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## SHEDDING LIGHT ON A BIODIVERSITY DARK SPOT: SURVEY OF AMPHIBIANS AND REPTILES OF PEMBA REGION IN NORTHERN MOZAMBIQUE

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**Abstract.**—The biodiversity of northern Mozambique is likely one of the least known in southern Africa but is expected to harbor rich herpetofaunal diversity due to the high diversity in neighboring countries, the presence of diverse habitats, and its large size. Here, we summarize 19 years of reported observations and collections from the Pemba region in Cabo Delgado Province to better document the herpetofaunal diversity and distribution in coastal northern Mozambique. We report the presence of two species of amphibians and 27 species of reptiles for the first time from the region. In total, the Pemba region is now known to harbor 54 herpetofaunal species (19 amphibians and 35 reptiles) of which two (sea turtles) are at risk. Additionally, of the six snake species regarded as medically important to humans, we have formally documented five for the first time from the entire Cabo Delgado Province. Our compilation of new records adds 15 verified herpetofaunal species for the province, raising the total from 86 to 101.

**Key Words.**—Africa; distribution range; herpetofauna; inventory; Mecufi; *Proscelotes aenea*; *Scolecoseps boulengeri*; urban biodiversity

**Resumo.**—A biodiversidade do norte de Moçambique é uma das menos conhecidas no sul de África, no entanto prevê-se uma grande diversidade herpetofaunística devido à sua grande extensão e variedade de habitats disponíveis. Neste estudo nós compilamos dezanove anos de observações e exemplares recolhidos na região de Pemba na província de Cabo Delgado numa tentativa de melhor conhecer a diversidade e distribuição de anfíbios e répteis do Litoral Norte de Moçambique. Nós reportamos a presença de duas espécies de anfíbios e 27 répteis pela primeira da região. No total, a região de Pemba alberga 54 espécies de herpetofauna, 19 anfíbios e 35 répteis respectivamente, dos quais dois estão ameaçados (duas tartarugas marinhas). Seis serpentes são de importância médica, das quais cinco são documentadas formalmente pela primeira vez em Cabo Delgado. A nossa compilação de novos registos adiciona 15 espécies de herpetofauna verificadas para Cabo Delgado, subindo o número de 86 para 101. Os nossos resultados testemunham a escassez de amostragem no Norte de Moçambique, e sugerem a existência de muitas espécies ainda por documentar na região.

**Palavras Chave.**—Africa; biodiversidade urbana; distribuição; herpetofauna; inventário; *Proscelotes aenea*; *Scolecoseps boulengeri*

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## INTRODUCTION

Northern Mozambique is likely one of the most poorly known areas in southern Africa in terms of biodiversity, especially with respect to herpetofauna (Poynton and Broadley 1991; Tolley et al. 2016). Before 2005, the only surveys conducted in northern Mozambique were conducted by Barbour and Loveridge (1928) and Blake (1965) and consisted of sampling from Quelimane north to the Island of Mozambique, approximately 220 km south of the city of Pemba. The amphibians collected by Blake (1965) were reported by Poynton (1966) in *Amphibia Zambeziaca* (Poynton and Broadley 1985a,b, 1987, 1988).

In recent years, researchers have initiated biodiversity surveys in the northernmost provinces of the country: Zambézia (Bayliss et al. 2014; Farooq et al. 2015; Conradie et al. 2016), Nampula (Julian Bayliss et al., unpubl. report), and Niassa (Branch 2005; Portik et al. 2013a; Jones et al. 2017, 2020). Most of these expeditions focused on the montane regions of the interior of northern Mozambique, including Mounts Chipirone, Mabu, Namuli, Inago, Mepalué, Mecula, and Njese. These surveys resulted in the discovery of new species of crabs (Daniels and Bayliss 2012), butterflies (Bayliss et al. 2016, 2018; Van Velzen et al. 2016), frogs (Conradie et al. 2018b), bats (Monadjem et al. 2010; Taylor et al. 2012), snakes (Branch and Bayliss 2009), chameleons (Branch et al. 2014; Branch and Tolley 2010), geckos (Branch et al. 2017; Portik et al. 2013b), a skink (Verburgt et al. 2018), a girdled lizard (Branch et al. 2005a), and an amphisbaenia (Broadley and Measey 2016). These surveys also resulted in range expansions of amphibians (Farooq and Conradie 2015; Farooq et al. 2015) and reptiles (Branch et al. 2019; Broadley and Farooq 2013). The only surveys on amphibians and reptiles of Cabo Delgado Province were conducted either on Vamizi Island (Broadley and Farooq 2013) or in the coastal dry forests and surroundings (Ohler and Fretey 2014; Verburgt et al. 2018; Jean-Yves Raspulus et al., unpubl. report).

