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# Diversity and distribution of amphibians and reptiles in Gashaka Gumti National Park, Nigeria

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**Abstract.** Gashaka Gumti National Park (GGNP), the largest national park in Nigeria, is located within the northernmost extension of Africa's Gulf of Guinean rain forest. Studies providing information on the diversity and distribution of herpetofauna are vital for understanding local biodiversity and influencing guidelines for conservation. Therefore, the present study was aimed to compile an inventory of herpetofauna of GGNP and compare patterns of distribution across habitats. Herpetological collection was carried out between 21 August to 25 September 2017, through visual encounter, opportunistic observation and non-lethal pitfall trap array. Literature data and previous herpetological records of GGNP were used to complement the species inventory. A total of 44 species including 18 amphibian and 26 reptile species were documented. Diversity analyses showed that forest and savannah regions of GGNP harbour high diversity and abundance of herpetofauna compared to wetland/swampy areas and agricultural fields. Our study improves knowledge of herpetofauna diversity and distribution of the region. Finally, we offer recommendation for the protection of habitats associated with high herpetofauna diversity.

**Keywords.** Sub-Saharan African, Guineo-Congolian forest, herpetofauna, biodiversity, species richness, habitat, threats

## Introduction

Nigeria is located within the Guinean rain forest (GRF) biodiversity hotspot of West Africa. From a biogeographic point of view, Nigeria is located between West and Central Africa (Bakarr et al., 2004). Thus, the country is situated between the biodiversity hotspots of the Upper and Lower Guinea forest regions (Bakarr et al., 2004). Consequently, Nigeria harbours high biodiversity and endemism consisting of both West and Central African species (Onadeko and Rödel, 2009). It comprises of highly diverse ecosystems ranging from savannah, montane to rain forest vegetation (Mohammed et al., 2013). Its ecosystems, thus, host one of the richest herpetofauna of the GRF region.

Many contributions to the knowledge of the country's herpetofauna date back to the 1960s (Dunger, 1967a,b, 1968; Schiøtz, 1963, 1966; Walker, 1966, 1967, 1968, 1969) or even earlier (Romer, 1953). However, in the last twenty years, there has been increase of studies on Nigerian herpetofauna (e.g. Luiselli et al., 1998, 2005, 2007; Akani et al., 1999, 2004, 2014a,b; Akani and Luiselli, 2009; Onadeko and Rödel, 2009; Amuzie and Akani, 2017; Ozemoka and Aisien, 2017; Nneji et al., 2018 to mention a few). Current record indicates 116 amphibian and 205 reptile species from Nigeria (AmphibiaWeb, 2018; Nneji et al., 2018, Uetz et al., 2018, Nneji et al., 2019a). In addition, about 18 endemic anuran species are known to occur marginally in the highlands of southern Nigeria (Onadeko and Rödel, 2009).

Despite the growing trend of herpetological studies in Nigeria, there is paucity of data on herpetofauna within some of its protected areas, particularly from the eastern region. Our study area, Gashaka Gumti National Park (GGNP), is the largest national park located in

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eastern Nigeria. Notwithstanding being a key area for biodiversity conservation, little is known about its herpetofauna. In recent times, there have been increases in human activities such as overgrazing, bush burning, deforestation and poaching within the park (Mohammed et al., 2013). These activities threaten the survival of amphibians and reptiles (Thompson and Donnelly, 2018). Thus, it is necessary to document the diversity and distribution of the herpetofauna of GGNP for improved conservation plans and management policies.

Herein, we present the results of our surveys and previous data on the herpetofauna of GGNP. The objectives of our study are to: (1) fill the gap in the inventory of amphibians and reptiles of GGNP; and (2) compare the patterns of distribution of herpetofauna across different habitats of GGNP. Our study draws attention on the major threats to herpetofauna of GGNP and further offers recommendations for improved conservation and management policies.

**Materials and Methods**

*Study area.*—GGNP is located within the northernmost extension of Africa's Gulf of Guinean rain forest. It lies between latitude 06º58ˈand 08º05ˈN, and longitude 11º10ˈN and 12º13ˈE. It is located along eastern border highlands on the Cameroon volcanic line (Udo, 1970; Dunn, 1999). It occupies an area of about 6,713 km$^2$ (about 30.20% of the entire area of national parks in Nigeria). The park is comprised of northern (Gumti) and southern (Gashaka) sectors whose topography, climate and vegetation are distinctively different. For instance, while the northern part is relatively flat and covered with woodlands and grasslands, the southern part is mountainous and has vast expanses of rainforests (Dunn, 1999). The altitude of the GGNP ranges from 450 m above sea level (a.s.l.) in the northern sector, to the peaks and pinnacles (2,400 m a.s.l.) of Gangirwal in the southern sector (Dunn, 1999). The park encompasses most of the catchment of the Taraba River, which is the largest tributary of Benue River, the second largest river in Nigeria (Dunn, 1999).

*Sampling sites.*—The sampling procedures and protocols followed strictly ethical approval issued by National Park Service Headquarters, Abuja, Nigeria. We conducted a herpetological survey in rainy season from 21 August – 25 September 2017, with the help of 18 park rangers at GGNP. We selected 11 sampling stations (Fig. 1) covering 58 sampling localities (Appendix 1).

*Site classification.*— Based on the vegetation type, we stratified habitats into four categories as follows: (1) savannah: grassland characterized by few scattered tropical, broadleaved, deciduous trees (House et al., 2003; Baudena et al., 2015); (2) wetland/swamp: an area of lowland forest partially or intermittently covered with water (Olalekan et al., 2014); (3) forest: a large area dominated mainly by tropical, broadleaved, evergreen trees with few grasses/shrubs (Baudena et al., 2015); and (4) agricultural field/fallowed farmlands: an area of land used for cultivating crops including fallow and arable land (Onadeko, 2016).

*Sampling and species identification.*—Diurnal (06:00–09:00) and nocturnal (18:00–20:00) searches were conducted by aid of visual encounter surveys and opportunistic observations following methods described by Rödel and Ernst (2004). Each sampling station was searched daily (diurnal and nocturnal) for three hours per search by a team of three persons each. The total sampling effort per station for 35 days was 210 man-hours of active searching. Additionally, we randomly chose different strategic localities that could harbour herpetofauna within our sampling stations. We installed non-lethal pitfall trap arrays with drift fences and traps for seven days at strategic localities within each of the 11 sampling sites, and continuously monitored them at two-day intervals during the sampling period.

