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The amphibians of the forested parts of south-western Ghana

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Abstract. We investigated the herpetofauna of four forests, designated as Globally Significant Biodiversity Areas in the Western Region, Ghana. We recorded a total of 47 amphibian species, among them the first country records for the genera *Acanthixalus* and *Phlyctimantis,* as well as new taxa within the genera *Arthroleptis* and *Astylosternus.* The species *Acanthixalus sonjae* was so far only known from Ivory Coast. *Phrynobatrachus ghanensis* and *Hyperolius bobirensis* are reported for the first time outside of the Kakum and Bobiri forest reserves, respectively. We comment on and illustrate these and other less known species. Most of the recorded species were either endemic to West Africa or even smaller parts of the Upper Guinean forest block.

The relatively high diversity, and/or unique species composition with respect to regional endemicity, documented during our surveys, clearly demonstrates that the western Ghanaian forests, although already highly fragmented, still have a high potential for nature conservation. However, we also documented several invasive species (e.g. *Bufo maculatus, Bufo regularis*, *Hoplobatrachus occipitalis, Phrynobatrachus accraensis, Afrixalus fulvovittatus*), normally not occurring in forest habitats. These species clearly indicate significant alteration of the original forest habitats by means of unsustainable forest use. The relatively high diversity of western Ghanaian amphibian communities and their unique composition is a further hint towards the existence of a Pleistocene forest refugium in south-western Ghana.

Key words. Amphibia: Gymnophiona: Anura: conservation, faunistics, forest, south-western Ghana, taxonomy.

Introduction

In 1988, HUGHES (1988) published a review of the history of herpetological investigations in Ghana and provided a country checklist (71 amphibian species). However, some of the listed species are of uncertain taxonomic status [*Arthroleptis bivittatus* MÜLLER, 1885, *A. zimmeri* (AHL, 1925), cf. RÖDEL & BANGOURA 2004 and results of this paper] or do not occur in Ghana [*A. variabilis* MATSCHIE, 1893, see RÖDEL 2000, RÖDEL & BANGOURA 2002; *Conraua alleni* (BARBOUR & LOVERIDGE, 1927), cf. RÖDEL & AGYEI 2003; *Astylosternus occidentalis* PARKER, 1931, see below]. The 2002-2004 Global Amphibian Assessment [GAA, by The World Conservation Union (IUCN)/Species Survival Commission, Conservation International Center of Applied Biodiversity Science and NatureServe, http://www.globalamphibians.org] equally lists 71 amphibian species for Ghana, still including doubtful country records. In fact, since A. SCHIØTZ's work in Ghana, conducted in the 1960's (SCHIØTZ 1964a, b, 1967), only a very few papers have been published on Ghanaian amphibians (e. g. HOOGMOED 1979, 1980, HUGHES 1979). A few forest surveys revealed between 10 and 20 amphibian species per site (SCHIØTZ 1964a, 1967, RAXWORTHY & ATTUQUAYEFIO 2000, RÖDEL & AGYEI 2003, LEACHÉ 2005). This is a rather low species richness compared to neighbouring Ivory Coast or Guinea. Well studied forest amphibian communities in these countries comprise between 40-60 species (RÖDEL & BRANCH 2002, RÖDEL 2003, RÖDEL & ERNST 2003, 2004, RÖDEL & BANGOURA 2004, RÖDEL et al. 2004).

RÖDEL & AGYEI (2003) speculate that one potential explanation for lower species richness in eastern Ghanaian forests might be the absence of Pleistocene forest refugia (PARREN & DEGRAAF 1995). RÖDEL & AGYEI (2003) argue that the lack of such refuges might have led to fewer species surviving drier periods in this area. Such a forest refugium, however, was proposed for the western Ghanaian/eastern Ivorian region (e.g. UICN 1996, FALK et al. 2003, POORTER et al. 2004a). Hence, amphibian species richness should be higher in this region. Unfortunately, the forests of western Ghana never have been the target of a thorough herpetological survey. It is for this reason that A. SCHIØTZ and M.-O. RÖDEL defined the western Ghanaian forests as an area with an exceptionally high priority level for rapid assessment during the Conservation Priority Setting Workshop in Ghana (BAKARR et al. 2001). As an outcome of that workshop, Conservation International conducted a Rapid Assessment Program (RAP) survey in three selected forest reserves of south-western Ghana from 22 October to 10 November 2003, at the end of the rainy season (DECHER in press). Independently, M. GIL recorded the herpetofauna in the Ankasa Conservation Area from 1 February to 19 April 2003 during the dry and the beginning of the rainy season. A.D. LEACHÉ, R.E. DIAZ and M.K. FUJITA targeted the Ankasa Conservation Area during the rainy season from 24 to 29 June 2004. The amphibian results of all three surveys are presented herein. We summarise all recorded species, describe and illustrate in more detail new, taxonomically difficult and less known species and discuss the conservation situation of Ghanaian amphibians in particular and the western Ghanaian forests in general.

Study sites

Our study areas in the Western Region of Ghana were the Ankasa, Draw River, and Boi-Tano forests situated within the zone of wet evergreen forest, comprising large trees with vertically compressed canopies rarely exceeding 40 m and the Krokosua Hills forest that is situated within the northwestern subtype of moist semi-deciduous forest (Fig. 1), comprising trees that are taller than those of any other West African forest type (50-60 m, HALL & SWAINE 1981, POORTER et al. 2004a, UNEP 2005, DECHER in press). Appendix 1 summarizes all RAP sites including their geographic position and a short habitat characterization.

The Ankasa Conservation Area (ACA) is a twin wildlife protected area. The reserve is approximately 518 km² (5°16'1''N, 2°36'5''W) and is composed of Nini-Suhien National Park (166 km²) to the north and the Ankasa Forest Reserve (343 km^2) to the south. The vegetation within this reserve is characterized as wet evergreen forest, which is restricted to the highest rainfall zone in Ghana (mean annual precipitation: 1700-2000 mm; HALL & SWAIN 1981). These forests have a high floristic and structural diversity (HALL & SWAIN 1981). Although relatively intact as a forest, ACA was un-intensely selectively logged in the early 1970's mainly in the southern portions of ACA leaving much of the rest of the reserve, as well as the Nini Suhien portion, untouched (HAWTHORNE 1999). The ACA has a few other attributes that influence its structural integrity including two roads inside the reserve, Nkwanta camp, old Nkwanta village and a power line corridor that runs through a large portion of the reserve. These areas have been altered from their original state and provide both habitat and corridors for non-rainforest species that are widespread and common elsewhere.

The Draw River Forest Reserve (DR; 5°14'5''N, 2°20'26''W; RAP camp site: 05º11'35''N, 02º24'26''W) was surveyed from 22 to 27 October. This wet evergreen forest covers an area of 235.4 km² of which 128 km² are classified by the Ghanaian government as being part of the Globally Significant Biodiversity Areas (GSBA). DR is contiguous to ACA (Fig. 1). The reserve is divided into three blocks by rivers and the

Ankrako-Kokum path. There are 40 ha of allowed farms within the reserve. Logging started in 1978 and peaked in 1988 (712 trees per annum). Figures after 1989 (332 trees) are not available. Old logging dumps and hauling tracks are at various stages of recovery. Human interference through small scale harvesting of minor forest products (canes, raphia palm, bamboo, trapping for game) is evident in many areas. However, DR is still in a relatively healthy condition. In some places, the large shrub *Scaphopetalum amoenum* naturally forms a dense, virtually monospecific understorey. Mean altitude of DR is 75 m above sea level. Mean annual precipitation is 2147 mm.

