction – essentially presenting the predator with the expendable tail. Furthermore, *P. tigrinus* is a slow-moving gecko that ambushes prey from within rock crevices or at their entrances (pers. obs.), whereas the *Parabuthus* species occurring within the range of *P. tigrinus* are typically fast-moving active hunters. Therefore *P. punctatus* is deemed to largely meet the criteria for having a similar behaviour to its presumed models, while *P. tigrinus* does not appear to meet the criteria for displaying a similar behaviour to its presumed models.

Do predators react in a similar way to *P. tigrinus*, *P. punctatus* and *Parabuthus* scorpions?

At present, there are no reports detailing any interactions between either *P. tigrinus* or *P. punctatus* and potential predators which suggest that a predator is deterred by the geckos' defensive behaviour. According to the list of scorpion predators provided by Leeming (2019), owls and mongooses are also the most likely potential predators of *Pachydactylus* geckos. Genets *Genetta* spp. are known to feed on scorpions, although scorpions account for <4% of their diet and are utilised more in habitats where they are plentiful (Delibes et al. 1989; Roberts et al. 2007). Owls, mongooses and genets are all visually-oriented predators with the cognitive and perceptual ability to respond to the sign-stimuli of geckos and scorpions, making them plausible targets of mimicry.

Bauer et al. (1993) reported that "In the case of *Pachydactylus namaquensis* no predators have been recorded in the literature. However, the typical retreat of these lizards in rock crevices suggests that snakes are likely predators." The same is inferred for *P. tigrinus* and considering its nocturnal habits, its main predators are probably nocturnal snakes that rely on scent detection and prey movement rather than a search image – a trait required in a predator that would be the target of mimicry. Such snakes would easily be misled by diversion but would not be deterred by scorpion mimicry. Furthermore, the dark colouration of *P. tigrinus* makes them conspicuous on the light sandstone and quartzite rocks on which they occur – a disadvantage if its main predators are visually-oriented. The above-mentioned tendency of *P. tigrinus* to ambush from within rock crevices suggests that it may be heavily preyed on by visually-oriented predators, although it is more likely a factor related to its feeding behaviour than it is an effort to avoid predators. If the major predators of *P. tigrinus* are snakes that are incapable of perceiving and cognitively responding to a sign stimulus, and if the likely mammalian and avian predators (of both gecko species) that are capable of recognising and responding to such stimuli all successfully prey on scorpions, then the benefit of mimicry to these geckos is highly questionable. Presently available information suggests that visually-oriented mammalian and avian predators likely respond in a similar way to both the gecko species and *Parabuthus* scorpions, but that they consume both rather than avoid them. Strictly speaking, the geckos appear to meet this final criterion, but not in a way that supports the existence of a Batesian mimetic relationship.

CONCLUSION

Circumstantial evidence is not a substitute for field research, but it may prospectively facilitate field research (Cota and Krebs 2015). Though both *P. tigrinus* and *P. punctatus* meet two of the four major criteria for mimicry (syntopy and morphological similarity), the two most crucial criteria (behavioural similarity and similar response of a predator to both mimic and model) are not fully satisfied. Taking into account the apparent lack of suitable target-predator species for mimicry, the widespread nature of diversionary tail-lifting among reptiles, and the comparatively high incidence of regenerated tails in adult *P. tigrinus* (considering that mimicry is impaired and ineffective without a tail or with a regenerated tail, c.f. Johnson and Brodie 1974), I suggest that the defensive tail-raising behaviour seen in *P. tigrinus* and *P. punctatus* is more likely a diversion tactic than mimicry. The posture assumed in such defensive behaviour naturally protects the head by making it much more likely that the tail will be attacked, and it is probably only coincidental that this posture resembles that of a scorpion. In both *P. punctatus* and *P. tigrinus*, no comment can currently be made as to the efficacy of this behaviour either in warding off predators (if it does in fact represent Batesian mimicry), or in distracting predators and allowing the gecko an opportunity to escape. Behavioural studies of these two species in particular, and the genus in general, are required to validate either or both of these interpretations of their defensive behaviour. Future studies should focus on identifying specific predators of these gecko species as a priority. Subsequently, thorough and rigorous experimentation with natural predators is required to establish the true nature of the defensive behaviour seen in *P. tigrinus*, *P. punctatus* and other members of the genus.

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AHN
NATURAL HISTORY NOTES

GERRHOSAURIDAE

Tetradactylus africanus

(Gray, 1838)

Eastern Long-tailed Seps

FIRE-INDUCED MORTALITY

P.R. JORDAAN, C. SHOLTO-DOUGLAS, T.R. DANDO & J.C.A. STEYL

While burning a firebreak on Phinda Private Game Reserve, northern KwaZulu-Natal Province, South Africa, on 17 August 2017, a post-burn survey was conducted to quantify fire-induced faunal mortality using walked transects. The firebreak was conducted in secondary grassland underlain by loamy clay soils and following a 1.95 km dirt track (situated between 27° 44' 42" S, 32° 24’ 55” E and 27° 45’ 36” S, 32° 24' 43" E). The width of the burnt firebreak varied from <10 m up to 30 m. Fieldworkers conducting the survey followed 5–30 minutes behind the fire front, in accordance with the methodology of Jordaan et al. (2020). A single Eastern Long-tailed Seps *Tetradactylus africanus* (SVL 83 mm, tail 283 mm, TL 366 mm) fatality (Fig. 1, https://vmus.adu.org.za/?vm=ReptileMAP-162402) was encountered in open burned grassland which covered 1.56 ha of the firebreak, translating into a relatively low observed mortality density of 0.64 fatalities per hectare. The specimen was cut into several cross-sections which were stored in 10% buffered formalin in preparation for subsequent light microscopic histopathological investigations, in an effort to describe the observable effects of fire on the individual (see Jordaan et al. 2020; Jordaan and Steyl 2021).

Figure 1. Eastern Long-tailed Seps *Tetradactylus africanus* fire-associated mortality *in situ*, Phinda Private Game Reserve, KwaZulu-Natal Province, South Africa. Photo: Philip R. Jordaan.