On sighting of herpetofauna, we recorded information such as habitat type and geographic coordinates. Geographic coordinates were determined with a Garmin GPS 72 and coordinates were recorded as latitude and longitude in decimal degrees. Though sightings were recorded, we did not collect herpetofauna such as chameleons but documented as well as took photographs of the animal. All captured individuals were contained in perforated plastic buckets containing fresh leaves until the search was terminated. We took digital photographs of representatives of all captured species. Subsequently, we released most specimens at about 50 m away from the capture area to avoid recapture, but some were collected as reference materials. We euthanised voucher specimens humanely using hydrous chlorobutanol (for amphibians) and tricaine methanesulfonate (for reptiles). We collected tissue (muscles/liver) samples from voucher specimens that were subsequently stored in 95% ethanol. We fixed the voucher specimens with 4% formalin and then transferred it to 75% ethanol for long-term storage. We deposited the vouchers and tissue samples in the museums of the Department of Zoology, University of Ibadan and Gashaka Gumti National

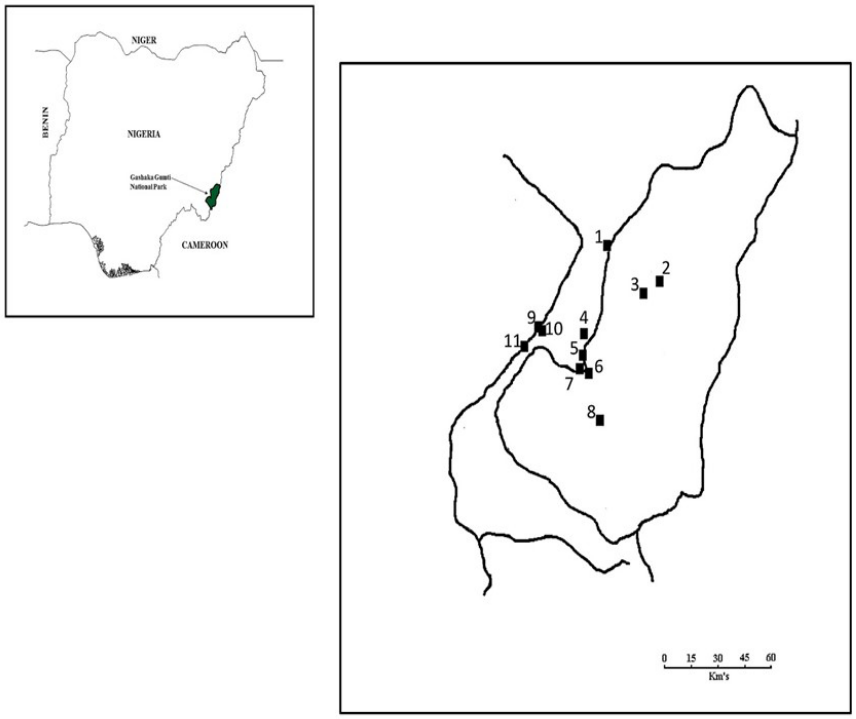


**Figure 1**. Map showing the sampling stations within Gashaka Gumti National Park, Nigeria. (1) Adagoro, (2) Gumti, (3) Lagaso, (4) Mayo Yim, (5) Tonga, (6) Bat Forest, (7) Gashaka, (8) Kwano, (9) Serti, (10) Dadun Kowa, and (11) Bodel.

Park, Nigeria. Species sampling information including sampling localities, number observed and collected, and voucher specimen number (s) are shown in Appendix 2.

We identified specimens to species level using following literatures: Romer (1953); Schiøtz (1963); Walker (1967); Dunger (1967a,b, 1968); Walker (1968); Perret and Amiet (1971); Perret (1977); Hoogmoed (1974); Hughes (1983); Branch (1988); Butler and Reid (1990); Reid et al. (1990); Schiøtz (1999); Rödel (2000); Chippaux (2006); Trape and Mediannikov (2016) and Mediannikov et al. (2012). Thereafter, we sought for additional species verifications from David C. Blackburn at Florida Museum of Natural History, University of Florida, Gainesville, Florida, USA. We further confirmed species' identity by DNA barcoding approximately 550 bp of the mitochondrial 16S rRNA gene following the methods described by Nneji et al. (2019b). Using combined taxonomic approach for species identification, specimens were classified and individuals with uncertain species level identification were referred to its genus.

In addition, we reviewed primary publication (Reeder et al., 2011) and unpublished report of fauna in GGNP for obtaining names of other existing herpetofauna of GGNP. However, we omitted records of individuals with uncertain taxonomic classifications from our checklist. Species nomenclature (scientific names) were in accordance with the AmphibiaWeb (AmphibiaWeb, 2018) and the Reptile Database (Uetz et al., 2018). Further, we assessed the conservation status of individuals identified to species level using the International Union for Conservation of Nature red list web interface (IUCN, 2018).

*Data analysis.*—Primary data (observational records) collected during our herpetological survey were used for the diversity analyses. The relative abundance (r), and Shannon – Weiner index (H'), Simpson index of diversity (1-D) and Margalef's index (d) as implemented in PAST (Hammer, 2011), were used to compare the species compositions within the different habitat types. Similarity of assemblage composition among habitats was evaluated using Sorensen's similarity index.

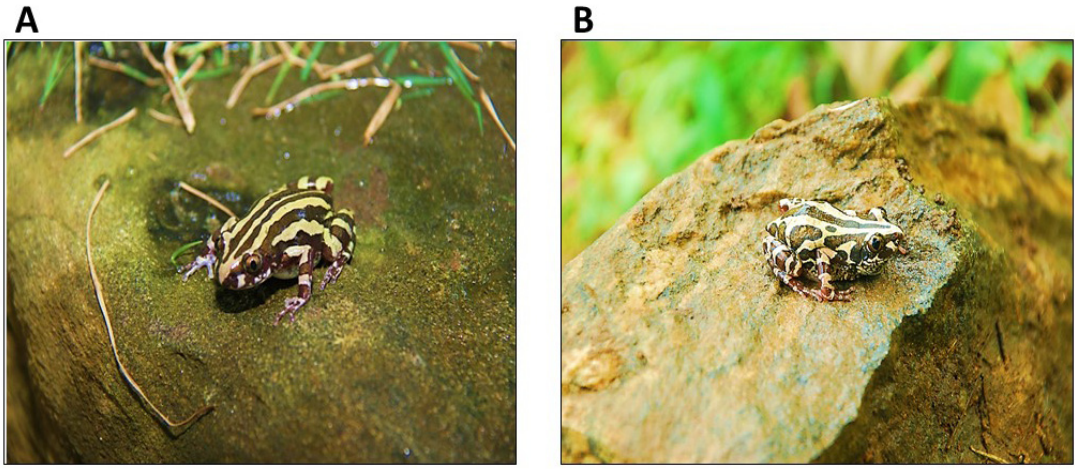


**Figure 2**: (A) *Kassina cassinoides* (Boulenger, 1903) (B) *Kassina senegalensis* (Dumeril and Bibron, 1841) from Gashaka Gumti National Park, Nigeria.