The Boi-Tano Forest Reserve (BT; 5°30'40''N, 2°38'48''W; RAP camp site: 05º31'55''N, 02º37'07''W) was surveyed from October 28 to November 2. BT comprises 128.5 km² of which 33 km² are classified as GSBA. Access to BT often was difficult due to watercourses and swamps. The GSBA covers a part in the south-eastern half of the forest, including portions along the Tano River, and another part in the northern section of BT. Logging progressed rapidly in the late 1990's, and by 2002 all non-GSBA compartments from the village Samreboi to the south-western tip were opened up, forming an extensive logging road network (Decher in press). The Tano River and larger tributaries support riverine forest that is still in healthy condition. The main hauling road appears unusually wide and is lined with *Cercropia peltata*, an introduced pioneer species. Mean altitude of BT is 72 m above sea level. Mean annual precipitation is 1603 mm.

The Krokosua Hills Forest Reserve (KH; 6°29'3''N, 2°48'27''W; RAP camp site: 06º36'47''N, 02º50'58''W) comprises a surface of 481.7 km². It was surveyed from 3 to 9 November. In contrast to the aforementioned forests it consists of moist semi-deciduous forest. Annual precipitation is 1250-1500 mm. The survey basis was the village of Mmem (population around 75) legally situated within the reserve boundary. The highest point within the reserve is 610 m above sea level. Much of KH is heavily logged and access roads are wide and clogged with the invasive weed *Chromolaena odorata*. KH consists of two forest blocks, one above and one below the Asempaneye-Kumasi road. During the RAP, only the northwestern portion of the reserve (GSBA) was surveyed. Because this northern portion has only few human inhabitants and more pronounced topography, the forest has remained in a more intact state than the southern portion. The central ridge still contains intact forest, and is in far better condition than lower adjacent forests. Within the reserve there are a number of farms, old mine pits, and villages. Alluvial gold mining was carried out in the south-western portion in the past. A botanical survey in 1991 confirmed extreme patchiness with very damaged, logged areas on flatter land and unlogged areas with less damage on steep slopes. Legally the GSBA was last logged in 1988. Illegal logging poses a major problem in the area. Mean altitude of KH is 209 m above sea level. Mean annual precipitation is 1515 mm.

Methods

Specimens were mainly located opportunistically, during visual (VES) and acoustic encounter surveys (AES) of all habitats by up to three people (cf. Heyer et al. 1994, Rödel & Ernst 2004). Surveys were undertaken during the day and during the evening (until 22:00 h). Search techniques include visual scanning of terrain, refuge examination, dip-netting in all types of waters, recording of known frog calls, and searching for unknown frog calls. Geographic positions were taken with a hand-held GPS receiver (Garmin 12 XL or Garmin 72). To supplement opportunistic collecting, habitats in all forests were also sampled using arrays of pitfall traps placed along drift fences (cf. Heyer et al. 1994, Branch & Rödel 2003). Trap lines (total of three per survey site, except one at ACA) were set in different microhabitat types

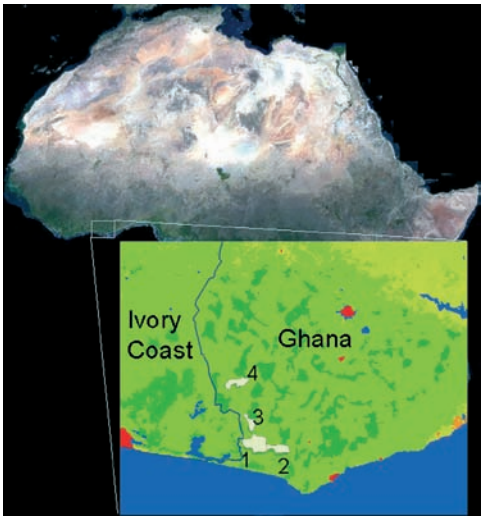

Fig. 1. Study area in south-western Ghana. Only dark green areas represent still primary forest. 1 = Ankasa Conservation Area. 2 = Draw River Forest Reserve. 3 = Boi-Tano Forest Reserve. 4 = Krokosua Hills Forest Reserve.

(Appendix 1). In DR, BT and KH, each trap array comprised a single straight line fence (15 m) with six buckets (approximately 10 l). In ACA we employed a three-arm array, 10 m per arm, with seven buckets. Traps were checked every morning and during the day. Drift fence orientation was tailored to local conditions.

Based on the assumption that relative sampling effort was the same for every habitat we calculated the approximate total number of amphibian species living in all forests. With our sampling design only qualitative and semi-quantitative data can be obtained. For exact quantitative data mark-recapture experiments along standardized transects or on definite plots would have been necessary. We therefore used the Jack-knife 1 and Chao 2 estimators (cf. VEITH et al. 2004). Calculation basis were the daily or weekly presence/absence species lists (see Tab. 4; software: EstimateS, http://viceroy.eeb.uconn. edu/index.html). To prevent order effects, calculations have been based on 500 randomized runs. For an introduction to the methods applied see R.K. COLWELL ["EstimateS, statistical estimation of species richness and shared species from samples – version 6.0b1" (1994-2000); „http://viceroy.eeb.uconn.edu/estimates"] and literature cited therein. Recordings were made in the field using a Sony WM-D6C tape recorder and a directional microphone (Sony ECM-Z157). Sound analysis was conducted with Raven 1.2, Cornell Laboratory of Ornithology (CHARIF et al. 2004).

Specimens not retained as voucher specimens were released in the vicinity of capture. Some voucher specimens were collected and killed using regular toothache pain relief gel, containing 20% Benzocaine or with a chlorotone solution. All vouchers were preserved in 70% ethanol. Vouchers from DR, BT and KH will be later deposited in various museum collections and are currently stored in the research collection of M.-O. RÖDEL (MOR). All voucher specimens from ACA are deposited at the Museum of Vertebrate Zoology, University of California, Berkeley (MVZ). A list of vouchers is provided in Appendix 2. Further records from ACA have been determined based on pictures, measurements and other field notes taken by M. GIL. Nomenclature is according to D.R. FROST's "Amphibian species of the World: an online reference. Version 3.0." (http://research.amnh.org/herpetology/amphibia/index.html. American Museum of Natural History, New York) or commented on below. Additional museum abbreviations are: MHNG = Muséum d'Histoire Naturelle, Genève; MNHNP = Muséum national d'Histoire Naturelle, Paris; ZMB = Naturhistorisches Museum der Humboldt Universität zu Berlin; ZMUC = Zoologisk Museum, København Universitet. Snout to vent length is abbreviated SVL.

Results and discussion

List of selected species

In all four forests several remarkable species were recorded. A complete list of the re-

corded species, including their preferred macro-habitats and their African distribution, is summarized in Table 1.

According to the literature the fossorial caecilian *Geotrypetes seraphini occidentalis* PARKER, 1936 was so far known from Ghana by less than 10 specimens (Parker 1936, SCHIØTZ 1964a, TAYLOR 1968). We found one specimen in our trap array at DR (Fig. 2). However, another 88 specimens from eastern Ghana, all collected by T. PAPENFUSS, are stored at MVZ, possibly indicating that this species is more abundant in eastern Ghana.

