

The herpetofauna of Koanaka South and adjacent regions, Ngamiland, Botswana

AARON M. BAUER^{1,4}, ALICIA M. KENNEDY², PATRICK J. LEWIS²,
MONTE L. THIES² and MOHUTSIWA GABADIRWE³

¹ *Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA.*

² *Department of Biological Sciences, Sam Houston State University, Box 2116 Huntsville, Texas 77341, USA.*

³ *Botswana National Museum, 331 Independence Avenue, Gaborone, Botswana.*

⁴ Author for correspondence: aaron.bauer@villanova.edu

ABSTRACT - The Koanaka South locality of western Ngamiland, Botswana, is a Plio-Pleistocene cave deposit. While this deposit has produced numerous reptile and amphibian fossils, a lack of comparative osteological material from the region has hampered taxonomic diagnosis, particularly below the level of family. In addition, the lack of a published account of the modern herpetofauna from the area prevents documenting how the reptile and amphibian faunas have changed over the last two million years. A collecting trip to Koanaka South in the winter dry season (19–30 June 2008) resulted in the collection of 38 specimens of nine species belonging to seven squamate families (Agamidae, Chamaeleonidae, Gekkonidae, Lacertidae, Scincidae, Viperidae). Two additional species, the gekkonid *Ptenopus garrulous* and the elapid snake *Dendroaspis polylepis* are documented from sound and sight records, respectively, and one additional lacertid, *Heliobolus lugubris*, is vouchered by older museum material. No amphibians were observed during the survey. Nine taxa are explicitly reported from the Koanaka Hills or in quarter degree square 2021 Aa for the first time and a range extension and size record are reported for *Pedioplanis namaquensis* and *Ichnotropis squamulosa*, respectively. Based on collections made in the surrounding quarter degree square (2021 Aa), as well as published range maps, we provide a list of 39 additional reptiles and amphibians expected, but not yet documented, in the vicinity of Koanaka South.

RECENT excavations in a Plio-Pleistocene cave system in the Koanaka Hills of the Ngamiland Province in northwestern Botswana (Fig. 1) have yielded a large assemblage of microvertebrate fossils (Pickford & Mein, 1988; Pickford, 1990). Among these fossils, 46 of the elements were identified as squamates and seven were identified as anurans (Kennedy & Bhullar, 2007). However, the lack of relevant comparative material representing the extant regional herpetofauna limits the taxonomic resolution for these fossils, and most elements are identified only to the level of family. Additionally, no published account of the modern herpetofauna of the Koanaka Hills exists. As such, reconstructing regional environmental change over the last two million years by comparing the modern and fossil

herpetofauna is currently impossible. These difficulties highlighted the need for sampling the herpetofauna from the Koanaka Hills, and a collecting trip was undertaken from 19–30 June 2008.

Three hills make up the Koanaka Hills, with Koanaka North and Koanaka South separated by ca. 0.5 Km. The third hill is 12 Km to the west. As the caves containing fossils are in Koanaka South, this is where our collecting efforts were based. Koanaka South (20° 09.451' S, 21° 11.7612' E, quarter degree square [QDS] 2021 Aa) is approximately 130 Km southwest of the westernmost of the main channels of the Okavango Delta and 20 Km east of the Namibian border (Fig. 2). The hills are composed primarily of dolomitic rocks (Fig. 3) and breccia infills (Cooke, 1965)



Figure 1. Map of Botswana illustrating the position of the Koanaka Hills in Ngamiland. Map prepared using Google Earth Pro®.



Figure 3. Slope of Koanaka South showing its composition of dolomitic rock. The entrance to the Plio-Pleistocene cave is near the summit of ca. 50 m hill.



Figure 4. Semi-arid dense shrub savanna on low sandy ridge immediately surrounding Koanaka Sth.

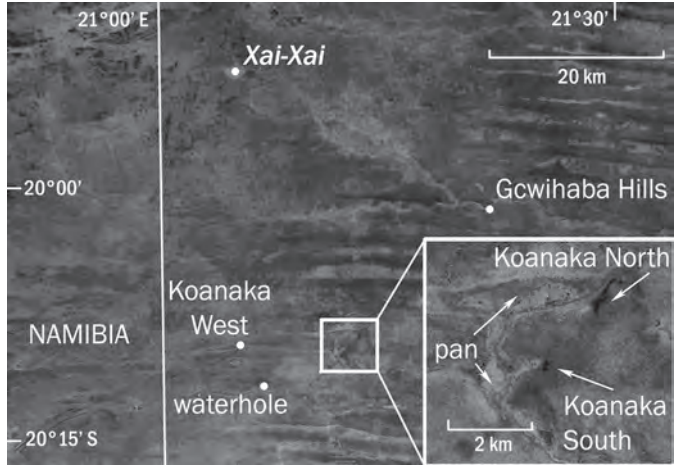


Figure 2. Map of a portion of northwestern Botswana showing landmarks and place names mentioned in the text. Inset shows Koanaka North and Koanaka South in greater detail. The pans adjacent to Koanaka South were the primary collecting site for lacertids. 'Waterhole' indicates the nearest open water source to Koanaka South located during the June 2008 survey. Map prepared using Google Earth Pro®.