**Results**

*Species composition.*—A total of 44 species comprising 18 amphibian species (10 genera belonging to eight families) and 26 reptile species (12 genera distributed in 10 families) were documented (Table 1). The most diverse families of amphibians were Hyperoliidae (n = 4 species), Arthroleptidae (n = 3 species) and Ptychadenidae (n = 3 species) while the most diverse reptile families were Scincidae (n = 5 species) and Lamprophiidae (n = 4 species; Table 1).

The results of the DNA barcoding showed that species morphologically identified as *Hoplobatrachus occipitalis* (Gunther, 1858), *Leptopelis nordequatorialis* (Perret, 1966), *Kassina senegalensis* (Dumeril and Bibron, 1841), *Amnirana galamensis* (Dumeril and Bibron, 1841), *Sclerophrys maculata* (Hallowell, 1855), *Sclerophrys regularis* (Reuss, 1833), *Ptychadena bibroni* (Hallowell, 1845), *Ptychadena pumilio* (Boulenger, 1920), *Ptychadena longirostris* (Peters, 1870), *Xenopus fischbergi* (Evans et al. 2015), *Xenopus tropicalis* (Gray, 1864), *Agama agama* (Linnaeus, 1758), *Agama parafricana* (Trapé et al., 2012), *Trachylepis perrotetii* (Duméril and Bibron, 1839), *Trachylepis affinis* (Gray, 1838), *Trachylepis maculilabris* (Gray, 1845), *Trachylepis quinquetaeniata* (Lichtenstein, 1823), *Chamaeleo gracilis* (Hallowell, 1844), *Varanus niloticus* (Linnaeus, 1758), *Psammophis lineatus* (Duméril et al., 1854), *Boadeon paralineatus* (Trape and Mediannikov, 2016) and *Boadeon perisilvestris* (Trape and Mediannikov, 2016) formed 16S clade with others of same species in GenBank, and thus, species names were maintained as valid. Additionally, individuals morphologically identified as *Hemidactylus* sp., *Lycophidion* sp. and *Python* sp. formed distinct 16S clades but were more closely related genetically to *Hemidactylus frenatus* (Gray, 1845), *Lycophidion laterale* (Hallowell, 1857) and *Python sebae* (Gmelin, 1788) respectively than it is to any other species. However, we referred these species to genera level pending detail morphological and genetic studies. Our genetic analyses could not ascertain the species level assignment of *Hyperolius concolor* (Hallowell, 1844) and *Hyperolius* sp. from GGNP and following phenetic analyses, they were referred as *Hyperolius* cf. *concolor* and *Hyperolius* cf. *viridiflavus* respectively pending further taxonomical identification. Further, morphologically unidentified *Leptopelis* sp. was identified as *Leptopelis aubryi* (Duméril, 1856) following tree-based identification approach.

One anuran species (*Kassina cassinoides* Boulenger, 1903; Fig. 2) represents a new record for Nigeria, extending this species' geographic distribution west by approximately 120 km from its nearest location in Northern Cameroon. This species was identified morphologically by its grey coloration with five longitudinal stripes on its dorsum. *Kassina cassinoides* is easy to separate from the sympatric *Kassina senegalensis* (Dumeril and Bibron, 1841) which is smaller in size and without a double dorsal stripe (Schiøtz, 1999).

**Table 1.** Herpetofauna recorded at Gashaka Gumti National Park Nigeria.

| Family | Scientific Name | Habitat | Record | Reference | IUCN Red List | Nigeria Protected Schedule |
|---|---|---|---|---|---|---|
| **Amphibians** | | | | | | |
| **Arthroleptidae** | | | | | | |
| | *Cardioglossa leucomystax* (Boulenger, 1903) | F | PR | Reeder et al. (2011) | LC | NL |
| | *Leptopelis aubryi* (Duméril, 1856) | F | NR | This study | NA | NA |
| | *Leptopelis nordequatorialis* (Perret, 1966) | F | NR | This study | LC | NL |
| **Bufonidae** | | | | | | |
| | *Sclerophrys maculata* (Hallowell, 1855) | S, F | NR | This study | LC | NL |
| | *Sclerophrys regularis* (Reuss, 1833) | S, F | NR | This study | LC | NL |
| **Dicroglossidae** | | | | | | |
| | *Hoplobatrachus occipitalis* (Gunther, 1858) | S, F, AF | NR | This study | LC | NL |
| **Hyperoliidae** | | | | | | |
| | *Hyperolius* cf. *concolor* | F | NR | This study | NA | NA |
| | *Hyperolius* cf. *viridiflavus* | S, F | NR | This study | NA | NA |
| | *Kassina cassinoides* (Boulenger, 1903) | S | NR | This study | LC | NL |
| | *Kassina senegalensis* (Dumeril and Bibron, 1841) | S | NR | This study | LC | NL |
| **Ptychadenidae** | | | | | | |
| | *Ptychadena bibroni* (Hallowell, 1845) | S, F | NR | This study | LC | NL |
| | *Ptychadena longirostris* (Peters, 1870) | F | NR | This study | LC | NL |
| | *Ptychadena pumilio* (Boulenger, 1920) | S, F | NR | This study | LC | NL |
| **Ranidae** | | | | | | |
| | *Amnirana galamensis* (Dumeril and Bibron, 1841) | S | PR, NR | This study, Reeder et al. (2011) | LC | NL |
| **Phrynobatrachidae** | | | | | | |
| | *Phrynobatrachus cornutus* (Boulenger, 1906) | F | PR | Reeder et al. (2011) | LC | NL |
| | *Phrynobatrachus natalensis* (Smith, 1849) | S, F | PR | Reeder et al. (2011) | LC | NL |
| **Pipidae** | | | | | | |
| | *Xenopus fischbergi* (Evans et al. 2015) | SW | NR | This study | LC | NL |
| | *Xenopus tropicalis* (Gray, 1864) | F, SW | NR | This study | LC | NL |
| **Reptiles** | | | | | | |
| **Lizards** | | | | | | |
| **Agamidae** | | | | | | |
| | *Agama agama* (Linnaeus, 1758) | S, F, AF | PR, NR | This study, UR | LC | NL |
| | *Agama parafricana* (Trapé et al., 2012) | S | NR | This study | LC | NL |