In ACA and BT, we recorded frogs of the genus *Aubria* (Fig. 3). These large, nocturnal, aquatic West and Central African forest frogs normally live in swamps and along small forest rivers. Their black tadpoles form schools and adults are known to feed on fish and other amphibians (SCHIØTZ 1964a, KNOEPFFLER 1976, HUGHES 1979, PERRET 1994). In recent years the taxonomic status of these frogs from various populations has been debated and changed several times. The recently described *A. masako* OHLER & KAZADI, 1990 from the "Forêt de Masako", approximately 15 km from Kisangani, Democratic Republic of Congo, was suggested to lack femoral glands (OHLER & KAZADI 1990). According to the original description, it is only known from the type locality, and OHLER & KAZADI (1990) assigned all other West and Central African records to *A. subsigillata* (DUMÉRIL, 1856), originally described from Gabon (holotype MNHNP 1566). PERRET (1995 "1994") realized that the known vouchers of *A. subsigillata* from West and Central Africa actually comprised two different species. He distinguished a short legged Central African taxon with femoral glands that are relatively close to the knee (*A. subsigillata*) and a species occurring in West and coastal Central Africa forests with longer legs and glands, positioned half way between knee and vent. The latter he described as *A. occidentalis* PERRET, 1995 "1994" (holotype MHNG 2129, from Banco forest, Ivory Coast). OHLER (1996) reexamined *Aubria* frogs from the complete range including the various type species. According to her, two species can be differentiated, almost exactly fitting the diagnostic characters used by PERRET (1994). However, the type of *A.*

Fig. 2. *Geotrypetes seraphini occidentalis* from Draw River Forest Reserve.

Fig. 3. Dorsal (above) and ventral (below) aspect of *Aubria subsigillata* from Boi-Tano Forest Reserve.

taxa	ACA	DR	BT	KH	restricted to			habitat		
					SSA	WA	UG	F	S	FB
Gymnophiona										
Caecilidae										
Geotrypetes seraphini occidentalis		1					1	1		
Anura										
Pipidae										
Silurana tropicalis	1			1	1			1		1
Bufonidae										
Bufo maculatus	1	1	1	1	1				1	1
B. regularis	1			1	1				1	1
Hemisotidae										
Hemisus cf. *guineensis*				1	1			1		1
Ranidae										
Amnirana albolabris	1		1	1	1			1		1
A. occidentalis	1		1				1	1		
Aubria subsigillata	1		1		1			1		
Hoplobatrachus occipitalis	1	1		1	1				1	1
Ptychadena aequiplicata	1	1	1	1	1			1		
P. longirostris	1	1	1	1		1		1		1
P. mascareniensis[1]	1	1		1		1				1
P. oxyrhynchus	1	1	1		1				1	
P. cf. *superciliaris*	1						1	1		
Petropedetidae										
Phrynobatrachus accraensis	1	1	1	1		1			1	1
P. alleni	1	1	1	1		1		1		
P. annulatus		1	1				1	1		
P. calcaratus	1			1	1					1
P. ghanensis	1	1	1				1	1		
P. gutturosus			1	1		1		1		1
P. liberiensis	1	1	1				1	1		
P. plicatus	1	1	1	1		1		1		1
P. tokba[2]		1	1				1			1
Arthroleptidae										
Arthroleptis/Schoutedenella sp. 3	?	1	?	?			1	1		1
A./S. sp. 4	?	1	?	?			1	1		1
A./S. sp. 5	?	1	?	?			1	1		1
Arthroleptis sp. nov.				1			1			1
Cardioglossa leucomystax	1	1	1		1			1		
Astylosternidae										
Astylosternus sp. nov.	1	1					1	1		
Hyperoliidae										
Acanthixalus sonjae	1			1			1	1		1
Afrixalus dorsalis	1	1	1	1	1					1
A. fulvovittatus	1						1			1
A. nigeriensis	1			1		1		1		
Hyperolius bobirensis	1						1	1		
H. concolor	1	1	1	1	1					1
H. fusciventris burtoni[4]		1	1			1		1		1
H. f. lamtoensis[4]	1						1			1
H. guttulatus	1				1					1

taxa	ACA	DR	BT	KH	restricted to			habitat		
					SSA	WA	UG	F	S	FB
H. laurenti	1	1	1				1	1		
H. cf. *picturatus*	1						1			1
H. sylvaticus	1			1		1		1		
H. viridigulosus	1	1	1				1	1		
Leptopelis hyloides	1	1		1		1		1		1
L. macrotis	?	1					1	1		
L. occidentalis	1	1					1	1		
Phlyctimantis cf. *boulengeri*	1				1			1		1
Rhacophoridae										
Chiromantis rufescens	1	1			1			1		1
Total (47)[3]	**36 (40)**	**28**	**21 (24)**	**21 (24)**	**16**	**10**	**21**	**32**	**5**	**28**

Tab. 1. Presence, distribution, habitat association and conservation status of the amphibians of the Ankasa Conservation Area (ACA), Draw River (DR), Boi-Tano (BT) and Krokosua Hills Forest Reserves (KH). SSA = distributed outside West Africa south of the Sahara; WA = endemic to West Africa, UG = endemic to the Upper Guinea forest zone; F = forest specialist; S = savannah species, FB = farmbush species; cf. = taxonomic status remains to be confirmed; [1] VENCES et al. (2004) provide evidence for a West African species within the *Ptychadena mascareniensis* complex; [2] RÖDEL et al. (2005) showed that *P. alticola* GUIBÉ & LAMOTTE, 1961 is a junior synonym of *P. tokba* (CHABANAUD, 1921), [3] numbers in parenthesis include *Arthroleptis* species (see text), [4] possibly representing distinct species (compare text and RÖDEL & BRANCH 2002).

subsigillata proved to belong to the long legged form of *Aubria* with the femoral glands half way between knee and vent, whereas *A. masako* proved to have femoral glands and in fact is conspecific with PERRET's (1994) short legged frogs (OHLER 1996). Hence, *A. occidentalis* was recognized as a junior synonym of *A. subsigillata* that is mainly distributed along the West and Central African coast down to Gabon, but ranging into the Upper Guinea highlands in Guinea. *Aubria masako* inhabits the Congo basin and the Cameroon plateau (OHLER 1996).

Whereas we found large differences in the coloration of *Aubria* specimens from various West African localities (e.g. MOR 9617 from Taï National Park, MOR Ba03.5, Ba04.4, Ba04.5 from Banco National Park, both Ivory Coast, MOR BTR0303, BT, Ghana, Fig. 3; specimens from Banco NP often being very colorful, those from other localities more dull beige or blackish-brown), the gland position and leg length of all our specimens very well fitted the *A. subsigillata* definition of OHLER (1996). A specimen from Dzanga-Sangah, Central African Republic (MOR DS9) fitted the *A. masako* definition by OHLER (1996). We therefore follow OHLER's (1996) *Aubria* definitions but will not be surprised if West African populations in the future prove to be specifically distinct from Central African ones, as has been shown for a variety of other species groups (e.g. compare various *Leptopelis* spp., SCHIØTZ 1967; *Bufo tuberosus* group, RÖDEL & ERNST 2000, TANDY & PERRET 2000; *Acanthixalus*, RÖDEL et al. 2003). We reexamined the type of *Phrynopsis ventrimaculata* NIEDEN, 1908 (holotype ZMB 20134 from Longji, Cameroon) and confirm SCHIØTZ (1963), PERRET (1966) and OHLER & KAZADI (1990) that this juvenile specimen (SVL 27.1 mm) is an *Aubria*, but in such poor condition (dehydrated, large parts of animal lacking, colours completely faded) that a determination on species level is impossible (M.-O. RÖDEL, unpubl. data). An *Aubria* record from Angola (PERRET 1996) remains of uncertain taxonomic status (probably the source of an Angolan *A. masako* record in CHANNING 2001 and GAA).

