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Author(s)	A. Hillers, N.-S. Loua, M.-O. Rödel
Faculty	FNWI: Institute for Biodiversity and Ecosystem Dynamics (IBED), FNWI: Institute for Biodiversity and Ecosystem Dynamics (IBED)
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A preliminary assessment of the amphibians of the Fouta Djallon, Guinea, West Africa

Annika Hillers, Néma-Soua Loua & Mark-Oliver Rödel

Abstract. We report on the amphibians of three sites in the Fouta Djallon highlands in central-northern Guinea. During our survey we recorded at least 25 frog species, including two first country records (*Kassina fusca* and *Leptopelis bufonides*) and one species new to science (*Conraua* sp.). Most of the recorded frogs were typical savanna or farmbush species with a distribution range that exceeds West Africa. Only a few species were more closely connected to forest habitats. For several species our records in the Fouta Djallon represent large range extensions. Despite the generally high degradation level of forests in the Fouta Djallon, the investigated sites all still harboured typical forest frogs and thus may represent last islands of forest in a nowadays savanna dominated landscape. All sites therefore have a high potential for conservation, especially the forest surrounding the Saala Waterfalls.

Key words. Amphibia, Anura, conservation, diversity, forest, Fouta Djallon, Guinea, habitat degradation, savanna.

Introduction

The Fouta Djallon highlands in central-northern Guinea are located at the western limit of the Upper Guinea forest bloc which is one of the most important global biodiversity hotspots (Myers et al. 2000, Bakarr et al. 2001). Schnell (1968) assumed that Guinea harboured the richest flora of the whole Upper Guinea region. Within Guinea, sandstone outcrops of the Fouta Djallon have proven to be an important center for floral endemism and diversity. The species richness and high rate of endemics are probably at least partly due to the long-term climatic stability in the past, which promoted the Fouta Djallon as a potential refugium during unfavourable, colder and drier climatic periods (Maley 1987, Porembski et al. 1994). In other postulated forest refugia, plant richness is paralleled by animal taxa (e.g. Lamotte 1998). Hence the Fouta Djallon also seems to be very interesting from a zoological point of view, including amphibians. This is especially underlined by the high diversity of different habitat types, including remaining forest, farmbush and savanna habitats that are located in a diversified landscape with many mountains, valleys and streams. However, apart from a few botanical studies, the Fouta Djallon has only rarely been tackled by scientific research. This appears to be especially problematic as the ecosystems of the Fouta Djallon have already suffered considerably from anthropogenic pressures (Porembski et al. 1994). Remaining forests are small and highly fragmented. These forests, as well as other habitats, are increasingly threatened by the fast growing human population, expanding agriculture, fires, logging and mining (Lebbie 2001).

So far the amphibian fauna of the Fouta Djallon highlands is completely unknown. Apart from a first survey in northwestern Guinea (Hillers et al. 2006) and one survey in central Guinea (Greenbaum & Carr 2005), almost all herpetological work has concentrated on the forested areas in the South-East of the country (e.g. Chabanaud 1919, 1920, 1921, Guibé & Lamotte 1958, 1963, Schiøtz 1967, 1968, Böhme 1994a, b, Rödel & Bangoura 2004, Rödel et al. 2004).

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Therefore we were surveying amphibians at three sites of the Fouta Djallon highlands.

Study sites and methods

The field work in the Fouta Djallon was carried out at the beginning of the rainy season between 29 May and 4 June 2006. Study sites were the Saala Waterfalls ("Chutes de la Saala"), the area of the Nialama Forest ("Forêt de Nialama") and the area around the Touri Dam ("Barrage de Touri"; Fig. 1).