Figure 5. Heavily elephant trampled waterhole 15 Km southwest of Koanaka South. ▼



Figure 6. View of Koanaka South from edge of dry pan to the west of the ca. 50 m hill. ◀

and, at ca. 50 m tall, represent the only topographic relief for over 18 Km. The modern climate of the Koanaka area is semi-arid with annual rainfall of 400-450 mm occurring only during the austral summer months (Van Regenmortel, 1995). Annual temperature variation near the Koanaka Hills varies from -8.5°C to 42.2°C (Botswana Department of Meteorological Services). Habitat around the hills varies, but is considered a semi-

arid dense shrub savanna (Fig. 4) often referred to as the Kalahari Thirstland (Pickford & Mein, 1988). The closest water source found during our survey was a small waterhole 15 Km west of Koanaka South (Fig. 5), although topographic maps based on a 1966 survey indicate three springs approximately 5 Km south of the site. Two pans (ephemeral ponds) are located approximately 200 m to the west of Koanaka South (Fig. 6),

although neither the frequency with which these pans contain water nor the duration of their water retention are known.

During the period of collection daytime temperatures averaged 26°C, night time temperatures averaged 2°C, and there was no precipitation.

METHODS AND MATERIALS

New collections were made chiefly within a 5 Km radius of Koanaka South with collecting teams of one to three persons. Collecting was concentrated on rocky outcrops of the hill, as well as in the dry pan west of the hill. Searches were made during both day and night, although temperatures dropped rapidly after sunset, precluding most reptile activity. As a result, most specimens were caught during daylight hours. Pitfall traps were also utilised in the collection process. Species identifications followed standard regional references (e.g., Auerbach, 1987; Branch, 1998; Alexander & Marias, 2007).

Specimens were euthanised with intraperitoneal injections of sodium pentobarbitol. Samples of either liver or tail tissue were taken from each specimen for future DNA sequencing. When present, stomach contents and parasites were also collected. The first two specimens of each taxon collected were prepared as osteological specimens and associated skins were preserved in 70% ethanol. Every third specimen of a taxon collected was fixed in 10% formalin in the field and later transferred to 70% ethanol. All material was deposited in either the Texas Natural History Collections (TNHC) at the University of Texas at Austin, Austin, Texas, USA or the Botswana National Museum (BNM), Gaborone, Botswana.

Our 2008 records are supplemented by data from a small, previously unpublished, collection made by Wulf Haacke at the Koanaka Hills in 1965. This collection is housed at the Transvaal Museum (TM) in Pretoria, South Africa. Occurrences based on literature records, as well as reliable, but unvouchered, sight or sound records were also compiled. Our confirmed species list includes all species represented by specimens actually collected in the Koanaka Hills, as well as those from elsewhere in QDS 2021Aa. Species not

confirmed, but expected to occur in the Koanaka Hills, based on literature and museum records, are listed in Table 1 (see Appendix).

SPECIES ACCOUNTS

The species observed at the Koanaka Hills are listed alphabetically within genera and by corresponding higher taxonomic group. Specimens collected during the 2008 survey are noted under the heading 'Material'. 'Other records' refers to Transvaal Museum material collected by Wulf Haacke at the Koanaka Hills in 1965, unvouchered sight and sound records, and to literature records based on unspecified museum material. Comments under the heading 'Habitat' relate to the specific habitat where the specimens were collected, as well as the precise GPS coordinate data for that capture. Additional information, such as size records or range extensions, is noted under heading 'Comments'.

Squamata: 'Lacertilia'

Agamidae

Agama aculeata Merrem, 1820

Material: Four specimens: TNHC 68737–40.

Other records: TM 30778 from 'Koanaka Hills.'

Habitat: TNHC 68737, TNHC 68738, and TNHC 68739 were collected in a dry pan at 20°08.30' S, 21° 11.40' E. TNHC 68740 was found on a sandy track in dense shrub 100 m north of Koanaka South.

Comments: As Auerbach (1987) did not cite the specimen collected by Haacke in 1965, this record constitutes the first published finding of this species for the Koanaka Hills and QDS 2021 Aa.

Chamaeleonidae

Chamaeleo dilepis Leach, 1819 (Fig. 7)

Material: One specimen: BNM (registration number pending).