**Table 1.** Continued.

| Family | Scientific Name | Habitat | Record | Reference | IUCN Red List | Nigeria Protected Schedule |
|---|---|---|---|---|---|---|
| **Chamaeleonidae** | | | | | | |
| | *Chamaeleo gracilis* (Hallowell, 1844) | S, F | NR | This study | LC | NL |
| **Gekkonidae** | | | | | | |
| | *Hemidactylus mabouia* (Moreau de Jonnès, 1818) | AF | PR | UR | NL | NL |
| | *Hemidactylus* sp. | AF, F, S | NR | This study | NA | NA |
| **Scincidae** | | | | | | |
| | *Panaspis togoensis* (Werner, 1902) | S | PR | Kadiri (2014) | LC | NL |
| | *Trachylepis affinis* (Gray, 1838) | S, F | PR, NR | This study, UR | LC | NL |
| | *Trachylepis maculilabris* (Gray, 1845) | F | PR, NR | This study, UR | LC | NL |
| | *Trachylepis perrotetii* (Duméril and Bibron, 1839) | S | PR, NR | This study, UR | LC | NL |
| | *Trachylepis quinquetaeniata* (Lichtenstein, 1823) | S | PR, NR | This study, UR | LC | NL |
| **Varanidae** | | | | | | |
| | *Varanus exanthematicus* (Bosc, 1792) | S, F, AF | PR | UR | LC | FS |
| | *Varanus niloticus* (Linnaeus, 1758) | S, F, AF | NR | This study | NL | FS |
| **Snakes** | | | | | | |
| **Elapidae** | | | | | | |
| | *Naja melanoleuca* (Hallowell, 1857) | S, F | PR, NR | This study, UR | NL | NL |
| | *Naja nigricollis* (Hallowell, 1857) | S, F, AF | PR | UR | NL | NL |
| **Lamprophiidae** | | | | | | |
| | *Boaedon paralineatus* (Trape and Mediannikov, 2016) | F | NR | This study | NL | NL |
| | *Boaedon perisilvestris* (Trape and Mediannikov, 2016) | F | NR | This study | NL | NL |
| | *Lycophidion* sp. | F | NR | This study | NA | NA |
| | *Psammophis lineatus* (Duméril et al., 1854) | AF | NR | This study | NL | NL |
| **Pythonidae** | | | | | | |
| | *Python regius* (Shaw, 1802) | S | PR | UR | LC | FS |
| | *Python sebae* (Gmelin, 1788) | S, F, AF | PR | UR | NL | FS |
| | *Python* sp. | F | NR | This study | NA | NA |
| **Viperidae** | | | | | | |
| | *Bitis arietans arietans* (Merrem, 1820) | S | PR | UR | NL | NL |
| | *Bitis gabonica rhinoceros* (Schlegel, 1855) | F | PR | UR | NL | NL |
| | *Causus maculatus* (Hallowell, 1842) | S, F, AF | PR | UR | NL | NL |

**Table 1.** Continued.

| Family | Scientific Name | Habitat | Record | Reference | IUCN Red List | Nigeria Protected Schedule |
|---|---|---|---|---|---|---|
| **Crocodiles** | | | | | | |
| **Crocodylidae** | | | | | | |
| | *Crocodylus suchus* (Geoffroy, 1807) | P | PR, NR | This study, UR | NL | NL |
| **Tortoise** | | | | | | |
| **Pelomedusidae** | | | | | | |
| | *Pelusios castaneus* (Schweigger, 1812) | SW | NR | This study | NL | NL |

*Note*:
i. Habitat classification: S = savannah, SW = swamp, F = forest, AF = Agricultural field, P = Pond;
ii. Record classification: PR = previously recorded by other studies, NR = newly recorded from our current survey;
iii. Reference: This study = our current herpetological surveys of GGNP, UR: Unpublished records from faunal list of GGNP.
iv. IUCN Red List: LC = Least Concern, NL = Not Listed, NA = Not assessed for individuals not identified to species level;
v. Nigeria Protected Schedule; NL = Not Listed; NA Not assessed for individuals not identified to species level; FS: Individuals listed as First Schedule (Animals in relation to which international trade is absolutely prohibited.

Among the herpetofauna species recorded during our field survey, *H. occipitalis*, *A. agama*, *Hemidactylus* sp. and *V. niloticus* were present in all four surveyed habitats. On the other hand, *L. aubryi*, *L. nordequatorialis*, *H.* cf. *concolor*, *T. maculilabris*, *B. paralineatus*, *B. perisilvestris*, *Lycophidion* sp. and *Python* sp. were forest specialists. Savannah specialists included *K. cassinoides*, *K. senegalensis*, *A. galamensis*, *A. parafricana*, *T. perrotetii* and *T. quinquetaeniata.* Species inhabiting both forest and savannah ecosystems were *H.* cf. *viridiflavus*, *S. maculata*, *S. regularis*, *P. bibroni*, *P. pumili*, *N. melanoleuca*, *C. gracilis* and *T. affinis*. We recorded *P. lineatus* only from an agricultural field.