The Fouta Djallon highlands (FDH) extend over 80,000 km² in central northern Guinea. They rise to an average of 1,000 m a.s.l. (the highest point is Mt. Loura at 1,600 m a.s.l.). The FDH are characterised by savanna formations (Fig. 2) with forest islands (Porembski et al. 1995). The rainy season lasts from May to October in the southern part of the FDH, further north only from June to October. Annual precipitation is mostly below 2,000 mm. In northern FDH annual rainfall ranges from 1,200-1,700 mm. During the rainy season humidity rises to more than 80%, while it can drop below 20% during the dry season. Due to the high altitude of the FDH the average temperatures are lower than in other Guinean regions. Daily temperature fluctuation can be as high as 30°C in the northern FDH. Night temperatures may drop below 10°C during the dry season. Anthropogenically caused fires are common during the dry period (Porembski et al. 1995).

The geology of the FDH is dominated by sandstones, and predominant geological formations are flat-topped mountains consisting of sandstone and dolerite. In the northern part of the FDH ferricretes or iron pans ("bowal", Fig. 2) are a typical feature of the landscape (Porembski et al. 1994). The soils are generally infertile, but some are rich in minerals such as iron ore (Morton 1986). The FDH is characterised by deep valleys with fast flowing streams. Numerous rivers like the Senegal and the Gambia originate in the Fouta Djallon (Lebbie 2001), others flow into the Niger (Porembski et al. 1994).

Our first study site was the area of the Saala Waterfalls (29-31 May; 873-917 m a.s.l.; Fig. 3). The river Saala is surrounded by a more or less closed gallery forest and other forest habitats that contain several smaller streams, all feeding into the river. This forest mainly consists of secondary forest with only a few big trees and a partly very dense shrub stratum. Anthropogenic alteration, i.e. forest degradation, is obvious, especially in the area above the waterfalls where a frequently used path

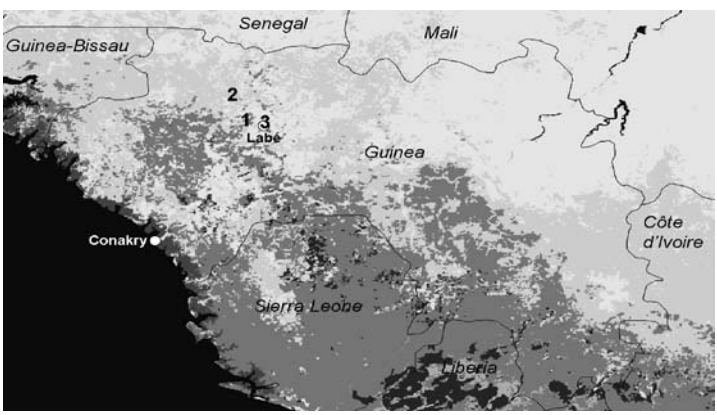

Fig. 1. Map of Guinea and position of the three study sites within the Fouta Djallon: 1 = Saala Waterfalls, 2 = Nialama Forest, 3 = Touri Dam; grey areas = natural forest areas; dark grey areas = remaining rainforest; thin lines = national borders.

Fig. 2. Two typical aspects of the landscape in the Nialama Forest area; the open dry forest and the "bowal" savanna.

Fig. 3. Saala River and Saala Waterfall, the habitat of an undescribed *Conraua* species (see Fig. 5).

crosses the river. There is ongoing construction of a tourist camp, while no measures have been taken to cater for waste or sanitary infrastructure. The forest around the Saala Waterfalls still harbours a big population of chimpanzees (E.O. Tounkara, pers. comm.) and an ornithological survey revealed a high diversity of birds (N. Keita & R. Demey, pers. comm.).

The second study site, the Nialama Classified Forest (1-3 June; 204-473 m a.s.l.; Fig. 2) was characterised by an open dry forest as well as farmbush and savanna habitats. It included several streams with narrow gallery forests that have been partly logged. An important part of Nialama Forest was characterised by mature secondary forest resulting from reforestation actions. Within the farmbush and savanna habitats rainfall leads to the formation of ponds and puddles. In some parts of Nialama the landscape was characterised by bowal areas. Some open savanna and farmbush areas served as pasture land.