There is currently no comprehensive checklist of reptiles for Mozambique, but 240 reptile and 97 amphibian species are believed to occur in the country. In contrast to most of Mozambique's neighboring countries, however, the herpetofaunal diversity of large areas of Mozambique, especially the northern coast, remains poorly known. Studies in South Africa have documented 410 species of reptiles (Tolley et al. 2022; South African National Biodiversity Institute: <http://biodiversityadvisor.sanbi.org/research-and-modelling/checklists-and-encyclopaedia-of-life/south-african-animal-checklist/>) and 133 species of amphibians (Du Preez and Carruthers 2017), whereas studies in Tanzania have identified 343 species of reptiles (Spawls et al. 2018) and 211 species of amphibians (International

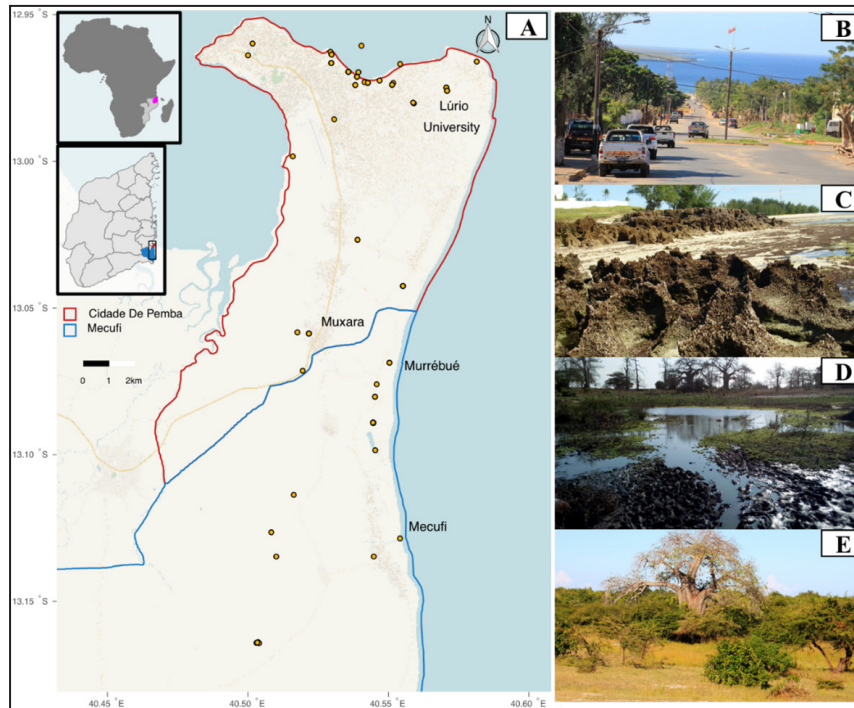
Union for Conservation of Nature [IUCN] 2021). Based on these findings, one might expect higher diversity in Mozambique than has been documented (IUCN 2021).

Mozambique has a diversity of available habitats across a large land area (Olson et al. 2001) and this, combined with data from neighboring countries, suggests a higher diversity than has been previously documented (Atauri and de Lucio 2001; Pianka 1967). Our study focuses on the region of Pemba including the city of Pemba and the northeastern part of the Mecufi District and was conducted because both regionally widespread species and local endemics may be present but undocumented in the study area and in Mozambique as a whole. Our study region forms part of the larger Coastal Forest of the Eastern Africa Biodiversity Hotspot (Myers et al. 2000) but remains one of the most understudied regions in Africa. Documenting the biodiversity in this region is especially important as local biodiversity, especially snake species, may be at risk due to the recent population growth and the urbanization of Pemba (Farooq et al. 2021).