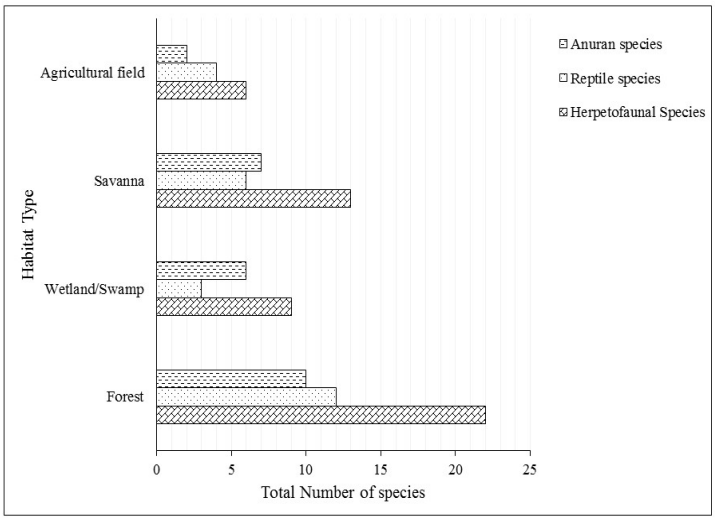


**Figure 3**. Total number of herpetofaunal species recorded in each of surveyed habitats in GGNP, Nigeria.

*Comparison of herpetofaunal diversity across habitat types*.—Herpetofaunal diversity varied among different habitats (Fig. 3, Tables 2–3). From our current survey, the highest anuran observational records were made from the forest (n = 58 individuals; r = 40.90%) while agricultural fields (n = 6 individuals; r = 4.20%) had the fewest amphibians (Table 2). High values of Simpson index of diversity (1-D), Shannon Weiner and Margalef indices (Table 2) indicated significantly higher levels of anuran diversities in the forest, wetland/swamp and savannah regions than in the agricultural fields. The highest similarity in species composition was found between forest and agricultural field (Sorensen's similarity index = 0.43), and the lowest similarity was found between forest and savannah (Sorensen's similarity index = 0.27).

Additionally, we observed that reptiles were more abundant in savannah (n = 61 individuals; r = 38.10%), although species richness was highest in forests (n = 12 species; r = 70.60%; (Table 3). Our result showed that forest and savannah regions were dominated mainly by lizards compared to other reptiles (Table 3). The diversity indices revealed consistent diversity patterns among habitats, that is, decreasing values of Simpson index of diversity, Shannon and Margalef indices from forest to wetland/swampy areas (Table 3). We observed higher similarity of reptile composition and diversity between forest and wetland/swamp, and forest and savannah (Sorensen's similarity index = 0.22), than between forest and agricultural field (Sorensen's similarity index = 0.17).

Further, our study classified the species encountered into three categories: Least Concern (25 species), Not Listed in IUCN red list (n = 13 species) and Not Assessed for Individuals with uncertain species level assignment (n = 6 species) (see Table 1).

**Table 2.** Observational Records and diversity analyses of anuran species encountered in each habitat type during the herpetological survey of Gashaka Gumti National Park, Nigeria.

| | | Number of individuals observed | | | |
|---|---|---|---|---|---|
| **Anuran species** | Total Records | Forest | Wetland/Swamp | Savannah | Agricultural field |
| *Hoplobatrachus occipitalis* | 57 | 23 | 12 | 17 | 5 |
| *Hyperolius* cf. *concolor* | 5 | 5 | 0 | 0 | 0 |
| *Hyperolius* cf. *viridiflavus* | 4 | 3 | 0 | 1 | 0 |
| *Kassina cassinoides* | 3 | 0 | 0 | 3 | 0 |
| *Kassina senegalensis* | 2 | 0 | 0 | 2 | 0 |
| *Leptopelis aubryi* | 3 | 3 | 0 | 0 | 0 |
| *Leptopelis nordequatorialis* | 4 | 4 | 0 | 0 | 0 |
| *Ptychadena bibroni* | 9 | 9 | 0 | 0 | 0 |
| *Ptychadena longirostris* | 3 | 3 | 0 | 0 | 0 |
| *Ptychadena pumilio* | 3 | 3 | 0 | 0 | 0 |
| *Amnirana galamensis* | 20 | 0 | 8 | 12 | 0 |
| *Sclerophrys maculata* | 6 | 1 | 3 | 2 | 0 |
| *Sclerophrys regularis* | 15 | 4 | 2 | 8 | 1 |
| *Xenopus fischbergi* | 4 | 0 | 4 | 0 | 0 |
| *Xenopus tropicalis* | 4 | 0 | 4 | 0 | 0 |
| Number of individuals observed | 142 | 58 | 33 | 45 | 6 |
| Relative Abundance (%) | | 40.90 | 23.20 | 31.70 | 4.20 |
| Total number of species (S) | 15 | 10 | 6 | 7 | 2 |
| Simpson index of diversity (1-D) | | 0.791 | 0.768 | 0.746 | 0.28 |
| Shannon weiner (H) | | 1.919 | 1.611 | 1.569 | 0.45 |
| Margalef index (d) | | 2.217 | 1.43 | 1.576 | 0.56 |

**Table 3.** Observational Records and diversity analyses of reptile species encountered in each habitat type during the herpetological survey of Gashaka Gumti National Park, Nigeria.

| Group | Species | Number of Individuals Observed | | | | |
|---|---|---|---|---|---|---|
| | | Total Record | Forest | Wetland/Swamp | Savannah | Agricultural field |
| Lizards | | | | | | |
| | *Agama agama* | 46 | 21 | 5 | 8 | 12 |
| | *Agama parafricana* | 24 | 2 | 0 | 22 | 0 |
| | *Chamaeleo gracilis* | 4 | 4 | 0 | 0 | 0 |
| | *Trachylepis affinis* | 3 | 1 | 0 | 1 | 1 |
| | *Trachylepis perrotetii* | 5 | 0 | 0 | 5 | 0 |
| | *Trachylepis maculilabris* | 9 | 9 | 0 | 0 | 0 |
| | *Trachylepis quinquetaeniata* | 12 | 0 | 0 | 12 | 0 |
| | *Hemidactylus* sp | 31 | 7 | 0 | 13 | 11 |
| | *Varanus niloticus* | 1 | 1 | 0 | 0 | 0 |
| | Total | 135 | 45 | 5 | 61 | 24 |
| | Relative Abundance (%) | 84.40 | 33.30 | 3.70 | 45.20 | 17.80 |
| Snakes | | | | | | |
| | *Boaedon paralineatus* | 2 | 2 | 0 | 0 | 0 |
| | *Boaedon perisilvestris* | 1 | 1 | 0 | 0 | 0 |
| | *Lycophidion* sp | 7 | 7 | 0 | 0 | 0 |
| | *Psammophis lineatus* | 1 | 0 | 0 | 0 | 1 |
| | *Naja melanoleuca* | 1 | 1 | 0 | 0 | 0 |
| | *Python* sp | 1 | 1 | 0 | 0 | 0 |
| | Total | 13 | 12 | 0 | 0 | 1 |
| | Relative Abundance (%) | 8.10 | 92.30 | 0 | 0 | 7.70 |
| Crocodile | | | | | | |
| | *Crocodylus suchus* | 1 | 0 | 1 | 0 | 0 |
| Tortoise | | | | | | |
| | *Pelusios castaneus* | 11 | 0 | 11 | 0 | 0 |
| | Number of individuals observed | 160 | 57 | 17 | 61 | 25 |
| | Individual relative abundance (%) | | 35.6 | 10.60 | 38.1 | 15.6 |
| | Total number of species (S) | 17 | 12 | 3 | 6 | 4 |
| | Simpson index of diversity (1-D) | | 0.793 | 0.491 | 0.762 | 0.572 |
| | Shannon weiner (H) | | 1.896 | 0.808 | 1.555 | 0.971 |
| | Margalef index (d) | | 2.484 | 0.706 | 1.211 | 0.932 |