The specimen was identified as *T. africanus* based on the serpentine body form and the presence of both hind- and forelimbs which were significantly reduced and exhibited only one toe (Branch 1998). *Tetradactylus africanus* is largely reliant on the grass layer, sheltering among grass tussocks and using its long tail to propel itself through herbaceous vegetation at relatively high speeds (Branch 1998). The species was documented as one of the most abundant reptiles in grassland in north-eastern KwaZulu-Natal Province, second only to the Large-scaled Grass Lizard *Chamaesaura macrolepis* by Bruton and Haacke (1980) who surveyed grasslands during prescribed fires. From that study, it seems as though the encountered individuals were mostly observed fleeing from fire and no mention is made regarding fire associated fatalities. Bates (2014a) suggested a decrease in fire frequency as a conservation measure to protect the integrity of *T. africanus* populations, which he also recommended for Breyer's Long-tailed Seps *Tetradactylus breyeri* (Bates 2014b). He also considered fire a threat to FitzSimons' Long-tailed Seps *Tetradactylus fitzsimonsi* (Bates 2014c). No prior published record of observed fire-induced mortality for any *Tetradactylus* species could be located in the available literature. Fire-induced mortality has, however, been recorded in the unrelated genus *Chamaesaura*, which exhibit similar adaptations and body plans (de Villiers and de Villiers 2004). Most of the reported *Chamaesaura* observations do not refer to mortalities observed in burnt vegetation, but rather document incidences when these lizards were flushed onto adjacent roads with most observed mortalities as a result of being driven over by vehicles (Coombs 2012; Jordaan and Steyl 2021). Raptors may be drawn to and scavenge fire mortalities, affecting the results and subsequently the estimated mortality density (Jordaan and Steyl 2021). Latent mortality from the effects of fire is probable (see Jordaan and Steyl 2021), and some instances of reptiles which have sustained and survived thermal injuries are known (Jordaan et al. 2019a,b).

Histopathological examination of cross-sections identified tissue damage associated with both thermal injuries and heated gas inhalation. External examination yielded no observable thermal damage to the specimen, however histopathological analyses exposed thermal injuries of variable severity present on the dorsum, including peripheral spongiosis of sections of the spinal cord, instances of haemorrhage, as well as inflammation and micro-vesiculation of epidermal and subcutaneous tissues. These thermal injuries were localised and are considered unlikely to have contributed to the death of the specimen. Pulmonary oedema was widespread and pronounced (Fig. 2) likely originating from heated or toxic gas inhalation, a conclusion supported by denuded ciliation of the trachea as well as the presence of observed hypereosinophilia. Additionally, myocardial fibre fragmentation was also observed during examination. The gut was full, containing both partially digested invertebrate matter as well as an unidentified reptile.

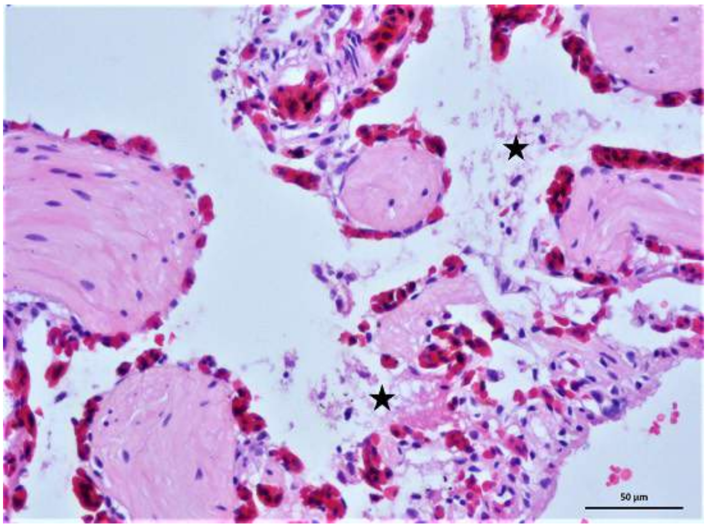

Figure 2. Severe amorphous eosinophilic exudation, demarkated with stars, into alveolar spaces (pulmonary oedema (Photomicrograph, 200x magnification, haematoxylin & eosin staining). Photo: Johan C.A. Steyl.

The low observed mortality density conforms to the notion that small management fires do not produce significant vertebrate mortalities (Jordaan et al. 2020) but illustrates that even when conducting relatively small, narrow-profiled firebreaks, relatively fast-moving species generally thought of as being able to evade the direct effects of fires (Engstrom 2010) may still be susceptible to fire-induced mortality (see Jordaan et al. 2019b). Light microscopic examination of samples suggests heated-gas inhalation as the most likely mechanism of mortality for this individual.

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GERRHOSAURIDAE
Matobosaurus validus
(Smith, 1849)
Common Giant Plated Lizard
AVIAN PREDATION

L.N. REYNOLDS & F.J. WILLEMS

On 4 April 2020, the authors discovered the roost of a Spotted Eagle-owl *Bubo africanus* in a hillside cave in the Nyanje Hills complex in the Sinda District of Zambia's Eastern Province (14° 23' 28" S, 31° 47' 06" E, 1431BD; 1 187 m a.s.l.). The roost was identified as belonging to a Spotted Eagle-owl as the only other owl occurring in the region that sometimes roosts in caves is the Western Barn Owl *Tyto alba*, although that species has comparatively smaller pellets. Furthermore, moulted feathers assignable to a Spotted Eagle-owl were found in the cave.

Various prey remains were collected from the cave floor immediately below the roost, from owl pellets that ranged in age from old and disarticulated to recently deposited. Among the prey remains were four pieces of connected reptilian scales, which were identified as belonging to a Common Giant Plated Lizard *Matobosaurus validus* (Fig. 1). Although the scales were not ensconced in a pellet when they were found, their location and general appearance strongly suggested that they originated from at least one owl pellet. The scales had been forced in on one plane (Fig. 1), suggesting that an external pressure had been exerted on them (such as having been compressed together with other indigestible matter in an owl pellet) rather than the *M. validus* having died in between the owl pellets. Furthermore, the absence of any other *M. validus* remains in the cave lends support to our hypothesis that this individual was captured and consumed by the Spotted Eagle-owl elsewhere, and the scales regurgitated in the cave as part of one or more pellets.

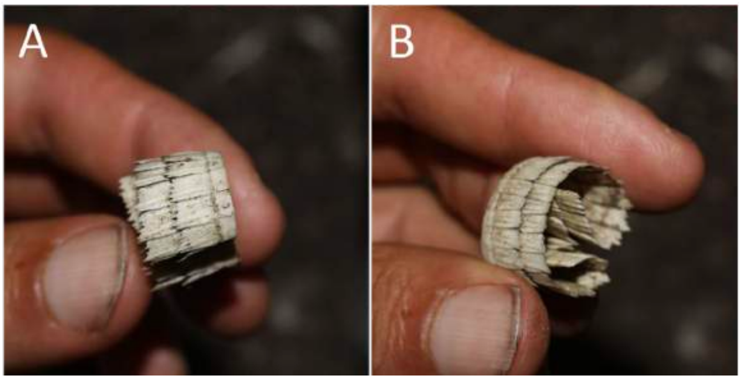

Figure 1. (A) Lateral and (B) postero-lateral views of caudal annuli of the Common Giant Plated Lizard *Matobosaurus validus* which were found in between several Spotted Eagle-owl *Bubo africanus* pellets in a cave in Zambia.