Habitat: This specimen was located in a tree around 20:00 in dense shrub surrounding Koanaka South, 21° 11.355' E, 20° 09.167' S.

Comments: Although the Koanaka area was included within the range maps of Branch (1998) and Clauss & Clauss (2002), this

specimen represents the first published record of voucher material of this species for the Koanaka Hills and QDS 2021Aa.

Gekkonidae

Chondrodactylus turneri (Gray, 1864) (Fig. 8)

Material: Two specimens: TNHC 68749–50.

Other records: Visser (1984a) plotted the occurrence of this species in QDS 2021 Aa (source locality not mentioned) and Haacke collected specimens from Drotzky's Cave, approximately 23 Km to the northeast in 2021 Ab.

Habitat: Both specimens were observed inside the entrance to a cave at the top of Koanaka South at 20° 09.451' S, 21° 11.712' E.

Comments: Benyr (1995) provided evidence for the separation of the more tropical *Pachydactylus turneri* from the temperate *Pachydactylus bibronii* (Smith, 1846). Bauer & Lamb (2005) demonstrated that the affinities of this large-bodied gecko were with the genus *Chondrodactylus* and subsequently reallocated the species to this genus.

Ptenopus garrulus (Smith, 1849)

Material: No specimens were collected in 2008.

Other records: Visser (1984b) and Auerbach (1987) recorded this species in QDS 2021 Aa, the later citing Transvaal Museum material from the Koanaka Hills (although the nearest specimens in the records we obtained were from Kwia, Camp 2, 15 Miles SE Kaikai in 2021 Ab). This highly vocal species was heard calling sporadically from approximately one hour before sunset until one hour after sunset on most evenings during the survey.

Habitat: Found in tall grass on loose sand substrate near the 2008 campsite, 50 m west of Koanaka South at 20° 09.451' S, 21° 11.712' E.

Lacertidae

Heliobolus lugubris (Smith, 1838)

Material: No specimens were collected in 2008. Additional specimens. TTM 30779; TM 30792 from 'Koanaka Hills.'

Comments: As Auerbach (1987) did not cite these specimens, this constitutes the first published record of this species for the Koanaka Hills and QDS 2021 Aa.

Ichnotropis capensis (Smith, 1838) (Fig. 9)

Material: Five specimens: TNHC 68743–47 from the 'Koanaka Hills.'

Habitat: TNHC 68743 was observed on a sand ridge northwest of Koanaka South. TNHC 68744 and TNHC 68745 were observed on a sandy track in dense shrub west of Koanaka South at 20° 09.167' S, 21° 11.355' E. TNHC 68746 and TNHC 68747 were caught in pitfall traps placed in dense shrub near Koanaka South.

Comments: Although the Koanaka area was included within Branch's (1998) range map for this species, these specimens represent the first published record of voucher material for the Koanaka Hills and QDS 2021 Aa.

Ichnotropis squamulosa Peters, 1854 (Fig. 10)

Material: One specimen: TNHC 68748.

Habitat: TNHC 68748 was collected in a dry pan at 21° 11.40' E, 20° 08.30' S.

Comments: This female specimen (79 mm SVL, 12 g) is slightly larger than the largest reported size for this species (75 mm; Branch, 1998). Although the Koanaka area was included within Branch's (1998) range map for this species, this specimen represents the first published record of voucher material for the Koanaka Hills and QDS 2021 Aa.

Pedioplanis namaquensis (Duméril & Bibron, 1839) (Fig. 11)

Material: 18 specimens: TNHC 68751–68. Other records. TM 3077 was collected at 'Koanaka Hills, Western Hill.'

Habitat: All *P. namaquensis* collected were active in and around the bases of shrubs in dry pans at 20° 08.30' S, 21° 11.40' E and 20° 08.46' S, 21° 11.14' E.

Comments: Auerbach (1987) did not cite the specimen collected by Haacke in 1965 and the range mapped by Branch (1998) did not include the Koanaka region, thus this constitutes the first published record of this species for the Koanaka Hills and QDS 2021 Aa.

Scincidae

Trachylepis varia (Peters, 1867)

Material: Four specimens: TNHC 68769–72.

Other records: Five specimens: TM 30774–76; TM



Figure 7. *Chamaeleo dilepis* found from dense shrub savanna surrounding Koanaka South (Photograph by Johan Marais).



Figure 8. *Chondrodactylus turneri* from cave at Koanaka South site. ▲

Figure 12. *Bitis arietans* from pan adjacent to Koanaka South (Photograph by Johan Marais). ►



Figure 9. *Ichnotropis capensis* from sand ridge adjacent to Koanaka South (Photograph by Johan Marais).



Figure 10. Large female specimen of *Ichnotropis squamulosa* from pan adjacent to Koanaka South (Photograph by Johan Marais).