## Discussion

With a total of 44 amphibian and reptile species, our study presents a more comprehensive inventory of herpetofauna of GGNP. Previous herpetological surveys of GGNP recorded anuran species of the genera *Astylosternus*, *Leptodactylodon* and *Petropedetes* (Reeder et al., 2011) and reptile species previously documented in GGNP such as *Panaspis togoensis* (Werner, 1902), *Hemidactylus mabouia* (Moreau de Jonnès, 1818), *Varanus exanthematicus* (Linnaeus, 1758), *Naja nigricollis* (Hallowell, 1857), *Bitis arietans arietans* (Merrem, 1820), *Bitis gabonica rhinoceros* [= *B. rhinoceros*] (Schlegel, 1855) and *Causus maculatus* (Hallowell, 1842). However, none of these species was recorded during our field study. Their absence from our survey may not necessarily indicate absence of such species, but rather that they are secretive and/or

difficult to find. Further, we only surveyed during the rainy season, and seasonality could have some effect on the abundance of herpetofauna. Hence, long-term herpetological survey of GGNP is warranted.

We documented a total of 18 anuran species from GGNP. This anuran diversity is apparently less compared to some other parts of Nigeria. For instance, anuran species richness observed in south-western Nigeria (35–38 species; Onadeko and Rödel, 2009), and southern/south-eastern Nigeria such as forest swamp areas of the River Niger Delta (28 species; Akani et al., 2004) and forest areas of Ikpan wetland (27 species; Eniang and Luiselli, 2002). In addition, anuran species composition of GGNP was less when compared to Mountain (Mt.) Kupe (72 species; Portik et al., 2016), Korup National Park (88 species; Lawson 1993), Mt. Manengouba (89 species; Hirschfeld et al. 2016) and Mt. Nlonako (93 species; Herrmann et al. 2005a) of Cameroon. In contrast, the anuran species richness of GGNP was higher when compared with species richness recorded in some parts of south-eastern Nigeria, e.g. Finima Nature Park (8 species; Akani and Luiselli, 2009), Edumanon Forest Reserve (9 species; Akani et al., 2014b), Agbada and Rumuesara communities (14 species; Amuzie and Akani, 2017), Agbede community (16 species; Ozemoka and Aisien, 2017),and Tchabal Mbabo Mt., Adamaoua Plateau in Cameroon (14 species; Herrmann et al. 2006). The presence of greater anuran diversities in some forest blocks of western and southern Nigeria, and Cameroon may be attributed to the presence of intact and relatively undisturbed primary rainforests which harbour diverse anuran species. However, further study investigating plausible reasons for the dramatic population declines of anurans from eastern Nigeria compared to other regions in Nigeria and nearby Cameroon appears necessary. Also, continuous herpetological surveys of GGNP may be vital to uncover additional species.

The reptile species diversity in GGNP (26 species) was lower when compared with Edumanon Forest Reserve (31 species; Akani et al., 2014b), Upper Orashi Forest Reserve (34 species; Akani et al., 2014a) and Ikpan wetland rainforest (46 species; Eniang and Luiselli, 2002) of southern/south-eastern Nigeria. In addition, the reptile species composition of GGNP (26 reptile species) was less when compared to nearby Mt. Kupe (36 species; Portik et al., 2016), Takamanda Forest Reserve (71 species; LeBreton et al., 2003); Korup National Park (83 species; Lawson, 1993), Mt. Cameroon (86 species; Gonwouo et al., 2006) and Mt. Nlonako (89 species; Herrmann et al., 2005b) in Cameroon. On the other hand, the snake diversity observed in this present study (12 species) was like that observed in Niger Delta, southern Nigeria (12 species; Akani et al., 2008), but lower compared to diversity in the forest-derived habitats of Eket territories (18–24 snake species; Akani et al., 1999). Our study also showed that reptile species richness observed in GGNP was higher when compared with species richness recorded in some parts of south-eastern Nigeria e.g. Finima Nature Park (21 species; Akani and Luiselli, 2009) and coastal barrier island of Brass (23 species; Akani et al., 2014b) and Tchabal Mbabo Mt. in nearby Cameroon (15 species; Herrmann et al., 2006). Sampling during the rainy season likely affected the diversity of reptiles recorded in this area. Additional species may still occur in GGNP but were not uncovered during our herpetological survey due to factors such as time constraints and season.

Some of the herpetofauna we found at GGNP were not surprising, given their occurrence in a broad variety of habitats and wide distribution throughout Guineo-Congolian forest blocks that extends from West to Central Africa. For instance, we documented species such as *Cardioglossa leucomystax* (Boulenger, 1903), *L. nordequatoralis*, *K. cassinoides*, *Xenopus tropicalis* (Gray, 1864), *A. agama* and *A. parafricana* known primarily from Guineo-Congolian forest blocks. In addition, our collection of *K. cassinoides* is regarded as new for the area and therefore represent range extension in Nigeria. Previously, its distribution was thought to span across Senegal, the Gambia, Mali, Burkina Faso, Ivory Coast, Ghana, Togo, Benin and Cameroon. Our current observation, in accordance with the findings of Nneji et al. (2018; 2019a), supports the biogeographic relatedness for Nigerian herpetofauna with others from lower Guineo-Congolian forest due to shared environmental and climatic factors.

Habitat type and preference are one of the major factors responsible for the distribution and diversity of tropical herpetofauna (Onadeko, 2016). Considering our diversity analyses, forest and savannah regions of GGNP were more favourable habitats for amphibians and reptiles than wetland/swampy areas and agricultural fields. The observed pattern of habitat preference for herpetofauna of GGNP is in agreement with previous studies carried out in tropical Africa (e.g. Akani et al., 1999, 2004, 2014a,b; Leaché et al. 2006; Wells, 2007; Onadeko and Rödel, 2009; Onadeko, 2016). This is certainly linked to herpetofaunal preference for intact forest and savannah for reproduction, feeding and

survival. Consistent with Onadeko (2016), the reduction in herpetofaunal species in agricultural fields could be the result of the negative effects of habitat destruction and the use of chemicals on species' survival, diversity and abundance. On the other hand, fewer individuals reported in the wetland/swampy areas may be attributed to the marshy nature of the area which made the visual encounter method and collections difficult. In addition, our data is insufficient to explain if the observed pattern of herpetofaunal habitat preference depends on seasonality.