Surprisingly little is known regarding natural enemies of *M. validus*. Broadley (1966) noted that a juvenile *M. validus* was found in the stomach of an Oates' Vine Snake *Thelotornis capensis oatesi* from the Matobos in Zimbabwe. Neither Branch (1998) nor Maritz and Maritz (2020) provide any further information on predators, however there is an observation of a Nile Monitor *Varanus niloticus* eating an adult *M. validus* (https://www.facebook.com/groups/PredationRecordsReptilesandFrogsSubSaharanAfrica/posts/1462128077156374), although there is speculation that this is a scavenging rather than a true predation event. Pietersen et al. (2021) mention that *M. validus* is a favourite prey of Wahlberg's Eagle *Hieraaetus wahlbergi*. Although no supporting evidence for this statement is provided in Pietersen et al. (2021), this statement stems from the monitoring of more than 20 Wahlberg's Eagle nests over a period of three years (J. Davies and D. Pietersen, pers. comm. February 2022).

Although geckos, small lizards and snakes have been recorded in the diet of the Spotted Eagle-owl (Nel 1969; Skinner 1980; Steyn 1982; Kemp 2006), no specific mention is made of any member of the Gerrhosauridae. How the Spotted Eagle-owl, which is nocturnal, managed to catch a large diurnal gerrhosaurid is open to speculation. The predation event may have occurred either early in the morning or late in the afternoon when the activity periods of the two species might overlap marginally, or represent an opportunistic diurnal predation event as is occasionally observed in this species (Pepler and Martin 2000). This note adds another known predator of *M. validus*, and another prey item to the diet of the Spotted Eagle-owl.

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Our thanks to Darren Pietersen for identifying the gerrhosaurid remains, and to John Davies and Darren Pietersen for comments regarding Wahlberg's Eagles as predators of Common Giant Plated Lizards. Michael Bates and Byron du Preez are thanked for their helpful comments on an earlier draft of this manuscript.

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AHN

NATURAL HISTORY NOTES

VIPERIDAE
Bitis arietans arietans
Merrem, 1820
Puff Adder
DIET

R.I. STANDER

Hedgehogs and Moonrats (Erinaceidae) are known to feed on snakes (Dierenfeld 2009; Maritz and Maritz 2020) but the inverse has not been recorded and there appear to be no published records of snakes feeding on hedgehogs *Atelerix* sp. Maritz and Maritz (2020) report one failed predation attempt on an African Hedgehog *Atelerix frontalis* by a Brown House Snake *Boaedon capensis.* The body armour of *Atelerix* apparently makes them an unsuitable prey item for most snakes. Despite this, the morphologically similar (in terms of body armour) Cape Porcupine *Hystrix africaeaustralis* has been recorded in the diet of the Southern African Python *Python natalensis*, as noted by Maritz and Maritz (2020).

Puff Adders *Bitis arietans arietans* are known to be dietary generalists (Marais 2004; Glaudas et al. 2017) which feed on nearly any prey item that is small enough to swallow, although Glaudas and Alexander (2017a) have demonstrated that *B. a. arietans* uses a particularly specialised behaviour to feed on amphibians. According to current literature, small mammals constitute the bulk of the diet of *B. a. arietans* in the Highveld and Bushveld of South Africa, followed by amphibians, while birds and lizards only make for occasional meals (Glaudas and Alexander 2017b; Glaudas et al. 2017).

On 29 February 2016, an adult female *B. a. arietans* measuring 910 mm total length was captured and removed from a residential property in Polokwane, Limpopo Province, South Africa (23° 52' 17" S, 29° 30' 18" E; 2329DC). Before its release in a local nature reserve, the snake remained in captivity for three days, during which time it defecated. Upon examination, the snake's faeces were found to contain the quills from an adult *A. frontalis*. The record was uploaded to the ReptileMAP Virtual Museum (https://vmus.adu.org.za/?vm=ReptileMAP-156871).

Although this certainly shows that the snake successfully ingested and digested an *A. frontalis*, it cannot be stated with certainty that it also captured the prey item, as *B. a. arietans* have previously been recorded scavenging road-killed animals (Petford et al. 2018). However, *B. a. arietans* have also been recorded preying on such unlikely animals as Rock Hyrax *Procavia capensis* (L. Kemp, pers. comm. November 2021), Scrub Hare *Lepus saxatilis* and a Leopard Tortoise *Stigmochelys pardalis* (Branch 1998) while in East Africa they have even been recorded feeding on Dik-diks *Madoqua* sp. (Spawls et al. 2018).

Whilst this observation possibly represents a scavenging record rather than a predation event, it could well be the first documented

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instance of a snake successfully consuming a member of the *Atelerix* genus and adds yet another small mammal to the list of known prey items for *B. a. arietans*. Also, considering the wide variety and size of prey species that *B. a. arietans* is known to feed on, it does not seem unrealistic that this observation could represent a valid predation record.

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COLUBRIDAE

Toxicodryas vexator

Greenbaum, Allen, Vaughan, Pauwels, Wallach,
Kusamba, Muninga, Mwenebatu, Mali, Badjedjea,
Penner, Rödel, Rivera, Sterkhova, Johnson, Tapondjou
and Brown, 2021

Eastern Black-and-Yellow Tree Snake

DIET

O.S.G. PAUWELS, J. BRECKO & R. HUTTERER

With a total length of about three meters, the recently described Eastern Black-and-Yellow Tree Snake *Toxicodryas vexator* is one of the longest arboreal venomous snakes in Africa, and a fierce predator. What is currently known of its varied diet has been compiled by Greenbaum et al. (2021), and includes frogs, squamates (chameleons and agamids), birds (including bush shrikes, sunbirds, weaver finches, and robber birds' eggs), bats and small rodents. Spawls and Branch (2020) mentioned, among other prey, arboreal rodents and arboreal lizards, but without further details on their taxonomic identities.