Figure 11. *Pedioplanis namaquensis* from pan adjacent to Koanaka South (Photograph by Johan Marais).



30786–87 from the ‘Koanaka Hills.’

Habitat: All specimens collected in 2008 were found on Koanaka South running in and out crevices between the dolomitic rock.

Comments: Although the Koanaka area was included within Branch’s (1998) range map for this species Auerbach (1987) did not cite Haacke’s (1966) 1965 material. This report is the first published record of voucher material for the Koanaka Hills / QDS 2021 Aa.

Trachylepis wahlbergii (Peters, 1869)

Material: One specimen: TNHC 68773.

Other records: TM 30788 from ‘Koanaka Hills.’

This specimen was presumably the basis of Auerbach’s (1987) record from the area.

Habitat: TNHC 68773 was found on a termite mound adjacent to a waterhole heavily used by elephants, 8 Km WSW of Koanaka South and 12 Km E of the Namibian border at 20° 11.37’ S, 21° 06.33’ E.

Comments: Until the work of Broadley (2000) this species was treated by most authors as a subspecies of *Trachylepis* (then *Mabuya*) *striata*, and earlier references to this species in northwestern Botswana are under this name.

Squamata: Serpentes

Elapidae

Dendroaspis polylepis (Günther, 1864)

Material: No specimens were collected in 2008.

Other records. B. Williams (pers. comm.) reported observing this species at Koanaka South in a cave entrance on Koanaka South in 1996.

Comments: Although not included in the species range map of Branch (1998), it was regarded as occurring in the Koanaka area by Clauss & Clauss (2002). This sight record is the first for the Koanaka Hills and QDS 2021 Aa.

Psammophiidae

Psammophis trinasalis Werner, 1902

Material: No specimens were collected in 2008.

Other records: TM 26922 was collected from Ngua, 24 Km SE of Kaikai (= Xai Xai), approximately 37 Km northwest of Koanaka South. Broadley (1990) recorded this species

from QDS 2021 Aa, probably based on this specimen, which is also entered into the Transvaal Museum database with the QDS 2021 Aa, although the locality actually lies near the border of 1921 Cc and 1921 Cd, probably in the latter. Auerbach (1987) also plotted a locality in 2021 Aa presumably based on a Transvaal Museum record from the Gcwihaba Hills, although this locality actually lies in 2021 Ab.

Comments: On two occasions a *Psammophis* sp. was observed at the Koanaka South site, but these were not captured so specific identity could not be established unambiguously. It is probable that *Psammophis trinasalis* was the species present, but several congeners are expected to occur in the region (Table 1).

Viperidae

Bitis arietans Merrem, 1820 (Fig. 12)

Material: One specimen: TNHC 68742.

Habitat: This specimen was found in a dry pan at 20° 11.37’ S, 21° 06.45’ E.

Comments: An additional specimen, TNHC 68741, was captured crossing a dirt road en route to the Koanaka Hills at 20° 42.2’ S, 21° 36.58’ E. Both specimens collected were heavily infested with nematode worms in the alimentary canal, lungs, peritoneum, and pericardium. Both Branch (1998) and Clauss & Clauss (2002) included the Koanaka region in their shaded range maps for this species, but this represents the first vouchered published record from the Koanaka Hills and QDS 2021 Aa.

DISCUSSION

The herpetofauna of Ngamiland was first commented upon by Wahlberg in 1856, who noted the presence of a Puff Adder (*Bitis arietans*) near Lake Ngami (Wahlberg, 1994). However, the region, and in particular, those areas distant from Lake Ngami and the edges of the Okavango, have been poorly surveyed overall. Indeed, the herpetological literature pertaining to Botswana as a whole is relatively limited. The whole of the country is included in a number of southern African herpetological guides and references (e.g.,

FitzSimons, 1943; Visser, 1984c; Broadley, 1990; Branch, 1998; Channing, 2001), but the only book length herpetological references specific to Botswana are Auerbach (1987) and Clauss & Clauss (2002). In addition Auerbach (1985) deals specifically with the herpetofauna of the Gaborone areas and Butchart (2000) with that of the Okavango Delta. Most of these references, however, are not of relevance to Ngamiland (Auerbach, 1985), do not provide distribution maps of any kind (Butchart, 2000), cover only selected species (Clauss & Clauss, 2002), or contain almost no records from northwestern Botswana (FitzSimons, 1943). Only Visser (1984c, lizards only), Broadley (1990, snakes only), and Auerbach (1987) provide quarter degree square records, while Channing (2001) provides degree square records, and Branch (1998) and Clauss & Clauss (2002) present general (non-point or QDS) distribution maps. Most of these sources are ultimately based on specimen records from southern African museums. In addition, a relatively small number of technical publications have discussed the herpetofauna of selected regions or have dealt with selected taxonomic groups (e.g., Haacke, 1966; Auerbach, 1984; 1986; McLachlan 1981).