Fig. 4. Unnamed *Astylosternus* species from Ankasa Conservation Area.

Amnirana occidentalis PERRET, 1960 is a rarely encountered primary rainforest frog (RÖDEL & BANGOURA 2004) with a very patchy distribution in the Upper Guinean forest zone (GAA). In Ghana, this species so far was only known from Kakum National Park [ZMUC 73577, adult female, SCHIØTZ (1964) as *A. albolabris*; PERRET 1983 referring to SCHIØTZ's specimen). We herein add records from ACA (juvenile, SVL 18 mm) and BT (adult male, SVL 58.8 mm).

The leaf litter frog *Phrynobatrachus annulatus* PERRET, 1966 was recorded from DR and BT. It so far was only known from Taï forest in Ivory Coast, the Monts Nimba range and the Bobiri forest in Ghana (GUIBÉ & LAMOTTE 1963, PERRET 1988, RÖDEL & ERNST 2004). Our records provide a first link bridging the gap between known localities. Preferred habitats and natural history data of this species remain elusive. However, the few sightings most often were in drier parts of true rainforest and hence might argue in favor of a reproductive mode independent from open water (cf. RÖDEL & ERNST 2002a).

Phrynobatrachus ghanensis SCHIØTZ, 1964 was previously only known from Kakum and Bobiri forest reserves (SCHIØTZ 1964a, PERRET 1988). We recorded this small leaf litter frog in ACA, DR and BT (SVL males: 13.4-14.1 mm, N = 4; females: 16.0-19.6 mm, N = 4). Furthermore, we are aware of unpublished records from Banco National Park, Ivory Coast. Hence, *P. ghanensis* occurs in the heavily fragmented forests from south-western Ghana to south-eastern Ivory

Fig. 5. Dorsal (above) and ventral (below) aspect of unnamed *Arthroleptis* from Krokosua Hills Forest Reserve.

Fig. 6. a. Juvenile *Acanthixalus sonjae* (SVL 24 mm) from Ankasa Conservation Area; b. *Hyperolius bobirensis* from Ankasa Conservation Area; c. *Hyperolius* cf. *fusciventris lamtoensis* female from Ankasa Conservation Area (SVL 47 mm); d. *Hyperolius laurenti* from Draw River Forest Reserve.

Coast. Two calling males and one female were recorded on 25 October 2003 at around 10:30 h at DR. Males were calling in the vicinity of small puddles in a comparatively open area at the reserve boundary in close vicinity to previously cultivated land. The call was not recorded; however, its tonal quality seemed to be very similar to the calls from *P. phyllophilus* Rödel & Ernst, 2002. Similar to the previous species males were never observed calling completely exposed. Additional individuals were recorded on 10 October 2003 at around 15:30 h at BT. This species might be confused with several other small *Phrynobatrachus* species. It differs from *P. villiersi* Guibé, 1959 and *P. taiensis* Perret, 1988 by the absence of an eyelid cornicle and the different ventral coloration (larger, partly fused black spots on whitish background). It differs from *P. guineensis* Guibé & Lamotte, 1961 and *P. phyllophilus* by more reduced webbing and the ventral coloration. Schiøtz (1964a) states that *P. ghanensis* lacks a Λ shaped wart on the neck. However, such warts are clearly discernible in live specimens (see also Fig. 11 in Perret 1988). Rödel & Ernst (2002b) list differences between *P. guineensis*, *P. phyllophilus* and

parameter	measures
number of notes	1
time between calls [s]	1.252 ± 0.111, 1.095 - 1.322
lower frequency [Hz]	2372.3 ± 48.6, 2331.8 - 2429.0
upper frequency [Hz]	3991.6 ± 71.8, 3918.8 - 4080.7
fundamental frequency [Hz]	3211.3 ± 55.2, 3154.0 - 3261.0
call duration [s]	0.069 ± 0.009, 0.057 - 0.0784
delta frequency [Hz]	1619.3 ± 59.1, 1554.6 - 1684.1
max power [db]	133.1 ± 1.5, 130.8 - 134.0

Tab. 2. Acoustic properties (mean ± SD, range) of advertisement calls (sample rate 48000.0 Hz) of four *Hyperolius laurenti* males from Draw River Forest Reserve. Given are mean ± standard deviation and range. All recordings were made at air temperatures between 24-26 °C (compare Fig. 7).

other described West African *Phrynobatrachus* species.

In ACA, we found an *Astylosternus* species (Fig. 4) that is neither conspecific with *A. occidentalis* PARKER, 1931, ranging from western Ivory Coast to Sierra Leone (GAA; for color pictures see BÖHME 1994, RÖDEL & BRANCH 2002), nor with *A.* sp. from Mont Péko in Ivory Coast (RÖDEL & ERNST 2003), nor with *A. diadematus* WERNER, 1898, whose distribution stretches from Cameroon into easternmost Nigeria (M. GARTSHORE, unpubl. photo record) or any other described Central African *Astylosternus* species (AMIET 1977; M.-O. RÖDEL and colleagues, unpubl. data). Similar frogs have been collected by us in Banco National Park in Ivory Coast (M.-O. RÖDEL and colleagues, unpubl. data). We collected two specimens in ACA and a tadpole in DR, which most likely belong to this new species that will be described in a separate publication. HUGHES' (1988) listing of *A. occidentalis* from the Ghanaian forest zone probably also refers to this undescribed species.

species	number
Geotrypetes seraphini	1
Silurana tropicalis	2
Bufo maculatus	16
Phrynobatrachus alleni	2
P. annulatus	1
P. ghanensis	1
Arthroleptis spp.	10
total	33

Tab. 3. Amphibians caught in trap arrays at Ankasa Conservation Area, Draw River, Boi-Tano, and Krokosua Hills.

Preliminary analysis of a fragment of the mitochondrial 16S rRNA gene revealed that we recorded three distinctly different *Arthroleptis* or *Schoutedenella* taxa in DR (A. HILLERS and colleagues, unpubl. data; for a discussion of the *Arthroleptis* and *Schoutedenella* problem see LAURENT 1954, POYNTON 2003a). All these taxa are morphologically similar, but genetically distinct to *Arthroleptis* or *Schoutedenella* from: the Volta region (RÖDEL & AGYEI 2003), the Banco National Park in eastern Ivory Coast (M.-O. RÖDEL, unpubl. data), western, central and northern Ivory Coast (RÖDEL 2000, RÖDEL & BRANCH, RÖDEL & ERNST 2003), south-eastern Guinea (RÖDEL & BANGOURA 2004, RÖDEL et al. 2004). Due to the large intraspecific variation of morphological characters in these frogs and the small interspecific differences, it is impossible to assign an available name to one of the DR taxa (cf. discussion in RÖDEL & AGYEI 2003, RÖDEL & BANGOURA 2004). Unfortunately, no vouchers of these small *Arthroleptis* or *Schoutedenella* have been collected in BT and KH. We collected 14 specimens of *Arthroleptis* sp. in ACA; however, without so far analyzing them genetically. Calls in BT and KH seem to be similar to those frogs from DR, but without call recordings and genetic material it is impossible to judge if one, all or none of the DR taxa occur in the other forests. It might be added that after the examination of the Holotype of *Arthroleptis*

region	daily/weekly	samples	Jack-knife 1		Chao2	
			mean	SD	mean	SD
Ankasa	weekly	11	46.6	3.9	52.2	17.9
Ankasa	daily	5	28.4	2.4	31.8	16.5
Draw River	daily	7	38.3	3.4	35.4	6.8
Boi-Tano	daily	4	31.8	3.8	30.8	7.7
Krokosua	daily	8	35.4	5.3	43.9	23.2