We dissected the stomach of an ethanol-preserved adult female *T. vexator* in the Royal Belgian Institute of Natural Sciences collection (specimen number RBINS 2845; snout-vent length 1 495 mm; tail length 448 mm; tail complete), collected in 1938 in "Yangambi, district Stanleyville" (currently Yangambi; 0° 47' 57" N, 24° 27' 01" E, QDS NE000024CD; ~450 m a.s.l.), Tshopo Province, in the Democratic Republic of the Congo. It contained a scaly-tailed squirrel (Rodentia: Anomaluridae), the head of which is partly digested (Fig. 1). It had been ingested head-first. In order to access as many diagnostic characters as possible to specifically identify this arboreal gliding squirrel, we used high resolution x-ray computed tomography (RX EasyTom 150, 110 kV, 30 W, 30.8–33.4 µm voxel size), with segmentation and rendering done using Dragonfly software version 4.0 for Windows (Object Research Systems Inc., Montreal, Canada, 2019; software available at http://www.theobjects.com/dragonfly; Fig. 2).

Figure 1. Adult female Eastern Black-and-Yellow Tree Snake *Toxicodryas vexator* from Yangambi, Democratic Republic of the Congo, with a juvenile Lord Derby's Scaly-tailed Squirrel *Anomalurus derbianus* prey removed from its stomach. Specimens not to scale. Scale bar = 50 mm.

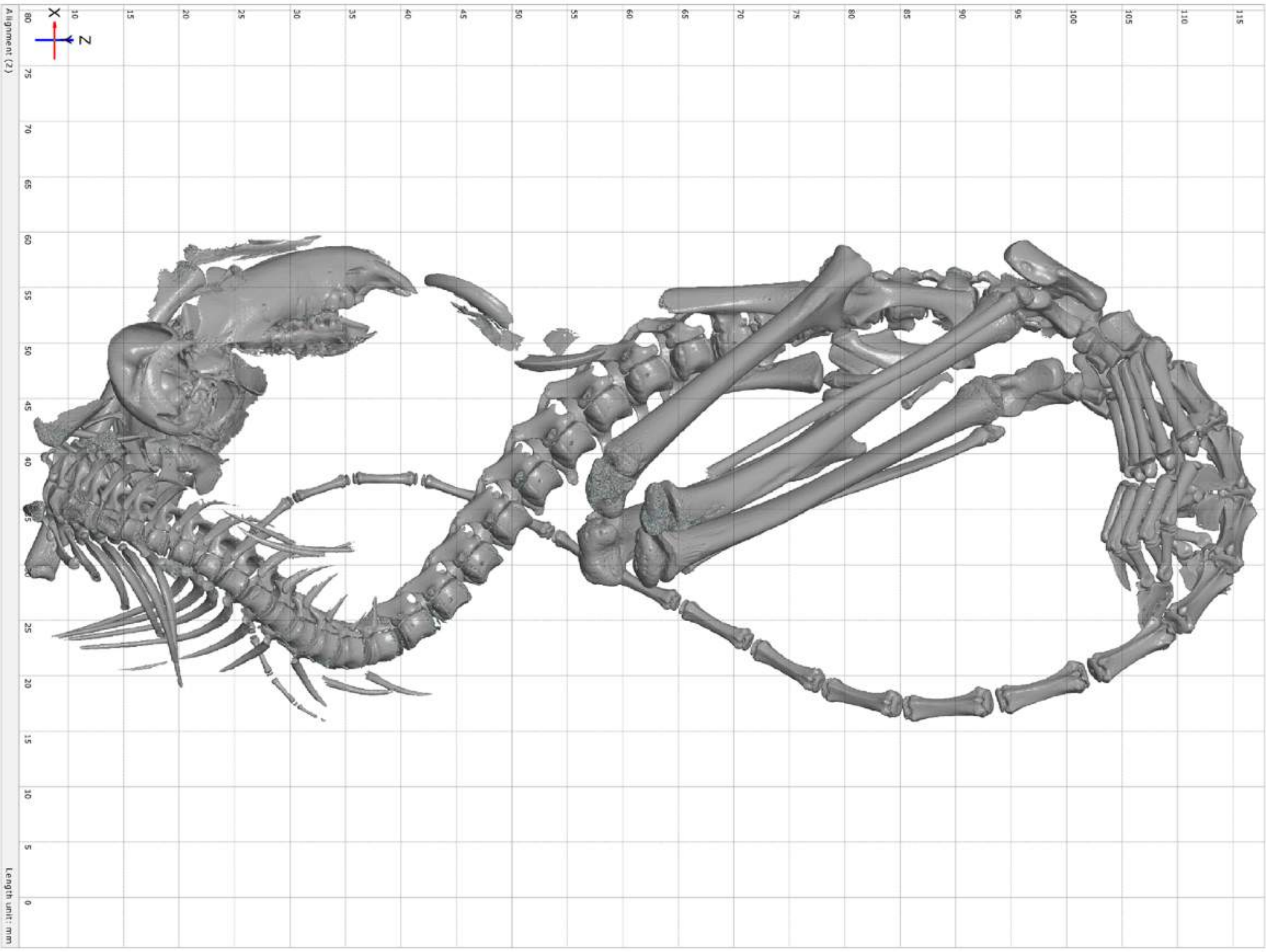

Figure 2. X-ray computed tomogram of the Lord Derby's Scaly-tailed Squirrel *Anomalurus derbianus* shown in Figure 1.

Based on its relatively long tail, the prey can be identified as a Lord Derby's Scaly-tailed Squirrel *Anomalurus derbianus* (Gray, 1842). The specimen is a juvenile, because the sutures of its long bones are not fused, and because its last molars are not yet erupted (Fig. 2). It is therefore possible that the animal was still in a nest or tree hole when the snake captured it. This represents the first record of an anomalurid in the food spectrum of *T. vexator* and confirms the arboreal hunting habits of this snake. *Anomalurus derbianus* was already known to be prey of eagles and the Blue Monkey *Cercopithecus mitis* Wolf, 1822 (Ray 2013), but no predation by snakes was documented to date.

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AHN
NATURAL HISTORY
NOTES

BLACK-NECKED SPITTING COBRA *NAJA NIGRICOLLIS* REINHARDT, 1843 REPELS A LARGE PACK OF BANDED MONGOOSES *MUNGOS MUNGO*

T. MADSEN & W. WÜSTER

Spitting cobras (*Naja* spp.) and the Rinkhals *Hemachatus haemachatus* are unique among snakes in that their ability to spit venom constitutes an example of contactless long-distance defence against predators. Recently Kazandjian et al. (2021) suggested that the spitting ability in cobras has evolved as a defence mechanism to repel attacks by early hominins.