Knowledge of the herpetofauna of western portions of Ngamiland is especially limited. Indeed, Auerbach (1987) recorded only four species of reptiles in degree square 2021 and neither he nor Channing (2001) gave any amphibian records for the same area. This is, in large part, due to the minimal collecting effort in this part of Ngamiland, chiefly because of difficulty of access. However, the region is also likely to be depauperate by southern African standards. It is relatively uniform in topography and does not provide, except in the Koanaka Hills and other nearby low hills (e.g., Gcwihaba Hills, Aha Hills), any significant rocky habitat. Rocky substrates are typically favored, for example, by *Pachydactylus* spp. geckos, and landscapes dominated by mountains or kopjes usually support a diversity of *Pachydactylus* spp., as well as *Trachylepis* spp., and other lizards (Bauer, 2000). Indeed, many such rocky areas in southern Africa support highly localised rupicolous endemics, such as *Pachydactylus tsodiloensis* in the Tsodilo Hills,

175 Km north of the Koanaka Hills, *Pachydactylus waterbergensis* and *Pedioplanis rubens* on the Waterberg, and *Pachydactylus otaviensis* in the Otavi Hills, both about 400 Km to the west in Namibia. However, our survey did not reveal the presence of any such localised, substrate-specific species, and virtually all of the species recorded, or previously signaled from the region are generalists with broad distributions in southern Africa.

Despite the probable absence of specialists in the region, our review of previously collected material and literature records plus our own collections, yield a probable species list of six frogs and 46 reptiles for the site (Table 1). Nine of these (all reptiles) are confirmed by our collection of 38 specimens made in June 2008. An additional species, the lacertid *Heliobolus lugubris*, was not observed in 2008 but was confirmed by specimens collected in 1965. We also consider as confirmed for the Koanaka Hills, the barking gecko *Ptenopus garrulus*. Although we could not confirm the supposed museum voucher for the area cited by Auerbach (1987), we regularly heard the characteristic call of this gecko at Koanaka South.

The presence of two other snakes is supported by sight records and nearby vouchers. We thus consider the total confirmed herpetofauna for the Koanaka Hills to include 13 squamate reptile species. For nine of these species, this report constitutes the first published record of occurrence in the Koanaka Hills or in quarter degree square 2021 Aa. While nearly all of these have been considered likely to occur in the region (Branch, 1998; Clauss & Clauss, 2002), our records of *Pedioplanis namaquensis*, vouchered by both new material and an older museum specimen, represents a slight extension to the hitherto recognised range of the species. Our material also includes a new size record (79 mm SVL) for *Ichnotropis squamulosa*.

The harsh winter conditions at Koanaka South (no precipitation and near-freezing night-time temperatures), as well as the limited time and collecting effort precluded the compilation of a complete species list for the area. Additional species expected but not observed at Koanaka

South certainly include all of the taxa represented by material in the Transvaal Museum from nearby localities, including Drotzky's Cave and the Gewihaba Hills (~ 23 Km NE), Nguaia, Gewisha, Kwia, and Khibo, all southeast of Xai-Xai (also sometimes spelled Kaikai or Nxai-Nxai), approximately 28–37 Km northeast of Koanaka South, and Dobe, approximately 67 Km north-northwest of Koanaka South. For the most part, these specimens also form the basis for the inclusion of these expected species in the regional herpetofaunal literature (Table 1). As noted above, all of the 39 additional species considered as probable in the region are more or less widespread in southern Africa and suitable habitats for each of these species occurs in and around the Koanaka Hills. We believe that a collecting expedition during the summer months (November-March) would be optimal. This period coincides with the rainy season in Botswana and are the months in which the dry pans are most likely to be filled.

The preliminary enumeration of the Koanaka amphibians and reptiles compiled here is the first herpetofaunal list for the region and provides a starting point for comparisons with the paleofauna of the Koanaka South site. Material collected and prepared as osteological specimens will serve as comparative material for the identification of fossils recovered from the Plio-Pleistocene cave system and will be invaluable in determining how the reptiles and amphibians have been impacted by climate change and the appearance of humans in Ngamiland during the Pleistocene. Future trips are planned for the summer months in order to obtain comparative osteological material of a more representative sample of the modern herpetofauna of Koanaka South.