## MATERIALS AND METHODS

**Study site.**—The study area was primarily located in the Cidade de Pemba District in Cabo Delgado Province, Mozambique. For completeness, we also included the northeastern part of the Mecufi District. Collectively, we refer to the entire study area as the Pemba region (Fig. 1), which represents approximately 0.36% of the land surface of Cabo Delgado Province. This region forms part of the larger Coastal Forest of the Eastern Africa Biodiversity Hotspot (Myers et al. 2000). Microhabitats for amphibians and reptiles in the region include urban areas, the coral rag around the bay, wetlands formed by the accumulation of rainwater, and coastal grasslands with Baobabs (*Adansonia digitata*), Mango Trees (*Mangifera indica*), and Cashew Trees (*Anacardium occidentale*; Fig. 1).

**Data collection.**—We used multiple methods to obtain records from the Pemba region between 2003 and 2021. These included direct collection of new survey data and searches of relevant databases. Our team collected data in the field and from specimens donated by others (mostly students). We captured specimens by hand or by trapping, when possible, but also recorded some species based on visual observations alone when capture was difficult or prohibited (e.g., for protected sea turtles). Most of the trapping was conducted in four-day sampling periods carried out on the Lúrio University campus for teaching purposes four times a year. Additionally, we also documented specimens collected and donated by other individuals, mostly students. We euthanized all specimens with MS222, fixed in 10%



**FIGURE 1.** (A) Map of the Pemba region of Mozambique showing the sites (circles) from which observations and records were obtained. Habitat characteristics of Pemba region are as follows: (B) urban area, city center; (C) coral rag at Maringanha's Beach; (D) wetland in Chuiba; and (E) coastal grassland in Murrébué. (B, C, E photographed by Harith Farooq and D photographed by Cristóvão Nanvonamuquitxo).

formalin for 10–30 d, immersed them in water for a day to remove the formalin, transferred them to a permanent storage solution of 70% ethanol, and then deposited them at the Faculty of Natural Sciences (FCN) at Lúrio University (Pemba Campus), Mozambique and Port Elizabeth Museum (PEM), South Africa.

We also searched available databases for the Pemba region. We compiled publicly available data for the region by searching iNaturalist (iNaturalist. 2019. Available from <https://www.inaturalist.org>. [Accessed 10 April 2019]), ReptileMap/FrogMap (FitzPatrick Institute of African Ornithology. 2019. Virtual Museum. Available from <https://vmus.adu.org.za> [Accessed 10 April 2019]) and VertNet (Vertnet. 2016. VertNet Version 2016-09-29. Available from <http://vertnet.org/> [Accessed 29 August 2021]). We further downloaded all species records from the Global Biodiversity Information Facility (GBIF; <https://doi.org/10.15468/dl.zofsjg>) using the search terms amphibians and reptiles and by drawing a polygon around the study area. To assess whether our records represented new records for Cabo Delgado Province, we compared our records to published species lists or records in existing reports (Pascal 2011; Ohler and Fretey 2014), published articles (Garnier et al. 2012; Farooq et al. 2015; Broadley and Measey 2016; Conradie et al. 2018; Verburg et al. 2018), and notes

(Broadley and Farooq 2013). We used these data to produce a preliminary species list for the province.

## RESULTS

Our surveys produced 135 records from the Pemba region including 47 herpetofauna species (12 amphibian and 35 reptile species). Although we identified an additional 39 records (including 12 amphibian species) using the publicly available dataset produced by the South African Institute for Aquatic Biodiversity (SAIAB; available from <https://doi.org/10.15468/dl.zofsjg>), one of us (WC) conducted physical verification of the SAIAB specimens and considered the records of Guibe's Ridged Frog (*Ptychadena guibeii*) and Delalande's River Frog (*Amietia delalandi*) to be misclassifications of the Broad-banded Grass Frog (*Ptychadena mossambica*). We added an additional 20 observations, including seven amphibian and seven reptile species, using the citizen science platform iNaturalist. These data added two additional species of amphibians (3.7%) to our final dataset for the Pemba region and brought the total herpetofauna diversity of the Pemba region to 54 species: 19 amphibian species (Table 1) and 35 reptile species (Tables 2 and 3). No other publicly available records exist for the study area except for two reptile records on the ReptileMap.