Although a major part of mongooses (Herpestidae) diet consists of invertebrates (Neal 1970; Rood 1975; Avenant and Nel 1992; Bothma 1998; Mahmood et al. 2011; Basuony et al. 2013; Graw and Manser 2017), their diet often includes snakes, and may on occasion include cobras (Haltenorth and Diller 1977; Bothma 1998; supported by multiple videos on YouTube and other social media, e.g., https://www.youtube.com/watch?v=Wev2CSOrAvg; https://www.youtube.com/watch?v=pq7791VZLYI; https://www.youtube.com/watch?v=IJgyos2HDTs, many clearly showing natural interactions in wild, unconfined animals). This is also supported by their increased immunity to elapid neurotoxins (Barchan et al. 1992): occasional large meals can disproportionately enhance a predator's energy budget, promoting the evolution of venom resistance (Wiseman et al. 2019).

The typical behaviour of a spitting cobra when confronted by humans is to spit at the face (Warrell and Ormerod 1976; Westhoff et al. 2005; Berthé et al. 2009). Spitting at domestic dogs has been noted in South Africa (e.g., Leisewitz et al. 2004), and there are frequent reports of this occurrence on social media, especially from South Africa. However, there is a remarkable lack of published reports of encounters between spitting cobras and natural predators, and to our knowledge no one has documented the behaviour of spitting cobras when confronted by mongooses.

In September 2021 we were sent a video (https://youtu.be/7SKZIT79-yA) filmed in Masai Mara National Park, Kenya, by Joyce Karry that shows how a Black-necked Spitting Cobra *Naja nigricollis* survives an encounter with approximately 15 Banded Mongooses *Mungos mungo* by spitting. The mongooses show clear signs of hesitation and reluctance to approach (Fig. 1). Eight seconds into the video, the cobra can be seen spitting (Fig. 2) resulting in the instant retreat of the entire pack of banded mongooses (Fig. 3). It is unclear whether any of the mongooses received venom in their eyes. The response of the first mongoose, directly opposite the cobra, corresponds to the first signs of the cobra opening its mouth. It is questionable whether any venom could have reached the mongoose by the time it started to turn its head, suggesting it may have done so in the expectation of being sprayed rather than in response to venom reaching it. None of the mongooses showed obvious signs of ocular discomfort after the spitting act. The mongooses subsequently dispersed away from the cobra. According to Joyce Karry the cobra was alive after the mongooses left the site. As mentioned above, a major part of the Banded Mongooses' diet consists of invertebrates. It is therefore unclear whether their initial interest in the cobra was motivated by predatory intent or defence. However, we consider it significant that these members of a clade comprising well-known predators of large, venomous snakes showed clear awareness of the threat that venom spitting by cobras poses.

To our knowledge, this is the first documented report of a spitting cobra using venom spitting in defence against an adversary other than a human or domestic dog. This raises the possibility that the ability to spit venom may also have evolved, or been retained, to reduce predation from not only hominins but also other predators like mongooses. Finally, the video discussed here underscores the potential and importance of citizen science in documenting rare encounters in the natural world (Maritz and Maritz 2020).

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We thank Joyce Karry for allowing us to publish the video, Robin and Bryan Maritz for insights into mongoose-snake interactions, and we are also very grateful to Björn Lardner who's editing of the video greatly improved its quality.

Figure 1. The Banded Mongooses' *Mungos mungo* reaction to the Black-necked Spitting Cobra *Naja nigricollis* prior to it spitting.

Figure 2. The Banded Mongooses’ *Mungos mungo* reaction when the Black-necked Spitting Cobra *Naja nigricollis* spits. The mongoose highlighted by the arrow turns its head down and away from the cobra, as would be expected if it were either just squirted or, even more interestingly, *expecting* to be squirted in the eyes. The blue arrow in the second panel indicates the left eye, which is plainly visible in the first panel.

Figure 3. The Banded Mongooses’ *Mungos mungo* reaction after the Black-necked Spitting Cobra *Naja nigricollis* has spat. Note the considerable distance between the cobra and the mongooses compared to Figure 1.

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AHN

GEOGRAPHICAL DISTRIBUTIONS

BUFONIDAE

Capensibufo tradouwi

(Hewitt, 1926)

Tradouw Mountain Toadlet

A.D REBELO & J. MORTON

The Tradouw Mountain Toadlet *Capensibufo tradouwi* is endemic to the Cape Fold Mountains of the Western Cape Province of South Africa, extending south from Matsikammaberg to the Hex River Mountains and eastwards to Misgund (Boycott 2004). The species breeds in montane fynbos seepages and ephemeral wetlands, much like other *Capensibufo* species (Channing et al. 2017). The genus is distributed across most mountain ranges in the Cape Fold Belt, but has not previously been reported from Oorlogskloof, which is a drier area to the north of their known range.

While walking the Oorlogskloof trail on 14 October 2021, the authors encountered a single *C. tradouwi*. The individual was found actively moving at the 1st arch on the 3rd day of the trail (31° 30' 43" S, 19° 02' 45" E, 3119CA; 816 m a.s.l.) at around 09h56 on a misty morning. The surrounding landscape was a flat plain with exposed bedrock and surface rocks. Despite checking under rocks along the rest of the trail, no additional individuals were observed. The individual was identified as *C. tradouwi* based on its distinctive, red-coloured glands (Fig. 1) and the location being within close proximity to known populations in the Matsikammaberg. The record was submitted to iNaturalist (https://www.inaturalist.org/observations/98366968).

Figure 1. Tradouw Mountain Toadlet *Capensibufo tradouwi*, 1st Arch, Oorlogskloof. Photo: Alex Rebelo.

This record extends the known distribution of *C. tradouwi* by ~30 km and represents the first observation of this species in the Northern Cape Province (Fig. 2). The fact that this population has gone unnoticed until now warrants further surveys in the surrounding areas to determine the true limits of this species' range. It also highlights the tolerance that this genus has to dry climates in comparison to other frogs that are endemic to montane fynbos wetlands, such as moss frogs *Arthroleptella* and marsh frogs *Poyntonia*.