The Touri Dam was our third study site (4 June; 1,021-1,038 m a.s.l.). The area mainly consisted of very open and partly degraded savanna habitat with a few shrubs and bushes. Only a very few small forest patches have been left. These include some small gallery forests and one forest fragment that partly

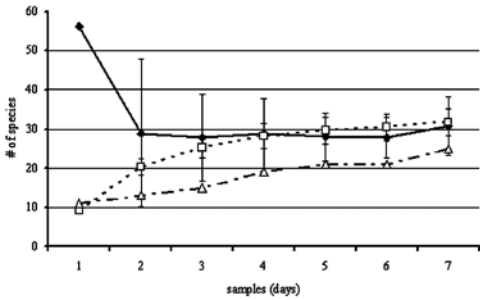

Fig. 4. Estimated species richness for amphibians in the Fouta Djallon (based on seven days of survey work). Open squares = Jack-knife 1 estimator (31.9 ± 3.3 species); black diamonds = Chao 2 estimator (30.8 ± 7.5 species); open triangles = species accumulation curve.

serves as a graveyard, for which reason it is rarely frequented by people. Within the area several villages and frequently used roads exist.

Due to the delayed onset of the rainy season and hence limited rainfall, all three study sites provided very dry conditions. This was most obvious in Nialama Forest where all streams were still almost completely dried up. Amphibian specimens were hence mainly recorded during visual (almost no calling activity) surveys by up to three people. The surveys were undertaken during both day and night. Searching techniques included visual scanning of the terrain and investigation of potential hiding places (see also Heyer et al. 1994, Rödel & Ernst 2004). Our sampling design only provided qualitative and semi-quantitative data. We therefore calculated the estimated species richness and hence our sampling efficiency with the Jack-knife 1 and Chao 2 estimators (software: EstimateS, Colwell 2005). These incidence based estimators were calculated based on the presence-absence data of our daily species lists (7 days) for 25 species. We accomplished 500 random runs of the daily species lists to avoid order effects.

In Appendix 1 we give a list of all investigated sites, including a short habitat description. Geographical positions were taken with a hand-held GPS receiver (Garmin 12XL). Our nomenclature follows the taxonomy of Frost (2004). Table 1 includes the changes according to Frost et al. (2006). Voucher specimens were anaesthetized in a chlorobutanol solution and subsequently preserved in 70% ethanol. Vouchers are currently deposited in M.-O. Rödel's collection and will be inventoried later on in the collection of the Zoological Museum Berlin (ZMB, Appendix 2). Tissue samples (toe tips) were preserved in 95% ethanol. They are stored at the Institute for Biodiversity and Ecosystem Dynamics at the University of Amsterdam, The Netherlands.

Results

During the FDH survey we recorded at least 25 amphibian species. So far it is not possible to reliably differentiate *Arthroleptis* spp. based on morphological data alone (Rödel & Bangoura 2004). Preliminary genetic investigations suggest that our samples comprise several species (A. Hillers, unpubl. data). A list of all recorded amphibians with site records, known habitat preference and African distribution is given in Table 1.

The comparison of the species accumulation curve with the species numbers calculated by the two estimators showed that more than the 25 recorded amphibian species are likely to occur at the three sites (Fig. 4). The Chao 2 and the Jack-knife 1 estimator calculated 31 and 32 species, respectively. We hence would have recorded about 78-81% of the regional species.

At the Saala Waterfalls we recorded 15, in Nialama Forest 17 and at the Touri Dam 14 species. The amphibian assemblage at the Saala Waterfalls included one species new to science (*Conraua* sp., judgment based on morphological and genetic characters that will be reported on elsewhere; Fig. 5). We also recorded two savanna frogs for the first time in Guinea: *Kassina fusca* (Fig. 6) in the Nialama Forest and *Leptopelis bufonides* (Fig.