In terms of threats to herpetofauna, our recent surveys revealed that a majority of the herpetofauna in GGNP are closely associated with forest habitats threatened by deforestation, slash and burn agricultural practices, habitat conversion and logging. It has been shown that amphibians are sensitive to comparatively minor forest degradation (Ernst and Rödel, 2005; and Ernst et al., 2006). Thus, any destruction to the associated habitats (such as clearing of the forest or illegal cutting down of trees) of these herpetofaunal species, could have devastating effects on the population's status and survival. During our field work at GGNP, some of the local people were involved in illegal cutting down of trees and the use of chemicals (e.g. fertilizer, pesticides) in farming within the protected area. While our studies do not document the population status of the herpetofauna in the threatened ecosystems, human encroachment together with the illegal logging and use of chemicals for agriculture pose a significant threat to herpetofaunal communities. Hence, successful conservation of amphibians and reptiles of GGNP will equate to protecting its associated habitat.

Our study showed that most species (n = 25 species) encountered in GGNP were listed as Least Concern by IUCN. However, following the ranking of the Federal endangered species lists of Nigeria (Act 11 of 1985 Schedules 1 and 2), GGNP is inhabited by four (4) herpetofaunal species (*V. niloticus*, *V. examthematicus*, *Python regius* Shaw, 1802 and *Python sebae* Gmelin, 1788) falling into the Schedule 1 category that includes animals that should not be removed by anybody and in which international trade is absolutely prohibited. None of the herpetofaunal species recorded in GGNP falls into Schedule 2, which includes species that could be taken or traded with permits from appropriate wildlife authorities. Hence, the presence of some species of conservation concern and increased anthropogenic activities within the park have drawn more attention to GGNP as an important and potentially threatened protected area in Nigeria that deserves attention. We recommend further biodiversity and ecological studies to ascertain the current status of species not listed by IUCN Red List, including the new unidentified species.

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**Appendix 1.** Geographic coordinates and habitat type at each sampling locality in Gashaka Gumti National Park, Nigeria.

| Station | Sampling locality | Geographic co-ordinates | | Habitat |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| **Adagoro** | | | | |
| | AD1 | 11.34433 | 7.43286 | Forest |
| | AD2 | 11.34085 | 7.43653 | Forest |
| | AD3 | 11.34356 | 7.43434 | Grassland |
| | AD4 | 11.34424 | 7.43306 | Lowland forest |
| | AD5 | 11.34433 | 7.43286 | Forest |
| | AD6 | 11.34491 | 7.43426 | Lowland forest |
| | AD7 | 11.34497 | 7.43438 | Humid forest with pond |
| | AD8 | 11.34505 | 7.43447 | Secondary forest |
| | AD9 | 11.34624 | 7.43394 | Lowland forest with few grasses |
| | AD10 | 11.35046 | 7.42047 | Forest |
| | AD11 | 11.35250 | 7.42999 | Forest |
| **Bodel** | | | | |
| | BO1 | 11.18480 | 7.26864 | Grassland |
| | BO2 | 11.18515 | 7.26859 | Forest with few grasses |
| | BO3 | 11.18516 | 7.26861 | Grassland |
| | BO4 | 11.18529 | 7.26928 | Grassland |
| | BO5 | 11.18601 | 7.267621 | Forest |
| | BO6 | 11.18638 | 7.26895 | Grassland |
| | BO7 | 11.18645 | 7.26851 | Grassland |
| | BO8 | 11.18681 | 7.268561 | Grassland |
| **Dadun Kowa** | | | | |
| | DK1 | 11.21662 | 7.20282 | Grassland |
| | DK2 | 11.21658 | 7.30219 | Grassland |
| **Gashaka** | | | | |
| | GS1 | 11.48562 | 7.365955 | Wetland/swampy area |
| | GS2 | 11.49125 | 7.36422 | Forest |
| | GS3 | 11.49136 | 7.37201 | Grassland |
| | GS4 | 11.49182 | 7.37212 | Humid forest |
| | GS5 | 11.49197 | 7.37222 | Forest |
| | GS6 | 11.49211 | 7.3751 | Forest |
| | GS7 | 11.49219 | 7.37187 | Grassland |
| | GS8 | 11.4945 | 7.36994 | Lowland forest |
| | GS9 | 11.49495 | 7.36931 | Lowland forest |
| **Gumti** | | | | |
| | GM1 | 11.39272 | 7.46026 | Moist forest |
| | GM2 | 11.39282 | 7.46053 | Wetland/swamps |
| **Kwano** | | | | |
| | KW1 | 11.46533 | 7.38859 | Forest |
| | KW2 | 11.58385 | 7.32981 | Forest |
| | KW3 | 11.58395 | 7.32957 | Forest |
| | KW4 | 11.58429 | 7.32884 | Forest |
| **Lagosa** | | | | |
| | LG1 | 11.34722 | 7.41331 | Forest |
| | LG2 | 11.35046 | 7.42047 | Forest |

**Appendix 1.** Continued.

| Station | Sampling locality | Geographic co-ordinates | | Habitat |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| | LG3 | 11.3514 | 7.41498 | Forest |
| | LG4 | 11.35219 | 7.41557 | Forest |
| **Serti** | | | | |
| | SR1 | 11.20538 | 7.29535 | Grassland with a pond |
| | SR2 | 11.21041 | 7.29871 | Grassland |
| | SR3 | 11.214 | 7.29892 | Agricultural field |
| | SR4 | 11.21541 | 7.30609 | Savannah |
| | SR5 | 11.21545 | 7.30618 | Agricultural field |
| | SR6 | 11.21657 | 7.30280 | Agricultural field |
| | SR7 | 11.21661 | 7.30283 | Agricultural field |
| | SR8 | 11.21669 | 7.30289 | Agricultural field |
| | SR9 | 11.2251 | 7.30523 | Agricultural field |
| | SR10 | 11.22561 | 7.30512 | Agricultural field |
| | SR11 | 11.22654 | 7.30490 | Agricultural field |
| | SR12 | 11.34433 | 7.43286 | Agricultural field |
| | SR13 | 11. 2235 | 7.30508 | Grassland |
| **Bat Forest** | | | | |
| | BF1 | 11.49481 | 7.36942 | Forest |
| | BF2 | 11.5092 | 7.35194 | Forest |
| **Mayo-Yim** | | | | |
| | MY1 | 11.19104 | 7.28028 | Lowland hilly areas with few trees near River Yim |
| | MY2 | 11.34722 | 7.41331 | Lowland hilly areas with few trees near River Yim |
| **Tonga** | TN1 | 11.1776 | 7.26284 | Secondary forest with grasses and few trees |