ACKNOWLEDGEMENTS

We thank the many people who helped in the 2008 collection including: D. Portik, T. Campbell, J. Marenga, J. Garcia, S. Thompson, M. McDonough, A. Ferguson, C. Kroll, and J. K. Forson. Special thanks are due to J. Marias who located and trapped the majority of the specimens retained and who provided a number of the photographs. Additional thanks are also due to Wulf Haacke, Lauretta Malengu, and Lemmy Mashinini of the

Transvaal Museum for allowing access to their northwestern Botswanan specimen records. This project was funded by a Faculty Research and Enhancement Grant from Sam Houston State University to P. J. Lewis. Specimens were collected under permit CYSC 1/17/21(81) issued by the Botswana Ministry of Youth, Sport and Culture to P. J. Lewis and imported into the United States under permits from the U. S. Centers for Disease Control and Prevention, U. S. Fish and Wildlife Service, and U. S. Department of Agriculture permit #105705 issued to M. Thies. A. M. Bauer was supported by Grant DEB 0515909 from the National Science Foundation of the United States.

REFERENCES

- Alexander, G. & Marais, J. (2007). *A Guide to the Reptiles of Southern Africa*. Cape Town: Struik Publishers. 408 pp.
- Auerbach, R.D. (1984). Botswana's dangerous snakes. *Marung* 2, 4, 3–5.
- Auerbach, R.D. (1985). *The Reptiles of Gaborone*. Gaborone: Botswana Book Centre. 48 pp.
- Auerbach, R.D. (1986). First steps in Setswana herpetology. *Botswana Notes Rec.* 18, 71–90.
- Auerbach, R.D. (1987). *The Amphibians and Reptiles of Botswana*. Gaborone: Mokwepa Consultants. 295 pp.
- Bauer, A.M. (2000). Evolutionary scenarios in the *Pachydactylus*-group geckos of southern Africa: new hypotheses. *Afr. J. Herpetol.* 48, 53–62.
- Bauer, A.M. & Lamb, T. (2005). Phylogenetic relationships of southern African geckos in the *Pachydactylus* Group (Squamata: Gekkonidae). *Afr. J. Herpetol.* 54, 105–129.
- Benyr, G. (1995). Systematik und Taxonomie der Geckos des *Pachydactylus bibronii-laevigatus* Komplexes (Reptilia: Squamata: Gekkonidae). Diplomarbeit, Universität Wien. 99 pp.
- Botswana Department of Meteorological Services. http://www.weather.info.bw/resources/climate_fs.html (Accessed: 16th January 2009).
- Branch, W.R. (1998). *Field Guide to Snakes and Other Reptiles of Southern Africa*, 3rd edition. Cape Town: Struik Publishers. 399 pp.
- Broadley, D.G. (1990). FitzSimons' Snakes of Southern Africa, revised edition with addendum. Parklands, South Africa: Jonathan Ball. 387 pp.