Tab. 1. List of amphibian species recorded in the Fouta Djallon with site of record (S = Saala Waterfalls; N = Nialama Forest; T = Touri Dam, compare Appendix 1), habitat preference, and African distribution. S = savanna, FB = farmbush (degraded forest and farmland), F = forest, A = Africa (occurs also outside West Africa), WA = West Africa (Senegal to eastern Nigeria), UG = Upper Guinea (forest zone West of the Dahomey Gap), E = endemic to Guinea, * = records possibly comprise several species, [1] = first country record. Frost et al. (2006) introduced many new names and relationships. As these changes are not yet generally accepted (Wiens 2007, but also see the authors' response) and to allow for better orientation, we herein use the old names (Frost 2004). The new affiliations according to Frost et al. (2006) are: The West African *Bufo* species are now in the genus *Amietophrynus,* the African *Amnirana* species in the genus *Hydrophylax. Astylosternus* and *Leptopelis* moved into the family Arthroleptidae. *Conraua* now is a member of the family Petropedetidae, *Hoplobatrachus* is in the family Dicroglossidae, *Ptychadena* forms the family Ptychadenidae and *Phrynobatrachus* forms the family Phrynobatrachidae. *Leptopelis spiritusnoctis* was previously termed *L. hyloides* (compare Rödel 2007).

Species	Site	S	FB	F	A	WA	UG	E
Arthroleptidae								
Arthroleptis spp. *	S 1, 2, 3, 5, 7; N 1, 7; T 3		x	x			x	
Astylosternidae								
Astylosternus occidentalis	S 3, 4			x			x	
Bufonidae								
Bufo maculatus	N 1; T 3	x	x		x			
Bufo regularis	S 1, 2; N 1, 3; T 3	x	x		x			
Hyperoliidae								
Hyperolius nitidulus	T 3	x			x			
Hyperolius picturatus	S 3; T 3		x	x			x	
Hyperolius sp.	T 3	x	x				?	
Kassina fusca[1]	N 2	x				x		
Kassina senegalensis	T 3	x			x			
Leptopelis bufonides[1]	T 3	x			x			
Leptopelis spiritusnoctis	S 1, 4; N 1		x	x		x		
Leptopelis viridis	S 7; N 1, 2, 4, 5; T 3	x	x		x			
Petropedetidae								
Petropedetes natator	S 1			x			x	
Phrynobatrachus accraensis	S 5; N 1, 7, 8; T 2	x	x			x		
Phrynobatrachus calcaratus	N 1, 4, 7			x	x			
Phrynobatrachus natalensis	S 1, 7; N 1, 3, 4, 7	x	x	x	x			
Phrynobatrachus tokba	S 2, 3, 4, 6; N 7; T 1, 2			x			x	
Ranidae								
Conraua sp.	S 1		(x)	x				(x)
Hoplobatrachus occipitalis	N 2; T 3	x	x	x	x			
Ptychadena bibroni	S 1; N 1; T 3	x	x		x			
Ptychadena longirostris	S 7; N 6		x	x		x		
Ptychadena oxyrhynchus	S 1; N 1; T 3	x	x	x	x			
Ptychadena pumilio	S 5; N 1, 5	x			x			
Ptychadena tellinii	N 6	x	x		x			
Ptychadena trinodis	N 5	x			x			

Fig. 5. Dorso-lateral and ventral view of an undescribed *Conraua* species from the Saala Waterfalls (see Fig. 3).

Fig. 6. *Kassina fusca* from the Nialama Forest area. This is a relatively common West African savanna species, herein recorded for the first time in Guinea.

7) around the Touri Dam. Based on their general distribution area, both species were supposed to occur in Guinea (Rödel 2000). *Kassina fusca* was represented by individuals that were unusually small. Male *K. fusca* reached 27.5-32.5 mm SVL (N = 5; 31-35 mm according to Rödel 2000), while a female measured 30.4 mm SVL (32-37 mm according to Rödel 2000; 29-33 mm SVL for both sexes according to Schiøtz 1967).

The majority of species (14 species, 56%) has a distribution range exceeding West Africa. Four species (16%) are restricted to West Africa, while five species (20%) only occur in the Upper Guinea forest area (Tab. 1). One species (*Conraua* sp.) is likely to be endemic for the Fouta Djallon. Genetic analyses will clarify the status of one *Hyperolius* specimen, i.e. if it can be referred to a described species. Most of the recorded species were related to savanna habitats, some of them also occurring in farmbush habitats (sensu Schiøtz 1967) or even forest. Only a few species could be considered real forest specialists, some of them being tolerant to disturbed forest situations.