Tab. 4. Estimated species richness of amphibians in the Ankasa Conservation Area, Draw River, Boi-Tano and Krokosua Hill Forest Reserves. Calculations were based on the daily or weekly species lists of the respective areas. Given are mean and standard deviation values of 500 random runs (compare text and Fig. 9).

brevipes AHL, 1924 (ZMB 26978 from Bismarckburg, Togo), it is at least clear that the Volta *Arthroleptis* of RÖDEL & AGYEI (2003) are not conspecific with this taxon. *Arthroleptis brevipes* indeed is an *Arthroleptis* but is much larger (SVL 30.8 mm) than the Volta frogs of RÖDEL & AGYEI (2003). It differs from all other West African *Arthroleptis* or *Schoutedenella* that we have seen so far by having a more slender body with nearly parallel flanks, remarkably short legs, and blunt snout. The types of *A. zimmeri* (ZMB 8389, 27806 from Accra, Ghana) and *A. poecilonotus* PETERS, 1863 (ZMB 3345 from "Holländischen Besitzungen, Boutry, an der Küste von Guinea", Ghana) are in such bad condition (dried or inflated, respectively) that measurements are meaningless.

In addition, we found a large *Arthroleptis* (MOR KHA0103, SVL 42.9 mm) on the slopes of a hill at KH, which resembles none of the described West African arthroleptids (Fig. 5). In a preliminary genetic analysis, this specimen clustered with samples assigned to *A. stenodactylus* PFEFFER, 1893 from Uganda and undetermined material from Central African Republic; however, being genetically distinct from these samples (A. HILLERS and colleagues, unpubl. data). This presumably new taxon seems to have its closest relatives within the large East African *Arthroleptis* forms (cf. POYNTON 2003b) and will be dealt with in detail in another publication.

At KH and ACA, the hyperoliid genus *Acanthixalus* was recorded for the first time in Ghana. The recorded specimens, juveniles (Fig. 6a) and tadpoles, were morphologically and genetically identical (only three substitutions in a fragment of the mitochondrial 16S rRNA gene, J. KOSUCH & M.-O. RÖDEL, unpubl. data) compared to *Acanthixalus sonjae* RÖDEL, KOSUCH, VEITH & ERNST, 2003 from western Ivory Coast. This species was only known from a small range in the south-western corner of the latter country (RÖDEL & BRANCH 2002, RÖDEL et al. 2003) and hence classified as Endangered by the GAA. Its occurrence in Ghana and the selection of wet evergreen (Taï region, ACA) and moist semi-deciduous forest (KH) advocate a much larger distribution area. Due to its reclusive life within large, water-filled tree-holes it probably has been overlooked in other forests. Taking into account that (i) its extent of occurrence is much larger than previously thought, but (ii) the species surely depends on old-standing forest, a new classification as Near Threatened seems to be more appropriate.

Afrixalus fulvovittatus COPE, 1860 was described from Liberia (COPE 1860), as was *A. vittiger* (PETERS, 1876), the latter long treated as a synonym of the former (e.g. SCHIØTZ 1967; "type A" of SCHIØTZ 1999). PERRET (1976) recognized two distinct forms of striped West and Central African *Afrixalus*, assigning the one with a small, partly dotted black line in the clear bands to *A. fulvovittatus* ("type B" of SCHIØTZ 1999). For a detailed discussion of this taxonomic problem see RÖDEL (2000). More recent studies seemed to

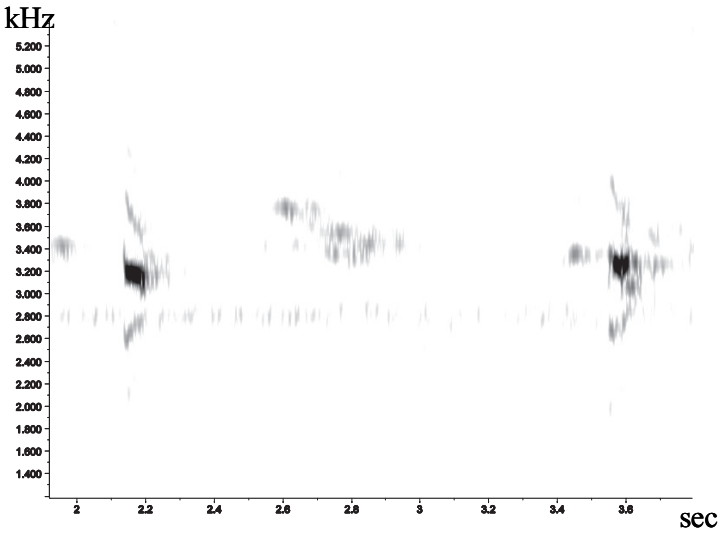

Fig. 7. Advertisement call of *Hyperolius laurenti* male from Draw River Forest Reserve (cf. Tab. 2).

confirm the presence of a "type B" */fulvovittatus* species in the West African forest/savanna ecotone, whereas real savannas are inhabited by "type A"/*vittiger* populations (RÖDEL & BANGOURA 2004, RÖDEL et al. 2004). The type materials of both taxa seem to confirm RÖDEL's (2000) treatment of the names (M. PICKERSGILL pers. comm.). In ACA, we found *A. fulvovittatus* ("type B", female SVL 30 mm, weight 1.25 g) along the powerline corridor.

Hyperolius bobirensis SCHIØTZ, 1967 is a large West African reed frog, so far only known from stagnant forest ponds at its type locality the Bobiri Forest Reserve (SCHIØTZ 1967, HOOGMOED 1980). We found this species in ACA (Fig. 6b). Four males, all with typically warty backs, measured 33-35 mm SVL.

In addition to typical *Hyperolius fusciventris burtoni* (BOULENGER, 1883), we recorded an unusual female from ACA (Fig. 6c). It displayed the coloration typical for *H. f. lamtoensis* SCHIØTZ, 1967 females: green back, red canthal stripe, red-whitish marbling on lower flank, green lower leg, red thighs, whitish foot and hands with small black spots, yellowish green discs, white throat and belly with grayish red marbling. *Hyperolius f. lamtoensis* is supposed to occur only in eastern and central Ivory Coast (SCHIØTZ 1967, 1999, RÖDEL 1998). Even more astonishing, however, was its size, measuring 47 mm SVL. None of the known females of the *H. fusciventris* complex ever measured more than 30 mm (RÖDEL 1998, SCHIØTZ 1999). Most likely this female only represents an extremely large *H. f. lamtoensis*. Eleven vouchers from ACA exhibited "- normal - " sizes (SVL males: 21-22 mm, N = 3; females: 28-31 mm, N = 8). These females exhibited the *H. f. lamtoensis* color pattern as well. This would speak in favor of the sympatric occurrence of two *H. fusciventris* "subspecies", as already observed in western Ivory Coast (sympatric occurrence of *H. f. fusciventris* PETERS, 1876 and *H. f. lamtoensis*), and would thus be a further hint for the specific distinctiveness of these three taxa (RÖDEL & BRANCH 2002).