TABLE 1. Checklist of amphibians from the Pemba region, Cabo Delgado Province, Mozambique. An asterisk (\*) = presence, minus (-) = not recorded, and the superscript a (a) = a new record for Cabo Delgado.

Species	Current study	iNaturalist	SAIAB
<b>Arthroleptidae</b>			
Common Squeaker ( <i>Arthroleptis stenodactylus</i> )	*	*	-
Mozambique forest Tree Frog ( <i>Leptopelis mossambicus</i> )	-	*	-
<b>Brevicipitidae</b>			
Mozambique Rain Frog ( <i>Breviceps mossambicus</i> ) <sup>(a)</sup>	-	-	*
<b>Bufoidea</b>			
Merten's Striped Toad ( <i>Sclerophrys pusilla</i> )	*	-	-
Chirinda Toad ( <i>Mertensophryne anotis</i> )	-	*	-
Lindner's Dwarf Toad ( <i>Mertensophryne lindneri</i> ) <sup>(a)</sup>	*	*	-
Red Toad ( <i>Schismaderma carens</i> )	*	-	-
<b>Microhylidae</b>			
Banded Rubber Frog ( <i>Phrynomantis bifasciatus</i> ) <sup>(a)</sup>	*	-	*
<b>Hemisotidae</b>			
Marbled Shovel-nosed Frog ( <i>Hemisis marmoratus</i> )	-	-	*
<b>Hyperoliidae</b>			
Delicate Leaf-folding Frog ( <i>Afrivalus delicatus</i> )	*	-	*
Greater Leaf-folding Frog ( <i>Afrivalus fornasini</i> )	*	-	*
Argus Reed Frog ( <i>Hyperolius argus</i> ) <sup>(a)</sup>	*	-	-
Tinker Reed Frog ( <i>Hyperolius tuberilinguis</i> )	-	-	*
Red-legged Kassina ( <i>Hylambates maculatus</i> )	*	-	*
<b>Phrynobatrachidae</b>			
Eastern Puddle Frog ( <i>Phrynobatrachus acridoides</i> )	*	-	*
<b>Ptychadenidae</b>			
Plain Grass Frog ( <i>Ptychadena anchietae</i> )	-	-	*
Mozambique Ridged Frog ( <i>Ptychadena mossambica</i> )	-	*	*
<b>Pyxicephalidae</b>			
Edible Bullfrog ( <i>Pyxicephalus edulis</i> )	*	*	*
<b>Rhacophoridae</b>			
Grey Foam-nest Tree Frog ( <i>Chiromantis xerampelina</i> )	*	*	*
<b>Total</b>	<b>12</b>	<b>7</b>	<b>12</b>

## DISCUSSION

Prior to our study, the compilation of published herpetofaunal records of Cabo Delgado, included 35 amphibians and 46 reptiles. We increased the preliminary species list for Cabo Delgado Province to 41 amphibian species (Supplemental Information Table S1) and 60 reptile species (Supplemental Information Table S2; see Supplemental Information file for systematic accounts of each species). Our study added to knowledge regarding the herpetofaunal diversity of the Pemba region by recording species not previously

documented from the region, greatly increasing the geographical ranges of some species, and suggesting that some previously recorded species are not now present. Additionally, this study provides information about species of medical and conservation significance. In total, there are 19 species of amphibians and 35 species of reptiles in the Pemba region including those reported by us, which added two amphibians and 27 reptiles. Our compilation of new records adds 15 verified herpetofaunal species for whole province, raising the total from 86 to 101 (Supplemental Information file for the full list of species).

## Herpetological Conservation and Biology

TABLE 2. Checklist of lizards from the Pemba region, Cabo Delgado Province, Mozambique. An asterisk (\*) = presence, minus (-) = not recorded, and the superscript a (a) = a new record for Cabo Delgado.