Our FDH records represent large range extensions for several species: *Hyperolius picturatus*, *Petropedetes natator* and *Ptychadena longirostris* have so far only been known from the far Southeast of Guinea. This had also been the case for *Astylosternus occidentalis*, *Leptopelis spiritusnoctis* and *Phrynobatrachus tokba*. However, these species have recently been recorded also from the northwestern part of the country (Hillers et al. 2006). The genus *Conraua* was likewise only known from the southeastern part of Guinea (Guibé & Lamotte 1958, Rödel & Bangoura 2004, Rödel et al. 2004). All known *Conraua* species are associated with forest streams. *Conraua* sp. occurred in more or less stagnant water between rocks at the edge of the Saala

Fig. 7. *Leptopelis bufonides* is a very patchily distributed savanna frog, occurring from Senegal to northern Cameroon. The record from the Touri Dam is a first Guinean record. This individual shows an unusual pattern with yellowish spots on the back.

River. The area around these rocks was rather open and frequently visited by humans who crossed the river exactly where *Conraua* sp. occurred. As rainfall was still rare, we were not able to observe if the habitat preference of the frogs changed with a rising water level.

Almost all recorded species are listed as of "Least Concern" in the IUCN Red list (IUCN et al. 2004). Only *Petropedetes natator,* typically occurring in fast flowing forest streams, is a "Near Threatened" species. *Conraua* sp. possibly should be considered as "Critically Endangered" due to its very special habitat requirements and restricted distribution. Both species were exclusively encountered at the Saala Waterfalls.

Discussion

The Fouta Djallon highlands are known to harbour a very rich flora with a high number of endemic species (Porembski et al. 1994, 1995). The stable climate of the Fouta Djallon, especially during the Pleistocene (Maley 1987), is assumed to be one of the reasons leading to this exceptional floristic assemblage (Porembski et al. 1994). The potential status of being a forest refugium and the high diversity of habitats and landscapes, including inaccessible areas, most likely promotes a diverse and endemic fauna as well.

In this paper we report for the first time on the amphibian fauna of the Fouta Djallon. While we were able to record some forest and potentially one endemic species, most of the recorded frogs were widespread species with preferences for savanna and farmbush habitats. We believe that this only partly reflects a natural situation. While in the northern part of the Fouta Djallon the dominance of savanna-related amphibians could be expected due to the generally drier climate that is strongly influenced by the exposure to dry Harmattan winds (Lebbie 2001), in other parts of the FDH the amphibian composition may be altered due to human activities, i.e. forest degradation and conversion. Nowadays it seems that there are no large tracts of forest left. The remaining forests are only represented by relatively small forest patches surrounded by savanna habitat. This forest reduction was observable at all our three sites. In Nialama Forest we observed active logging of the gallery forests, which may lead to even drier conditions. During our survey the delayed rains had already resulted in most streams being dried up in the Nialama area. A vanishing forest cover would certainly increase this problem, including disastrous effects for the amphibians. Although the lake in Touri might contribute to a still relatively humid local climate, the forest habitat around the Touri Dam seemed to be much reduced and degraded.

Despite this high degree of habitat degradation, the remaining forest habitats at the three sites still provided suitable habitats for true forest species. However, all the forests still left need urgent protection to assure the long-term persistence of these species. Based on the observed species, as well as on the anthropogenic pressure (local population and tourist activities), the Saala Waterfalls deserve the highest priority for conservation actions. *Conraua* sp. may be restricted to this

site and thus might be highly endangered. The diverse mixture of habitats around the Saala Waterfalls makes us believe that many more amphibian species might occur than recorded by us. This could especially be the case for the Nialama Forest, where we only visited a small part of the existing habitats.