- Broadley, D.G. (2000). A review of the genus *Mabuza* in southeastern Africa (Sauria: Scincidae). *Afr. J. Herpetol.* **49**, 87–110.
- Broadley, D.G. & Wüster, W. (2004). A review of the southern African ‘non-spitting’ cobras (Serpentes: Elapidae: *Naja*). *Afr. J. Herpetol.* **53**, 101–122.
- Butchart, D. (2000). *Wildlife of the Okavango*. Cape Town: Struik Publishers. 126 pp.
- Channing, A. (2001). *Amphibians of Central and Southern Africa*. Ithaca: Cornell University Press. 470 pp.
- Clauss, B. & Clauss, R. (2002). *Common Amphibians and Reptiles of Botswana*. Windhoek: Gamsberg Macmillan Publishers. 114 pp.
- Cooke, H. J. (1975). The paleoclimatic significance of caves and adjacent landforms in western Ngamiland, Botswana. *Geogr. J.* **141**, 430–444.
- FitzSimons, V.F.M. (1943). The lizards of south Africa. *Mem. Transvaal Mus.* **1**, 1–528.
- Haacke, W.D. (1966). A new gekko (Sauria, Geckonidae) from Bechuanaland. *Arnoldia (Rhodesia)* **2**, 25, 1–7.
- Haacke, W.D. (1997). Systematics and biogeography of the southern African scincine genus *Typhlacontias* (Reptilia: Scincidae). *Bonn. Zool. Beitr.* **47**, 139–163.
- Hughes, B. (1997). *Dasypeltis scabra* and *Lamprophis fuliginosus* – two pan-African snakes in the Horn of Africa: A tribute to Don Broadley. *Afr. J. Herpetol.* **46**, 68–77.
- ICZN (International Commission for Zoological Nomenclature). (2005). Opinion 2104 (3226). Lacepède, B.G.É. de la V., 1788, Histoire Nat. des Quad. Ovipares: rejected as a non-binominal work. *Bull. Zool. Nomencl.* **62**, 55.
- Kelly, C.M.R., Barker, N.P., Villet, M.H., Broadley, D.G. & Branch, W.R. (2008). The snake family Psammophiidae (Reptilia: Serpentes): phylogenetics and species delimitation in the African sand snakes (*Psammophis* Boie, 1825) and allied genera. *Mol. Phylogen. Evol.* **47**, 1045–1060.
- Kennedy, A.M. & Bhullar, B.A.S. (2007). Preliminary analysis of the fossil herpetofauna from the Koanaka Hills site, Ngamiland, Botswana (abstract). *J. Vert. Paleont.* **27**, 3, 98.
- McLachlan, G.R. (1981). Taxonomy of *Agama hispida* (Sauria: Agamidae) in southern Africa. *Cimbebasia*, ser. A, **5**, 219–227.
- Pickford, M. (1990). Some fossiliferous Plio-Pleistocene cave systems of Ngamiland, Botswana. *Botswana Notes Rec.* **22**, 1–15.
- Pickford, M. & Mein, P. (1988). The discovery of fossiliferous Plio-Pleistocene cave fillings in Ngamiland, Botswana. *C. R. Acad. Sci., Paris* **307**, 1681–1686.
- Savage J.M. (2003). Lacepède, B.G.É. de la V., 1788, Histoire Naturelle des Quadrupèdes Ovipares: proposed rejection as a non-binominal work (Case 3226). *Bull. Zool. Nomencl.* **60**, 138–140.
- Van Regenmortal, G. (1995). Regionalization of Botswana rainfall during the 1980s using principal component analysis. *Internatl. J. Climatol.* **15**, 313–323.
- Vidal, N., Branch, W.R., Pauwels, O.S.G., Hedges, S.B., Broadley, D.G., Wink, M., Cruaud, C., Joger, U. & Nagy, Z.T. (2008). Dissecting the major African snake radiation: a molecular phylogeny of the Lamprophiidae Fitzinger (Serpentes, Caenophidia). *Zootaxa* **1945**, 51–66.
- Vidal, N., Delmas, A.-S., David, P., Cruaud, C., Couloux, A. & Hedges, S.B. (2007). The phylogeny and classification of caenophidian snakes inferred from seven nuclear protein-coding genes. *C. R. Biol.* **330**, 182–182.
- Visser, J. (1984a). Geniepsige blinkogies’n goeie huisvriend. *Landbouweekblad*. 18 Mei 1984, 72–77.
- Visser, J. (1984b). Klein grondgeitjies hou hul lyfies skaars. *Landbouweekblad*. 1 Junie 1984, 40–43.
- Visser, J. (1984c). Akkedisse van Suider-Afrika. *Landbouweekblad*. 1984 [41 part series].
- Wahlberg, J. A. (1994). *Johan August Wahlberg. Travel Journals (and Some Letters) South Africa and Namibia/Botswana, 1838–1856*. Cape Town: Van Riebeeck Society. 249 pp.
- Wüster, W. & Broadley, D. G. (2007). Get an eyeful of this: a new species of giant spitting cobra from eastern and north-eastern Africa (Squamata: Serpentes: Elapidae: *Naja*). *Zootaxa* **1532**, 51–68.

APPENDIX

Table 1. Checklist of observed and expected taxa at the Koanaka Hills. Confirmed species include those recorded from Koanaka Hills or otherwise known from QDS 2021Aa (a maximum of ~20 Km distant from the Koanaka Hills) 1 = collected in 2008, 2 = collected in 1965, 3 = unvouchered record, 4 = literature record (see species accounts). Unless noted by an asterisk (*), taxa in the list of expected species were plotted with ranges including the Koanaka region by Branch (1998). Additional literature records including the Koanaka Hills in shaded range maps or from neighboring quarter degree squares are also indicated: Visser (1984c) [a], Auerbach (1987) [b], Broadley (1990) [c], Channing (2001) [d], Clauss & Clauss (2002) [e], Wüster & Broadley (2007) [f], as are Transvaal Museum specimens not previously cited in the literature (TM).