Common name	Current study	iNaturalist	Reptile map
Amphisbaenidae			
Pestle-tailed Worm Lizard ( <i>Dalophia pistillum</i> ) <sup>(a)</sup>	*	-	-
Gekkonidae			
Common Dwarf Gecko ( <i>Lygodactylus grotei</i> )	*	-	-
Tropical House Gecko ( <i>Hemidactylus mabouia</i> )	*	-	-
Speckled-lipped Thick-toed Gecko ( <i>Pachydactylus punctatus</i> ) <sup>(a)</sup>	*	-	-
Fischer's Thick-toed Gecko ( <i>Chondrodactylus laevigatus</i> ) <sup>(a)</sup>	*	-	-
Chamaeleonidae			
Flap-necked Chameleon ( <i>Chamaeleo dilepis</i> )	*	-	-
Agamidae			
Mozambican Agama ( <i>Agama mossambica</i> )	*	*	-
Scincidae			
Sundevall's Writhing Skink ( <i>Mochlus sundevalli</i> )	*	-	-
Wahlberg's Snake-eyed Skink ( <i>Panaspis</i> aff. <i>Walbergi</i> )	*	-	-
Rainbow Skink ( <i>Trachylepis margaritifera</i> )	*	*	*
Striped Skink ( <i>Trachylepis striata</i> )	*	-	-
Variable Skink ( <i>Trachylepis varia</i> )	*	-	-
Coral Rag Skink ( <i>Cryptoblepharus africanus</i> )	*	-	*
Gerrhosauridae			
Eastern Black-lined Plated Lizard ( <i>Gerrhosaurus intermedius</i> )	*	*	-
Varanidae			
Rock Monitor ( <i>Varanus albigularis</i> )	*	-	-
Total	15	3	2

We recorded four species of amphibians considerably outside of their known distributional range: the Brown-backed Tree Frog, *Leptopelis mossambicus*, 250 km northeast of its known range (IUCN 2013a), Red-backed Toad, *Schismaderma carens*, 250 km east of its known range, Lindners Dwarf Toad, *M. lindneri*, 100 km east of known range (IUCN 2013b), and Chrinda Toad, *M. anotis*, historically considered to be restricted to 1,000 km south-west to Chirinda and Dombe forests, but recently found in Cabo Delgado and Zambezi Provinces (IUCN 2013c; Farooq et al. 2015; Bittencourt-Silva et al. 2020). Our study further adds four species to the published list of amphibians occurring in Cabo Delgado Province, bringing the provincial number up to 41 species (Ohler and Fretey 2014; Supplemental Information Table S1). We also increased the ranges of four amphibians between 100 and 250 km depending on the species and raised concern regarding the existence of two Data Deficient species last collected in Pemba in 1948 (Laurent, 1964) but not recorded by us.

We added 13 reptile species to published sources for Cabo Delgado Province, bringing the total to 60

species (Supplemental Information Table S2). Of the 35 reptile species recorded from the Pemba region (Tables 2 and 3), two are of particular conservation importance: the Green Sea Turtle (*Chelonia mydas*) is listed as Endangered (Seminoff 2004) and the Hawksbill Sea Turtle (*Eretmochelys imbricata*) is listed as Critically Endangered (Mortimer et al. 2008). Six of the documented snakes are of medical importance: the Stilleto Snake (*Atractaspis bibronii*), Puff Adder (*Bitis arietans*), Green Mamba (*Dendroaspis angusticeps*), Black Mamba (*Dendroaspis polylepis*), Boomslang (*Dispholidus typus*), and Mozambique Spitting Cobra (*Naja mossambica*). Only the Puff Adder was previously documented from Cabo Delgado Province (Jean-Yves Raspulus et al., unpubl. report).

We did not find evidence for the presence of either Boulenger's Limbless Skink (*Scolecococephalus boulengeri*) or Montane Skink (*Proscelotes aenea*) from the Pemba region. These species were originally described from Lumbo, 220 km south of Pemba (Loveridge 1920), but Laurent (1964) recorded additional material from Pemba collected in September 1948. No precise



TABLE 3. Checklist of snakes and turtles from the Pemba region, Cabo Delgado Province, Mozambique. An asterisk (\*) = presence, minus (-) = not recorded, a superscript a (a) = a new record for Cabo Delgado, superscript b (b) = endangered, superscript c (c) = critically endangered, superscript d (d) = Medically important species (such as those responsible for deaths and/or amputations to humans) following the World Health Organization guidelines (Longbottom et al. 2018).