Hyperolius laurenti SCHIØTZ, 1967 was described from eastern Ivory Coast to central Ghana. Besides its description no data on this medium sized frog have been published. We recorded this species in all wet evergreen forests investigated (ACA, DR, BT; Fig. 6d).

Males measured 26.7-33.0 mm SVL, two females measured 38.0 mm SVL. The frogs always had the characteristic white spot on the heel, however, sometimes smaller than illustrated in SCHIØTZ (1967, 1999). Most males showed SCHIØTZ's (1967) color phase F. In DR and BT, individuals began calling with the onset of darkness. Calling activity peaked between 19:30 h and 20:00 h. Activity decreased subsequently. Calling sites were usually located in heights of 3-4 m in trees overhanging water of swiftly flowing creeks in rainforest. In ACA, males were calling from lower sites (120-130 cm above ground) in similar habitats. The *H. laurenti* advertisement call consists of a high-pitched single note with a major harmonic at around 3000 Hz and additional distinct harmonics at around 2500 (lower harmonic) and 3600 (upper harmonic) Hz. These harmonics show complex patterns of intensity maxima (cf. Tab. 2 and Fig. 7).

Hyperolius viridigulosus SCHIØTZ, 1967 was described from central-southern Ivory Coast to central Ghana. After its description no additional data have been published. We recorded this species in all wet evergreen forests investigated, most often near forest streams (ACA, DR, BT). Males measured 30.5-31.2 mm SVL and thus were in the lower range of measures given by SCHIØTZ (1967: 32-37 mm SVL). So far no females were known. A female from DR measured 29.9 mm SVL. Its coloration is shown in Figure 8. Another female from ACA measured 36 mm SVL and also showed a yellow venter. It had a beige to reddish back, dark lower flank line, red legs, and spines on neck.

Phlyctimantis boulengeri PERRET, 1986 was recorded from ACA. It is the first record of the genus from Ghana. PERRET (1986) described *P. boulengeri* from Cameroon (type locality: Fainchang, Mamfe region) and Ivory Coast (RÖDEL & ERNST 2001), separating it from the exclusively Central African *P. leonardi* (BOULENGER, 1906). SCHIØTZ (1999) and LÖTTERS et al. (2001) mention on differences between the Cameroonian and West African populations of *P. boulengeri*, the latter possibly representing an undescribed species. Males measured 52-59 mm SVL (mean = 54.8 mm, N = 9). One gravid female measured 52 mm SVL. One metamorph measured 23.5 mm SVL.

Fig. 8. Dorsal (above) and ventral (below) aspect of female *Hyperolius viridigulosus* from Draw River Forest Reserve.

In addition to the discovery of the aforementioned forest specialists, a number of typical farmbush [e.g. *Bufo maculatus* HALLOWELL, 1855, *Afrixalus dorsalis* (PETERS, 1875), *Hyperolius concolor* (HALLOWELL, 1844)] or even savanna species [*Bufo regularis* REUSS, 1833, *Hoplobatrachus occipitalis* (GÜNTHER, 1858), *Ptychadena oxyrhynchus* (SMITH, 1849), *Phrynobatrachus accraensis* AHL, 1925] were recorded (SCHIØTZ 1967, RÖDEL 2000). This indicates that all forest reserves have already been invaded by species that are not normally present in real forest situations (compare RÖDEL & BRANCH 2002).

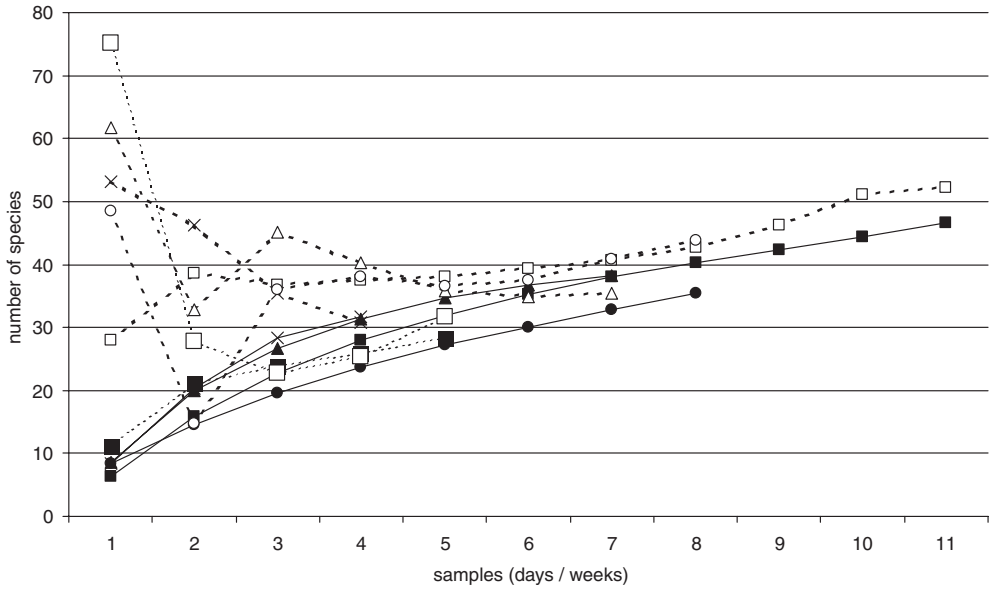

Fig. 9. Amphibian species richness estimations (Jack-knife 1 estimator: closed symbols; solid lines; Chao2 estimator: open symbols; stippled lines) of records from Ankasa Conservation Area (squares; large squares: daily species lists 2003; small squares: weekly species lists 2004). Draw River (triangles; daily species lists). Boi-Tano (crosses; daily species lists) and Krokosua Hill Forest Reserve (circles; daily species lists). Given are mean values of 500 random runs. For exact values and standard deviation see Table 4.

Species richness, sampling efficiency and species composition

In total, 47 amphibian species, 46 anurans and one caecilian have been recorded in the course of our surveys (Tab. 1). In DR, BT and KH, 39 amphibian species belonging to seven families were recorded employing VES, whereas AES only yielded 24 species, belonging to three families. However, AES was an important tool, especially for most arboreal anurans that vocalized frequently but were rarely encountered otherwise (e. g. *Leptopelis* spp.). Pitfall traps along drift fences captured seven species belonging to five families. Trapping success was very variable, depending on particular locations. A total of 33 amphibians have been captured, comprising 30 leaf litter frogs, an aquatic frog (*Silurana tropicalis* GRAY, 1864 two specimens) and a fossorial caecilian [*Geotrypetes seraphini* (DUMÉRIL, 1859)]. The latter two species representing two families not recorded otherwise (Tab. 3). During the RAP, the frog family Astylosternidae was recorded by dip-netting only. We calculated the approximate total number of amphibian species occurring at each site. Still increasing slopes indicates that additional amphibian species remain to be discovered within the study sites (Fig. 9).