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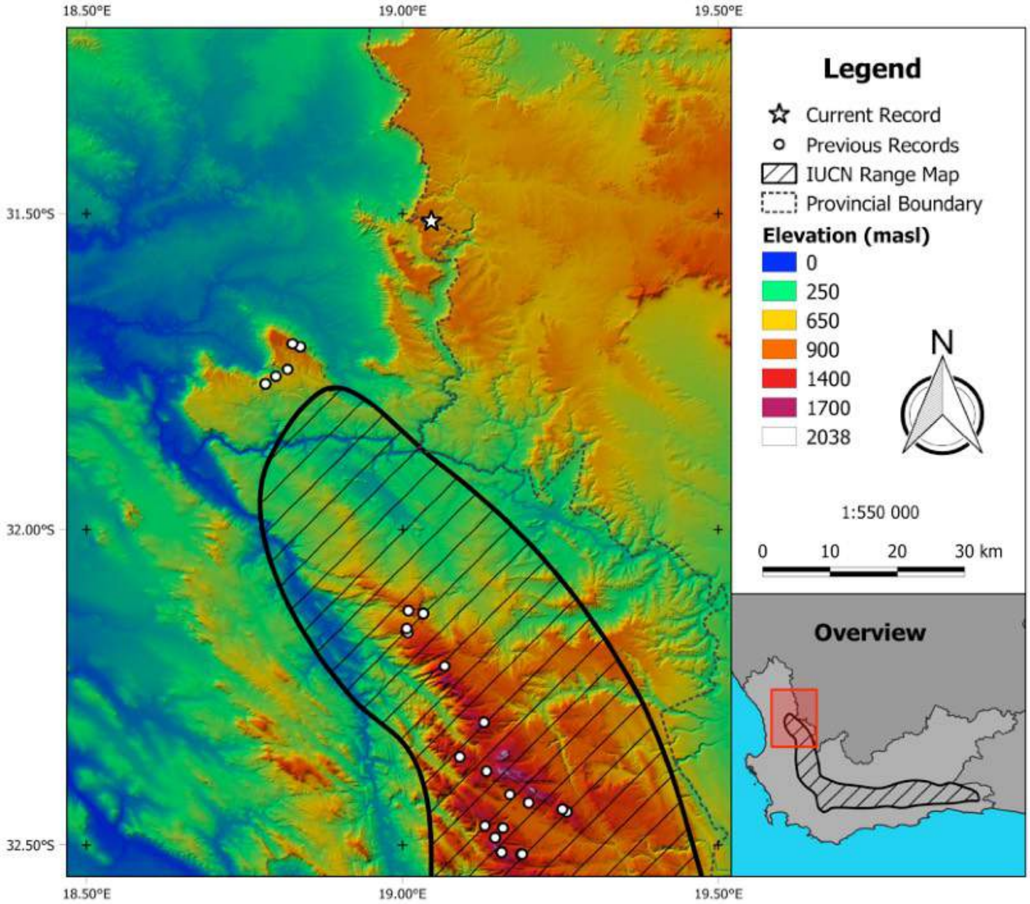

Figure 2. Range extension for Tradouw Mountain Toadlet *Capensibufo tradouwi*, also showing the species' range (IUCN SSC Amphibian Specialist Group 2013) and known occurrences (FrogMAP 2021; GBIF 2021) in the northern part of the species' range. Incorrectly georeferenced occurrence records were removed.

PYXICEPHALIDAE

Microbatrachella capensis

(Boulenger, 1910)

Micro Frog

O.L. ANGUS

Microbatrachella is a monotypic genus containing only the Micro Frog *Microbatrachella capensis* – an anuran species endemic to the southern coastal lowlands of South Africa's Western Cape Province. Following the discovery of the species on the Cape Flats at various localities in the early 1900s, it was later discovered at Betty's Bay and Kleinmond in the 1970s, and then on the Agulhas Plain in 1980. Site occupancy across its range is limited by strict habitat requirements, in the form of blackwater ephemeral wetlands with a distinct vegetation community (de Villiers 2004). Its small area of occupancy (AOO) of 7 km^2, and the fact that this AOO is decreasing, in combination with its severely fragmented distribution, has resulted in *M. capensis* being listed as Critically Endangered (IUCN and SA-FRoG 2017).

On 17 July 2021, the author recorded a frog call at the seasonal Nuwejaars Wetlands on the floodplain of the Nuwejaarsrivier, in the Overberg region of the Western Cape Province in South Africa (34° 37' 30" S, 19° 49' 39" E, 3419DB; 17 m a.s.l.). Upon inspection of the call's spectrogram, and through consultation with expert herpetologists Atherton de Villiers and Marius Burger, we identified the call as *M. capensis.* The author, accompanied by Tyrone Ping, Kurt van Wyk and Eugene Hahndiek, returned to the same wetland on 31 July 2021 and captured five male frogs which were identified as *M. capensis.* These five individuals were distinguished from the similar-looking and sympatric Southern Caco *Cacosternum australis* by the presence of webbing between the phalanges of the toes, as the latter species lacks webbing (du Preez and Carruthers 2017). The author returned to the Nuwejaarsrivier for a third time in mid-October 2021 to perform a targeted survey along a 7 km stretch of the Nuwejaarsrivier. Through call identification, the presence of *M. capensis* was confirmed at four additional sites (Fig. 1). Calls were heard coming from shallow sections of the main channel and small wetlands adjacent to it. The presence of *M. capensis* appeared to correlate with floating vegetation, such as Cape Pondweed *Aponogeton distachyos* and the sedge *Isolepis* sp. The water level at each site ranged from several centimetres to waist deep, although this would vary greatly depending on the time of year (Eugene Hahndiek, pers. comm.). At one site, males were heard calling from an area recently cleared of invasive Weeping Wattle *Acacia saligna*, suggesting either a degree of tolerance to alien plant invasion, or the ability to recolonize areas previously invaded by *A. saligna.* Their presence has also been confirmed just east of Elim, through an audio recording by Amy Williams. In addition,

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several misidentified records uploaded to iNaturalist in 2019 have now been recognized as *M. capensis* (https://www.inaturalist.org/projects/micro-frogs-of-nuwejaars-sma).

In summary, *M. capensis* has been discovered within a relatively large stretch of the Nuwejaarsrivier, translating to a 16 km north-east range extension for the species. The nearest population of *M. capensis* occurs in the western section of Agulhas National Park, which is considered a stronghold for the species (Turner and de Villiers 2017). This new locality extends their presence into a third tertiary river catchment.