Common name	Current study	iNaturalist
Typhlopidae		
Zambezi Blind Snake ( <i>Afrotyphlops mucruso</i> ) <sup>(a)</sup>	*	-
Leptotyphlopidae		
Long-tailed Thread Snake ( <i>Myriopholis longicauda</i> )	*	-
Peter's Thread Snake <sup>(a)</sup> ( <i>Leptotyphlops scutifrons</i> ) <sup>(a)</sup>	*	*
Pythonidae		
Southern African Rock Python ( <i>Python natalensis</i> )	*	-
Atractaspididae		
Stiletto Snake ( <i>Atractaspis bibronii</i> ) <sup>(a)(d)</sup>	*	-
Lamprophiidae		
Brown House Snake ( <i>Boaedon fuliginosus-capensis</i> complex)	*	-
Dwarf Sand Snake ( <i>Psammophis angolensis</i> ) <sup>(a)</sup>	*	-
Olive Grass Snake ( <i>Psammophis mossambicus</i> ) <sup>(a)</sup>	*	*
Eastern Stripe-bellied Sand Snake ( <i>Psammophis orientalis</i> )	*	-
Rufous Beaked Snake ( <i>Rhamphiophis rostratus</i> )	*	-
Common Tiger Snake ( <i>Telescopus semiannulatus</i> )	*	-
Boomslang ( <i>Dispholidus typus</i> ) <sup>(d)</sup>	*	-
Elapidae		
Mozambique Spitting Cobra ( <i>Naja mossambica</i> ) <sup>(a)(d)</sup>	*	*
Black Mamba ( <i>Dendroaspis polylepis</i> ) <sup>(a)(d)</sup>	*	-
Green Mamba ( <i>Dendroaspis angusticeps</i> ) <sup>(a)(d)</sup>	*	-
Viperidae		
Puff Adder ( <i>Bitis arietans</i> ) <sup>(d)</sup>	*	-
Testudinidae		
Speke's Hinge-back Tortoise ( <i>Kinixys spekii</i> )	*	*
Pelomedusidae		
Serrated Hinged Terrapin ( <i>Pelusios sinuatus</i> )	*	-
Cheloniidae		
Green Sea Turtle ( <i>Chelonia mydas</i> ) <sup>(b)</sup>	*	-
Hawksbill Sea Turtle ( <i>Eretmochelys imbricata</i> ) <sup>(c)</sup>	*	-
Total	20	4

locality details were provided in those publications, so the species could have been collected outside the periphery of Pemba or Mecufi as covered in our study. It is possible that the increase in urbanization since 1948 have resulted in the local extinction of these two species; however, considering the absence of precise localities and the fact that there have not been any long-term continuous sampling targeting specifically *S. boulengeri* and *P. aenea*, the species may still be present in the Pemba region. Based on the recent discovery of a sister species, Palma's Limbless Skink (*S. broadleyi*) further north, there is evidence that these are very specialized

fossorial lizards living in weak soil development in coastal woodland and hard to detect (Verburgt et al. 2018). It is therefore important that targeted surveys are conducted in similar sites in Pemba targeting specifically *S. boulengeri* and *P. aenea*.

In recent years, three species endemic to the coastal regions of northeastern Mozambique have been described as new to science: Yellow-spotted Reed Frog (*Hyperolius stictus*) by Conradie et al. (2018), Marais's Dwarf Worm Lizard (*Zygaspis maraisi*) by Broadley and Measey (2016), and Broadley's Limbless Skink (*Scolecoseps broadleyi*) by Verburgt et al. (2018). These

new scientific discoveries and the growing species list for Cabo Delgado Province reinforce the likelihood that herpetofaunal diversity of northern Mozambique has been underestimated. Although our species list should be regarded as preliminary because unpublished species records may exist in other public and private databases that may further increase the number of species known from the province, our survey suggests that additional surveys of Cabo Delgado Province are needed to better document and protect the rich biodiversity of northern Mozambique.

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