Several species that, according to literature, occur in western Ghanaian forests could not be recorded by us. This concerns the two toad species *Bufo superciliaris* BOULENGER, 1888 and *B. togoensis* AHL, 1924 recorded by SCHIØTZ (1964a) in Kumasi and Kakum, respectively (the latter assigned to *B. cameronensis* by A. SCHIØTZ). HUGHES (1988) lists the farmbush species *Ptychadena bibroni* (HALLOWELL, 1845) as occurring in the forest zone (termed *P. maccarthyensis* in his paper). *Phrynobatrachus batesii* (BOULENGER, 1906)

was recorded from Kakum forest by SCHIØTZ (1964a, b). However, the taxonomic status of this record should be verified as a Ghanaian occurrence of this basically Central African species seems to be doubtful. A record of *Phrynobatrachus villiersi* from Kumasi (SCHIØTZ 1964a) was confirmed by PERRET (1988). Otherwise this species has so far only been recorded from south-eastern and south-western Ivory Coast (GAA; cf. RÖDEL & ERNST 2004). We also failed to record *Kassina arboricola* PERRET, 1985 that is known to occur from central Ghana to central-western Ivory Coast (SCHIØTZ 1964a, 1967, PERRET 1985, RÖDEL et al. 2002) and *Afrixalus vibekae* SCHIØTZ, 1967, ranging from central Ghana into western Ivory Coast (SCHIØTZ 1967, 1999, RÖDEL & BRANCH 2002). However, according to our calculations we were able to record about 66-85% of the species living in this region (Tab. 4, Fig. 9).

In contrast to large mammals, habitat size per se does not seem to be as important in conserving amphibian diversity as habitat diversity (R. ERNST & M.-O. RÖDEL, unpubl. data). This may be one of the reasons why both diversity and species composition in the areas under investigation indicate a high potential in preserving amphibian species typical for the Upper Guinean forest region. We recorded 36-40 amphibian species in ACA, 28 species in DR, 21-24 species in BT and 21-24 species in KH, respectively (Tab. 1; range is given because of uncertainty in *Arthroleptis* species numbers). With a total of 47 species recorded and an additional seven species likely to occur, the species richness of the region under investigation can be considered high. This is especially true when compared to the most diverse West African regions so far investigated, western Ivory Coast and south-eastern Guinea (RÖDEL & ERNST 2004, RÖDEL et al. 2004). Although the recorded species richness does not completely reach the level of the latter regions, there is a high resemblance in the species composition, with other West African sites. In a species similarity analysis (based on presence/absence data) including all other well known West African amphibian assemblages (M.-O. RÖDEL & M. WEGMANN, unpubl. data), the western Ghanaian forests cluster together. These forests are most similar to a small cluster comprising Banco National Park and Mont Péko National Park (RÖDEL & ERNST 2003). The latter two forests are situated in eastern and central Ivory Coast, respectively. These two clusters group together with a cluster comprising the western Ivorian forests, namely Taï National Park and the Haute Dodo and Cavally Forest Reserves (RÖDEL & BRANCH 2002, RÖDEL & ERNST 2004). Hence, the western Ghanaian forests are (i) clearly characterized as comprising a distinct anuran assemblage but (ii) also clearly form part of the Upper Guinea forest anuran assemblage. In all these three clusters (western Ghana, eastern and central Ivory Coast, western Ivory Coast) the vast majority of the species were either Upper Guinean rain forest endemics or at least restricted to West Africa (defined as the region from Senegal to eastern Nigeria, Tab. 1). Only about a third of the species recorded by us (34.0%), have distributions that exceed West Africa. Almost two thirds (65.9%) of the species are endemic to West Africa and 44.6% are even restricted to the Upper Guinean Forest zone or smaller parts of this zone (Tab. 1). The occurrence of a distinct western Ghanaian assemblage, characterized by many unique and range restricted species, as well as, in comparison to other Ghanaian sites high species richness (cf. RÖDEL & AGYEI 2003 for review) is also apparent in other groups of organisms, mainly plant species. The distance to postulated refugia was the foremost important factor explaining the spatial patterns in West African tree species diversity (WIERINGA & POORTER 2004). The latter authors found that plant diversity was even richer around ACA, compared to the most often mentioned position of a Pleistocene forest refugium around Cape Three Points and hence support the idea of a refugium, situated a bit further to the West (FALK et al. 2003). Our findings add support to the latter theory.

Conclusions and conservation recommendations

Logging activities in West Africa date back to the 16th century when the first *Lophira alata* tree samples were sent to the United Kingdom. The first trunks of African mahogany appeared in Britain in 1833, and from 1878 onwards the export of wood from West Africa steadily increased, e.g. Ghana exported 88,200 m³ mahogany in 1913 (PARREN & DEGRAAF 1995). In Ghana, shifting agriculture probably occurred for centuries. However, the rate of deforestation highly increased about a century ago because of timber demands for newly mechanized gold mines, development of communications and a rapidly expanding area of farmland, including cocoa plantations (HAWTHORNE & ABU JUAM 1995). As far back as the 1920's and 1930's, foresters in Ghana demarcated and placed under management 280 forests for the purpose of ensuring the sustainable use of Ghana's forest resources and the preservation of forests with important roles as watersheds and windbreaks (PARREN & DEGRAAF 1995, DECHER in press). The forests investigated during the RAP have been managed as productive forests, but were reclassified by the Government of Ghana as Globally Significant Biodiversity Areas (GSBAs). In principle no logging or hunting should take place in GSBAs.

Despite the early awareness of the necessity to preserve the natural forests, nowadays Ghana only possess about 11.8-14.5% of its former forest cover (UICN 1996, POORTER et al. 2004b). Virtually all remaining forests in reasonable condition are old designated reserves. The forests surveyed showed that various degrees of selective logging have taken place, but in most the possibility of regenerating to high forest is maintained (DECHER in press).

The amphibian species composition of western Ghanaian forests reported herein was typical for the eastern part of the Upper Guinea forest zone. However, the presence of typical farmbush and even savanna species is a clear indication that the forests were already seriously degraded. This concerns in particular the obviously unsustainable forest management. Habitat loss through illegal plantations and encroachment is a major concern in all of the areas visited. It is most dramatic at KH, where virtually the entire low-lying forests were disturbed due to well established illegal plantation (mainly subsistence farming and cocoa plantations), with forest only on steep slopes remaining relatively intact. Continued logging activities also lead to high levels of disturbance and severe alteration in microclimate and water balance. Due to their physiology and biphasic lifecycle, amphibians are especially susceptible to these alterations and thus prone to local extinctions. Although habitat size per se may not be of outmost importance for the protection of amphibians, habitat diversity, which is important, is likely to increase with habitat size. A minimum habitat size is also essential to maintain ecosystem functions that determine e.g. climatic conditions and thereby directly affect amphibians. Our observations clearly proved that some of the invasive species are already well established within the forests reserves. It is not unlikely that they will compete and eventually displace true forest species. Highest priority should thus be given to impede or strictly control ongoing encroachment and illegal farming activities, as well as logging and road building within these reserves.

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Appendix 1

Locality list and short habitat characterization of amphibian record sites in the Ankasa Conservation Area (ACA), Draw River (DR), Boi-Tano (BT), and Krokosua Hills (KH) Forest Reserves.