**Appendix 2.** Species sampling information including sampling localities, number observed and collected, and voucher specimen number (s).

| Species | Sampling Localities | Number observed | Number collected | Voucher specimen Number |
|---|---|---|---|---|
| **Amphibians** | | | | |
| *Leptopelis aubryi* | AD1, AD5, AD6 (not collected but observed at AD1). | 3 | 2 | DZ_UI170066–67 |
| *Leptopelis nordequatorialis* | AD4, AD5 (observed but not collected from AD5). | 4 | 1 | DZ_UI170068 |
| *Sclerophrys maculata* | GS1, GS4, GS9, KW3, KW4, (not collected but observed at GS1 and KW4). | 6 | 5 | GGNPA066–70 |
| *Sclerophrys regularis* | AD1, AD2, AD9, AD13, LG1, LG2, LG4 (not collected but observed at AD1, AD2, AD13, LG1 and LG4). | 15 | 8 | GGNPA071–77 |
| *Hoplobatrachus occipitalis* | AD1–11, GM1, KW1, KW3, KW4, LG2, LG4, SR3, SR4, SR5, SR6, SR7, SR8, SR9, SR10, SR11, SR12, SR13 (not collected but observed at AD3, AD5, AD6, AD8, AD9, KW4, SR5, SR6, SR7, SR8, SR9, SR10 and SR13). | 57 | 18 | DZ_UI170039–56 |
| *Hyperolius* cf. *concolor* | AD10, BO5, LG2, LG3, LG4 (not collected but observed at LG2 and LG3) | 5 | 1 | GGNPA043 |
| *Hyperolius* cf. *viriflavus* | LG1, LG2, LG3, LG4 (not collected but observed at LG3) | 4 | 3 | GGNPA043–44 |
| *Kassina cassinoides* | KW3, SE2, SE4 (not collected but observed at KW3) | 3 | 2 | DZ_UI170197–198 |
| *Kassina senegalensis* | BO3, BO5 (not collected but observed at BO3) | 2 | 1 | GGNPA049 |
| *Ptychadena bibroni* | AD2, BO2, BO5, SR2 (not collected but observed at SR2) | 9 | 4 | GGNPA051–054 |
| *Ptychadena longirostris* | AD9, GM1, GM2 (not collected but observed at GM1) | 3 | 3 | GGNPA055–56 |
| *Ptychadena pumilio* | AD9, LG1, LG2 (not collected but observed at LG1 and LG2) | 3 | 1 | GGNPA057 |
| *Amnirana galamensis* | AD1, BO4, BO5, DK2, GS3, GS7, SR4 | 20 | 9 | DZ_UI170025–33 |
| *Xenopus fischbergi* | AD7 | 4 | 1 | DZ_UI170195 |
| *Xenopus tropicalis* | AD1, AD3, BF2 | 4 | 4 | DZ_UI170005–8 |
| **TOTAL** | | **142** | **63** | |
| | | | | |
| **Reptiles** | | | | |
| *Agama agama* | AD2, AD5, AD9, AD13, BO4, BO5, DK2, GS3, GS7, LG3, LG4, SR1, SR2, SR4, TN1 (not collected but observed in BO4, BO5, SR2 and TN1). | 46 | 12 | DZ_UI170025–33 |
| *Agama parafricana* | AD3, AD8, AD9, BO1, BO4, BO6, BO7, BO8, MY1, MY2, GS3 (observed but not collected from AD3, BO1, BO8, MY1) | 24 | 10 | GGNPR031–40 |
| *Chamaeleo gracilis* | AD8 | 4 | 0 | |
| *Hemidactylus* sp. | AD3, AD8, AD9, DK1, DK2, KW2, KW4, SE7, SE8 | 31 | 14 | DZ_UI170181–194 |
| *Trachylepis affinis* | BF2 | 3 | 2 | GGNPR048–49 |
| *Trachylepis maculilabris* | GS2, GS6, GS8, GS9 | 9 | 4 | DZ_UI170100–103 |
| *Trachylepis perrotetii* | AD9, KW4, SE13 (not collected but observed at SE13) | 5 | 2 | DZ_UI170069–070 |
| *Trachylepis quinquetaeniata* | BO3 and SR13 | 12 | 4 | DZ_UI170035–038 |
| *Varanus niloticus* | AD7 | 1 | 1 | DZ_UI170199 |

**Appendix 1.** Continued.

| Species | Sampling Localities | Number observed | Number collected | Voucher specimen Number |
|---|---|---|---|---|
| *Naja melanoleuca* | KW4 | 1 | 1 | DZ_UI170203 |
| *Boaedon paralineatus* | GS9 | 2 | 1 | GGNPR043 |
| *Boaedon perisilvestris* | GS5 | 1 | 1 | GGNPR041 |
| *Lycophidion sp* | D6, GS8 | 7 | 3 | GGNPR079–81 |
| *Psammophis lineatus* | AD3 | 1 | 1 | GGNPR097 |
| *Python* sp. | KW3 | 1 | 1 | DZ_UI170202 |
| *Crocodylus suchus* | SR1 | 1 | 0 | |
| *Pelusios castaneus* | AD9, GS1, GM2 (observed but not collected from GS1 and GM2). | 11 | 2 | GGNPR087–88 |
| **TOTAL** | | **160** | **59** | |

Note: AD: Adagoro, GM: Gumti, LG: Lagaso, TN: Tonga, MY: Mayo Yim, BF: Bat Forest, GS: Gashaka, KW: Kwano, SR: Serti, DK: Dadun Kowa, BD: Bodel. Detailed information on the geographic coordinates of the sampling localities are found in Appendix 1. Vouchers and associated tissue samples are preserved in the museums of the Department of Zoology, University of Ibadan and Gashaka Gumti National Park, Nigeria

*Accepted by Werner Conradie*