In general, we assume that we were not able to assemble a complete picture of the amphibian community of the FDH. This assumption is supported by the higher estimated species richness compared to the recorded number of species. However, the fact that we succeeded in detecting at least 25 amphibian species despite the dry weather conditions and the short survey period may be taken as a hint of high amphibian diversity in the FDH. Further amphibian surveys in this region are highly recommended. These should predominantly concentrate on all remaining forests. Especially hard to assess areas, like forests and streams in valleys between the highlands, might still give home to other undescribed and potentially endemic amphibians.

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Appendix 1

Locality list and short description of habitats in the Fouta Djallon, Guinea: Saala Waterfalls (S), Nialama Forest (N), Touri Dam (T).

Site	Latitude (N)	Longitude (W)	Description
S1	11°17.693'	12°30.795'	Rocky stream, some gallery forest and savanna
S2	11°17.814'	12°31.135'	Degraded forest
S3	11°17.917'	12°30.001'	Forest, partly swampy area, small stream
S4	11°17.824'	12°30.834'	Gallery forest, partly degraded
S5	11°17.611'	12°30.734'	Gallery forest, partly degraded, grass and puddles on clearings
S6	11°17.606'	12°30.722'	Partly degraded forest on hill above river
S7	11°17.769'	12°30.878'	Savanna
N1	11°43.239'	12°43.404'	Almost dried up stream in savanna, sparse gallery forest
N2	11°46.073'	12°40.844'	Savanna, rocky soil, puddles
N3	11°42.592'	12°42.294'	Confluence of two partly dried up rivers, sparse gallery forest
N4	11°44.221'	12°41.099'	Partly dried up stream in savanna, sparse gallery forest
N5	11°42.894'	12°41.743'	Large puddle and swampy area in savanna
N6	11°43.264'	12°41.701'	Large puddle in savanna
N7	11°48.160'	12°44.593'	Partly dried up stream in savanna, sparse gallery forest
N8	11°48.855'	12°46.111'	Large pond ("Mare de Nialama") in savanna near forest
T1	11°22.749'	12°17.606'	Partly dried up stream in savanna, sparse gallery forest
T2	11°23.847'	12°16.246'	Partly dried up stream in savanna, sparse gallery forest
T3	11°22.798'	12°17.719'	Lake in savanna area

Appendix 2

List of voucher specimens deposited in the collection of M.-O. Rödel. The taxonomy is in accordance with Frost (2004); for recent taxonomic changes compare Tab. 1:

Arthroleptidae: *Arthroleptis* spp.: FD 24, 26, 71, 99, 103, 120; Astylosternidae: *Astylosternus occidentalis*: FD 25; Bufonidae: *Bufo regularis:* FD 46, 69; Hyperoliidae: *Hyperolius picturatus*: FD 38; *H.* sp.: FD 116; *Kassina fusca*: FD 75, 80; *K. senegalensis*: FD 118; *Leptopelis bufonides*: FD 119; *L. viridis*: FD 50, 70; Petropedetidae: *Petropedetes natator*: FD 22; *Phrynobatrachus accraensis*: FD 43, 72, 117; *P. calcaratus*: FD 74, 100; *P. natalensis*: FD 49, 73; *P. tokba*: FD 28, 98, 101-102, 115; Ranidae: *Conraua* nov. sp.: FD 27, 44-45, 47-48; *Ptychadena bibroni*: FD 23, 67; *P. tellinii*: FD 81; *P. oxyrhynchus*: FD 69; *P. pumilio*: FD 41-42; *P. trinodis*: FD 82.

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Authors' addresses: Annika Hillers, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Kruislaan 318, 1098SM Amsterdam, The Netherlands, E-Mail: hillers@science.uva.nl; Néma-Soua Loua, Guinée Ecologie, Bâtiment 210, rue DI 501, Dixinn, B.P. 3266, Conakry, Guinea, E-Mail: nsloua@yahoo.fr; Mark-Oliver Rödel, Museum of Natural History of the Humboldt University Berlin, Herpetology, Invalidenstraße 43, D-10115 Berlin, Germany, E-Mail: mo.roedel@museum.hu-berlin.de.