The genetic difference between this new population and those from adjacent catchments has yet to be determined. Will (2005) showed that two evolutionary distinct lineages are present within *M. capensis*, one corresponding to those populations on the Agulhas Plain and the other to those from the Cape Flats, Bettys Bay and Kleinmond. Future genetic analyses should seek to ascertain whether all populations on the Agulhas Plain, including those from the newly discovered locality described here, belong to the same lineage. Given the presence of relatively continuous habitat, there is potential for *M. capensis* to have a considerable presence in the Nuwejaars Wetlands, which cover an area of approximately 6 km^2. Thus, future surveys should seek to establish where the range of *M. capensis* ends, both upstream and downstream of the newly discovered localities. Regarding the conservation of the newly discovered population, it is situated

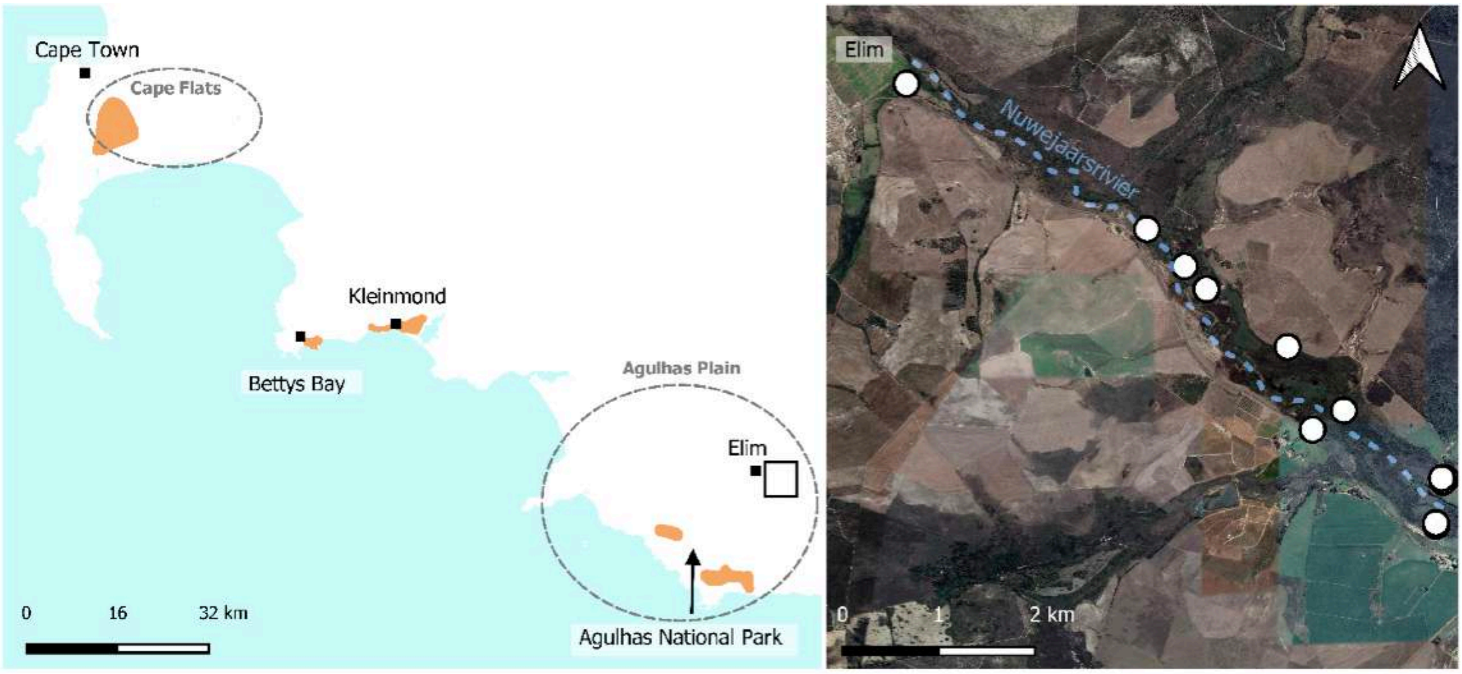

Figure 1. (Left) Micro Frog *Microbatrachella capensis* distribution as of the last IUCN assessment in 2017. The five known populations are indicated by orange polygons. Dashed ellipses indicate the relative positions of the Cape Flats and Agulhas Plain, respectively, and the box on the latter indicates the location of the image on the right. (Right) An orthophoto of the Nuwejaars Wetlands, with white dots indicating sites along the river where the presence of *M. capensis* has been confirmed.

within the Nuwejaars Special Management Area (SMA), meaning the species will ultimately be included in a conservation management plan. The biggest threat to this population appears be the invasion of alien trees in their breeding habitat. The Nuwejaars SMA facilitates an ongoing alien plant clearing program which should ultimately improve the quality of *M. capensis* habitat along the river.

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I would like to thank Eugene Hahndiek and Erica Brink from Nuwejaars SMA for arranging access, accommodation and transport to sites along the Nuwejaarsrivier. Marius Burger is thanked for his help in identifying the species through audio recordings. Tyrone Ping and Kurt van Wyk are thanked for assisting with the capture of specimens. Amy Williams is thanked for providing the audio recording from Elim. Atherton de Villiers is thanked for assisting with the identification of frog calls from audio recordings and for reviewing this manuscript. Nicholas Telford is thanked for reviewing this manuscript.

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CHAMAELEONIDAE

Bradypodion ventrale

(Gray, 1845)

Eastern Cape Dwarf Chameleon

B. FARQUHARSON & L.R.G. RAW

The Eastern Cape Dwarf Chameleon *Bradypodion ventrale* naturally occurs across most of the Eastern Cape Province of South Africa (Tolley and Burger 2007; Tilbury 2018; Tolley 2020). However, it is also prone to anthropogenic translocations with singletons and established populations having been reported widely across South Africa (Tolley and Burger 2007; Tilbury 2018; Tolley 2020).

The first author photographed dwarf chameleons in gardens in Kokstad, southern KwaZulu-Natal Province (KZN), South Africa (3029CB, 1300 m a.s.l.) and on a farm approximately 7 km north-west of the town during the period 2019–2021 (Figs. 1 & 2). After seeing the photographs, L.R. identified them as Eastern Cape Dwarf Chameleons *Bradypodion ventrale*. The identification of these chameleons is based on the tail being shorter than the snout-vent length (longer in Natal Midlands Dwarf Chameleon *B. thamnobates*); the low, strongly backward-projecting casque (raised in *B. thamnobates*; low but not strongly projecting backwards in KwaZulu Dwarf Chameleon *B. melanocephalum*); rugose body tubercles (much finer in *B. melanocephalum* and Drakensberg Dwarf Chameleon *B. dracomontanum*); body size (*B. melanocephalum* is much smaller); the yellowish skin behind the casque that is typical of many *B. ventrale*; and general colouration (see Tolley and Burger 2007). These morphological characters exclude the other dwarf chameleon species already known to occur in southern KZN.