Site	Latitude (N)	Longitude (W)	Description
ACA1	5°16'54.22"	2°38'24.79"	bamboo cathedral forest, small river with sandy bottom, nearby closed canopy forest
ACA2	5°16'54.55"	2°38'29.04"	Nkwanta Camp, open area bordered by dense vegetation and large trees
ACA3	5°16'55.04"	2°38'28.02"	bucket trap line
ACA4	5°17'24.14"	2°38'22.45"	Medium pond surrounded by thick vegetation, nearby deforested powerline corridor

ACA5	5°17‘3.62"	2°38‘54.99"	medium pond surrounded by thick vegetation, near trail through forest
DR1	5°09‘41.95"	2°23‘31.16"	small rainforest creek with quartzite bottom and rocky outcrops, foot of small hill
DR2	5°11‘58.35"	2°23‘33.59"	fast flowing granitic bottom creek with small pools
DR3	5°10‘05.36"	2°23‘37.32"	swampy area in vicinity of reserve boundary line, bordered to the left by clear-cut area.
DR4	5°10‘08.53"	2°23‘37.42"	small partially stagnant quartzite bottom creek, bordered by dense vegetation and extensive swampy area
DR5	5°11‘47.67"	2°23‘49.12"	dry closed canopy forest uphill area app. 500 m away from next creek
DR6	5°11‘47.54"	2°23‘53.12"	bucket trap line
DR9	5°11‘34.87"	2°24‘16.10"	plantation, mainly cocoa and banana/plantains, several swamps and stagnant creek
DR10	5°11‘35.49"	2°24‘26.08"	base camp, open area, clearing near village
BT1	5°31‘55.58"	2°37‘07.26"	base camp, open area bordered by cocoa plantations
BT2	5°31‘38.04"	2°37‘14.43"	stagnant irrigation canal between access road and cocoa plantation extending in swampy area
BT3	5°31‘30.59"	2°37‘22.50"	bucket trap line
BT4	5°31‘19.79"	2°37‘23.95"	bucket trap line
BT5	5°31‘08.94"	2°37‘25.72"	dry closed forest uphill area
BT6	5°31‘44.22"	2°37‘31.32"	small creek at bottom of steep descent near reserve boundary line, flooded pool
BT7	5°31‘13.80"	2°37‘32.10"	bucket trap line
BT8	5°31‘09.00"	2°37‘40.30"	small gravel bottom rainforest creek in closed canopy forest, fast running segments alternating with larger pools
BT9	5°32‘06.16"	2°37‘46.97"	swampy area near reserve boundary line, bordered to the right by plantation area
BT10	5°32‘32.75"	2°38‘06.95"	dry closed forest uphill area
BT11	5°30‘27.30"	2°38‘26.34"	medium pond at bottom of steep descend next to access road, open area, no canopy above pond
KH1	6°37‘01.23"	2°50‘29.75"	permanent pond between access road and forest edge
KH2	6°35‘35.39"	2°50‘36.39"	large water filled holes in buttress root, hilltop (480 m above sea level), SE of base camp
KH3	6°36‘33.08"	2°50‘48.58"	bucket trap line
KH4	6°36‘31.73"	2°50‘53.87"	bucket trap line
KH5	6°36‘50.09"	2°50‘58.31"	base camp, open area, clearing near village
KH6	6°36‘36.28"	2°51‘01.44"	small creek with large stagnant pools, used for irrigation and water supply by local villagers, vicinity to cocoa plantations
KH7	6°36‘37.04"	2°51‘02.35"	stagnant pool within creek, dense vegetation
KH8	6°36‘36.75"	2°51‘05.17"	steep hill W of base camp, dry forest
KH9	6°36‘31.73"	2°51‘28.15"	bucket trap line
KH10	6°35‘58.18"	2°52‘24.94"	SW-extension of reserve, closed canopy forest patch between extensive cocoa plantation and settlement
KH11	6°35.970'	2°50.705'	steep hill SE (300 m above sea level) of base camp, dry forest, granitic outcrops, thick leaf litter

Appendix 2

List of voucher specimens collected in Ankasa Conservation Area (ACA), Draw River (DR), Boi-Tano (BT), and Krokosua Hills (KH) Forest Reserves, Ghana. Vouchers stored in the collection of the Museum of Vertebrate Zoology, Berkley (MVZ) and the research collection of the senior author:

Gymnophiona, Caecilidae, *Geotrypetes seraphini*: DR: DRC0103. **Amura, Pipidae**, *Silurana tropicalis*: KH: KHP0103, ACA: MVZ

245093-97, MVZ 245420; **Bufonidae**, *Bufo maculatus*: BT: BTB0103.1, BTB0103.2, DR: DRB0103, ACA: MVZ 244923-25, MVZ 244944-45, MVZ 244942; **Hemisotidae**, *Hemisus* cf. *guineensis*: KH KHHE0103; **Ranidae**, *Amnirana albolabris*: DR: DRR0503, ACA: MVZ 245205-18; *A. occidentalis*: BT: BTR0203; *Aubria subsigillata*: BT: BTR0303; *Ptychadena aequiplicata*: DR: DRR0603, KH: KHR0203, KHR0303, KHR0403.1-2, ACA: MVZ 245196; *P. longirostris*: DR: DRR1203, DRR1303, ACA: MVZ 245181-89, MVZ 245424; *P. mascareniensis*: ACA: MVZ 245190; *P. oxyrhynchus*: DR: DRR1703; *P. pumilio*: DR: DRR0403, ACA: MVZ 245191-92, MVZ 245426; **Petropedetidae**, *Phrynobatrachus accraensis*: DR: DRR0703; *P. alleni*: DR: DRR0103, DRR0203, DRR0903, DRR1003, ACA: MVZ 245169-76; *P. annulatus*: DR: DRH1103, DRR1803; *P. calcaratus*: KH: KHR0103.1, KHR0103.2; *P. ghanensis*; BT: BTR0503, DR: DRR1403, DRR1503, DRR1603, ACA: MVZ 245149; *P. gutturosus*: BT:BTR0103, KH: KHR0103.1-3; *P. liberiensis*: DR: DRA0303, DRR0308; *P. plicatus*: DR: DRR1903, ACA: MVZ 245164-67; *P. tokba*: BT: BTR0403; **Arthroleptidae**, *Arthroleptis* sp. nov.: KH: KHA0103; *Arthroleptis* spp.: DR: DRA0103, DRA0203, DRA0303, DRA0403-04, DRA0603, DRA0703, ACA: MVZ 244895-908; *Cardioglossa leucomystax*: DR DRA0503, ACA: MVZ 244911; **Astylosternidae**, *Astylosternus* sp. nov.: ACA: MVZ 244909-10; **Hyperoliidae**, *Acanthixalus sonjae*: KH: KHH0303.1; *Afrixalus dorsalis*: DR: DRH0303, DRH0403, DRH0503, ACA: MVZ 244948-67, MVZ 245398, MVZ 244977; *A. nigeriensis*: KH: KHH0303; *Hyperolius concolor*: DR: DRH1303, DRH1403, DRH1603, ACA: MVZ 244989-006, MVZ 245405; *H. fusciventris burtoni*: BT: BTH0203.1, BTH0203.2, BTH0203.3, DR: DRH1203; *H. fusciventris lamtoensis*: ACA: MVZ 245007-12, MVZ 245406-08; *H. guttulatus*: ACA: MVZ 245013-30, MVZ 245409; *H. laurenti*: BT: BTH0103, DR: DRH0803, DRH0903, DRH1003, DRH1103, DRH1703, DRH1803; *H. sylvaticus*: BT: KHH0103.1, KHH0103.2, ACA: MVZ 245056-57, MVZ 245064; *H. viridigulosus*: DR: DRH2003, DRH0703, DRRH0603; *Leptopelis hyloides*: BT: KHH0203, DR: DRH1903; *L. macrotis*: DR: DRH1503; *L. occidentalis*: DR: DRH0103, DRH0203, ACA: MVZ 245412, MVZ 245067-68; *Phlyctimantis boulengeri*: ACA: MVZ 245083-92, MVZ 245416; **Rhacophoridae**, *Chiromantis rufescens*: DR: DRRC0103.

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