	Taxon	Confirmed	Expected
AMPHIBIA: ANURA			
Brevicipitidae	<i>Breviceps adspersus</i> Peters, 1882		d,e
Hyperoliidae	<i>Kassina senegalensis</i> (Duméril & Bibron, 1841)		e
Microhylidae	<i>Phrynomantis bifasciatus</i> (Smith, 1847)		d
Pyicephalidae	<i>Cacosternum boettgeri</i> (Boulenger, 1892)		TM
	<i>Tomopterna cryptotis</i> (Boulenger, 1907)		d,e
	<i>Tomopterna tandyi</i> Channing & Bogart, 1996		d
REPTILIA: TESTUDINES			
Pelomedusidae	<i>Pelomedusa subrufa</i> (Bonnaterre, 1789) ¹		e
Testudinidae	<i>Geochelone pardalis</i> (Bell, 1828)		e
	<i>Psammobates oculifera</i> Kuhl, 1820		e
REPTILIA: SQUAMATA: 'LACERTILIA'			
Agamidae	<i>Agama aculeata</i> Merrem, 1820	1,2	e
Amphisbaenidae	<i>Dalophia pistillum</i> (Boettger, 1895)		
	<i>Monopeltis anchietae</i> (Bocage, 1873)		
	<i>Monopeltis sphenorhynchus</i> Peters, 1879		e
	<i>Zygaspis quadrifrons</i> (Peters, 1862)		
Chamaeleonidae	<i>Chamaeleo dilepis</i> Leach, 1819	1	e
Gekkonidae	<i>Chondrodactylus turnerii</i> (Gray, 1864)	1	e
	<i>Lygodactylus capensis</i> (Smith, 1849)		TM
	<i>Pachydactylus capensis</i> (Smith, 1845)		
	<i>Pachydactylus punctatus</i> Peters, 1854		a
	<i>Ptenopus garrulus</i> (Smith, 1849)	3	e
Gerrhosauridae	<i>Gerrhosaurus multilineatus auritus</i> Boettger, 1887		a,b
Lacertidae	<i>Heliobolus lugubris</i> (Smith, 1838)	2	e
	<i>Ichnotropis capensis</i> (Smith, 1838)	1	
	<i>Ichnotropis squamulosa</i> Peters, 1854	1	
	<i>Pedioplanis namaquensis</i> (Duméril & Bibron, 1839)	1	*
Scincidae	<i>Lygosoma sundevalli</i> (Smith, 1849) ²		e
	<i>Trachylepis varia</i> (Peters, 1867)	1,2	
	<i>Trachylepis punctulata</i> (Bocage, 1872)		a,b
	<i>Trachylepis wahlbergii</i> (Peters, 1869)	1,2	e
	<i>Typhlacontias rohani</i> Angel, 1923 ³		
	<i>Typhlosaurus lineatus</i> Boulenger, 1887		
Varanidae	<i>Varanus albigularis</i> (Daudin, 1802)		e

Table 1. cont.

REPTILIA: SQUAMATA: SERPENTES

Leptotyphlopidae	<i>Leptotyphlops scutifrons</i> (Peters, 1854)		e
Typhlopidae	<i>Rhinotyphlops boylei</i> (FitzSimons, 1932)		
Colubridae	<i>Dasypeltis scabra</i> (Linnaeus, 1758)		e
	<i>Telescopus semiannulatus</i> Smith, 1849		e
Lamprophiidae ⁴	<i>Amblyodipsas ventrimaculata</i> Roux, 1907		
	<i>Atractaspis bibronii</i> Smith, 1849		e
	<i>Xenocalamus bicolor</i> Günther, 1868		e
	<i>Lamprophis capensis</i> (Duméril, 1854) ⁵		e
	<i>Psammophis jallae</i> Peracca, 1896		b
	<i>Psammophis mossambicus</i> Peters, 1882		*,e
	<i>Psammophis subtaeniatus</i> Peters, 1881		b,e, TM
	<i>Psammophis trinasalis</i> Werner, 1902	3,4	
	<i>Psammophylax tritaeniatus</i> (Günther, 1868)		
	<i>Pseudaspis cana</i> (Linnaeus, 1758)		e, TM
Elapidae	<i>Aspidelaps scutatus</i> (Smith, 1849)		c
	<i>Dendroaspis polylepis</i> (Günther, 1864)	3	*, e
	<i>Elapsoidea sundevallii fitzsimonsi</i> Loveridge, 1944		b,c
	<i>Naja anchietae</i> Bocage, 1879 ⁶		e
	<i>Naja mossambica</i> Peters, 1854		b,f
Viperidae	<i>Bitis arietans</i> Merrem, 1820	1	e

¹ See Savage (2003) and ICZN (2005) for discussion of authorship of this species.

² This species is sometimes allocated to the genus *Mochlus*.

³ Mapped in the Koanaka region by Branch (1998) as *Typhlacontias brevipes* (Fitzsimons, 1938). See Haacke (1997).

⁴ We here follow Vidal et al. (2007; 2008) in recognizing the Lamprophiidae, including snakes assigned by other authors to the Psammophiidae and Atractaspidae (e.g., Kelly et al., 2007).

⁵ Mapped in the Koanaka region by Branch (1998) and Clauss & Clauss (2002) as *Lamprophis fuliginosus* (Boie, 1827). See Hughes (1997).

⁶ Mapped in the Koanaka region by Branch (1998) and Clauss & Clauss (2002) as *Naja annulifera*. See Broadley & Wüster (2004).