Figure 1. Eastern Cape Dwarf Chameleon *Bradypodion ventrale* from Kokstad, southern KwaZulu-Natal Province, South Africa. Photograph: Bruce Farquharson.

Figure 2. Eastern Cape Dwarf Chameleons *Bradypodion ventrale* from Kokstad and vicinity, South Africa. Photographs: Bruce Farquharson

The three western species allied to *B. ventrale*, namely Western Dwarf Chameleon *B. occidentale*, Little Karoo Dwarf Chameleon *B. gutturale* and Swartberg Dwarf Chameleon *B. atromontanum*, were also eliminated on the basis of their distribution and morphology. The identification was confirmed by comparing the photographs with photographs of two museum specimens (PEM R05703 from Zastron, Free State Province, South Africa [Fig. 3] and PEM R05709 from Aliwal North, Eastern Cape Province, South Africa), both previously identified as *B. ventrale* on the basis of their morphology and DNA analysis (as CT10 & 11; Tolley *et al*. 2004).

Figure 3. Eastern Cape Dwarf Chameleon *Bradypodion ventrale* from Zastron, Free State Province, South Africa in the Port Elizabeth Museum collection (PEM R05703). Photograph: Werner Conradie.

L.R. also compared the photographs with specimens of this species as currently understood (Tolley and Burger 2007; Tolley 2014) in his personal collection. These include six specimens (LR2671, LR2674–5, LR2678, LR2682–3 [Fig. 4]) from Zastron, Free State Province, South Africa; two (LR2672, LR2681) from Lady Grey, Eastern Cape Province, South Africa; 12 (LR1746, LR1795–7, LR1803, LR1808, LR1815, LR1843, LR1876–8, LR1887) from Butterworth, Eastern Cape Province, South Africa; and six (LR1860, LR1872, LR1874–5, LR2752 [Fig. 5], LR2794) from Mthatha (formerly Umtata), Eastern Cape Province, South Africa, where the nearest populations to Kokstad are found.

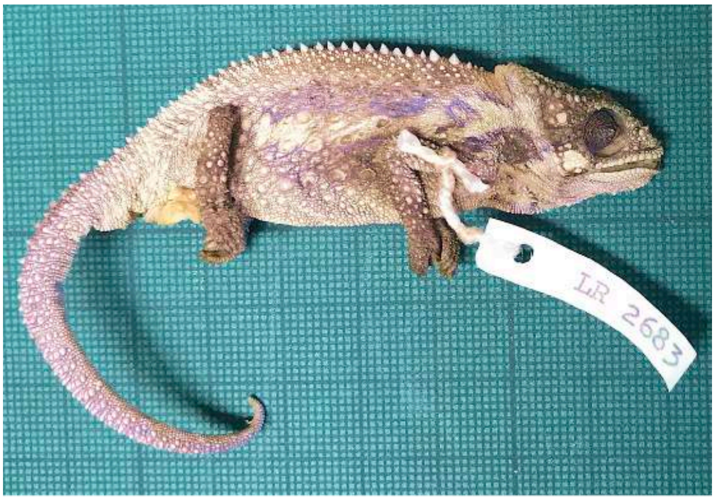

Figure 4. Eastern Cape Dwarf Chameleon *Bradypodion ventrale* from Zastron, Free State Province, South Africa, in L.R.'s personal collection (LR2683). Photograph: Lynn Raw.

Figure 5. Eastern Cape Dwarf Chameleon *Bradypodion ventrale* from Mthatha (Umtata), Eastern Cape Province, South Africa, in L.R.'s personal collection (LR2752). Photograph: Lynn Raw.

The current records confirm Tilbury's first record of the species from Kokstad (Tilbury 2018), and are an interesting addition to the herpetofauna of the KwaZulu-Natal Province. It is also a northern range extension east of the Drakensberg escarpment of approximately 130 km north-east of the previous eastern-most record from Mthatha in the Eastern Cape Province (Raw 1995; Tolley and Burger 2007; Tolley 2014). *Bradypodion ventrale* is known to extend west and north of Lesotho into the Free State, Gauteng and Mpumalanga provinces, although these populations have been introductions by human agency (Douglas 1992; Tolley 2014, 2020; Tilbury 2018). While the present record may also represent an introduced population (Tilbury 2018), it is also possible that it is a natural part of its eastern range. Comments made to B.F. by long-term residents of Kokstad indicate that these chameleons have been present in the area for at least many decades.

ACKNOWLEDGEMENTS

The authors thank Ortwin Bourquin, Darren Pietersen, Andrew Whittington and the two reviewers, Krystal Tolley and Colin Tilbury, for their valuable comments on the draft of this note, Darren Pietersen also for providing scans of the relevant section from the book by Tilbury (2018). L.R. thanks Werner Conradie for kindly providing photographs of the two Port Elizabeth Museum specimens.

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Brief notes of new geographical distributions of amphibians and reptiles on the African continent and adjacent regions, including the Arabian Peninsula, Madagascar, and other islands in the Indian Ocean. Records should be based on specimen(s) deposited in a recognised collection or to photograph(s) submitted to a recognised, curated citizen science platform. A standard format is to be used, as follows:

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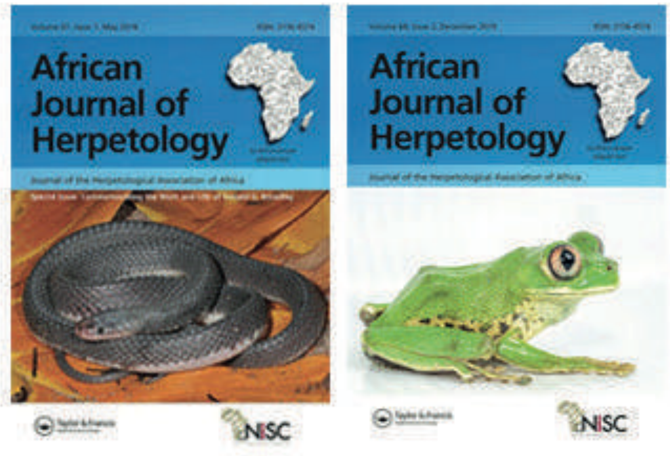

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