A Rapid Survey of the Amphibians from the Atewa Range Forest Reserve, Eastern Region, Ghana

Authors: Kouamé, N'goran Germain, Ofori Boateng, Caleb, and Rödel, Mark-Oliver

Source: A Rapid Biological Assessment of the Atewa Range Forest Reserve, Eastern Ghana: 76

Published By: Conservation International

URL: https://doi.org/10.1896/054.047.0114

Chapter 9

A apid ur ey of he amphibians om he ewa Range ores eser e, Eas ern egion, hana

N'goran Germain Kouamé, Caleb Ofori Boateng and Mark-Oliver Rödel

SUMMARY

We report the results of the first rapid amphibian survey in the Atewa Range Forest Reserve. We recorded a total of 32 species, but predict that overall species richness of the area can be expected to reach 40-50 species. The amphibian community of the Atewa Range is exceptional in that it comprises a) almost exclusively forest species and hence indicates a very intact forest ecosystem, b) a species mixture including species that, prior to our survey, were known only from either east or west of this site, c) a very high percentage of species that are endemic to the Upper Guinea forests or even much smaller parts of these forests, and d) an extremely high proportion of threatened species (almost one-third are ranked as threatened on the IUCN Red List). For one Critically Endangered species (*Conraua derooi*) the Atewa Range is likely to harbor the largest remaining populations. In summary, the Atewa Range clearly represents an exceptional site for the maintenance of West African amphibian diversity in particular and outstanding biodiversity in general. We urgently recommend an upgrading of its protection status to a national park and conclude that any exploitative activity in this area would have devastating effects to this irreplaceable ecosystem of national and regional importance.

INTRODUCTION

The Guinean Forests of West Africa rank as one of 34 global biodiversity hotspots (Bakarr et al. 2004). Within the western part of this region, mountainous forests are under particular pressure as montane habitats are a) extremely restricted in extent and b) almost all the focus of actual or planned mining activities. Within the Upper Guinea Highlands, larger areas of mountain forest are limited to eastern Sierra Leone, northern Liberia, south-eastern Guinea and western Côte d'Ivoire. These montane forest areas are unique ecosystems with exceptional species richness and high levels of endemism in general (Bakarr et al. 2004), and for amphibians in particular (Guibé and Lamotte 1958, 1963; Laurent 1958; Lamotte 1971, Rödel et al. 2004). In-between the Upper Guinea Highlands and the Cameroon Highlands, another hotspot of amphibian diversity (Gartshore 1986), only the Atewa Range in Ghana, the Volta Highlands in the Ghanaian/Togolese border region, and the Jos Plateau in Nigeria harbor significant upland forest patches. However, of these three areas, moist evergreen forest is found only in the Atewa Range (Swaine and Hall 1977). This area was designated a national forest reserve in 1925 and has recently been designated as a Globally Significant Biodiversity Area (GSBA), as well as an Important Bird Area (IBA) (Abu-Juam et al. 2003). The Priority-Setting Workshop for Upper Guinea ranked the Atewa Range Forest Reserve (Atewa) to be of "Very High" priority for overall biodiversity conservation. The participants recommended updating the scientific information of this area through surveys. An improved protection of the area seemed to be desirable (Bakarr et al. 2001). Although the scientific knowledge of the Atewa Range is still fragmentary, it has recently been the focus of mineral exploration, making a comprehensive survey of the biological richness more pressing than ever.

Atewa (23,665 ha) is located in the Eastern Region of Ghana and comprises a third of

the remaining closed forest there (Mayaux et al. 2004). The mountain range (highest peak 842 m a.s.l.) runs roughly from north to south with numerous plateaux separated by steep gorges. The misty conditions on the plateaux are the basis for a unique floristic composition here known as Upland Evergreen Forest (Swaine and Hall 1977). Hence, many plant species have their only Ghanaian record from Atewa and several butterfly species are endemic to the range (Larsen 2006). The northern part of the reserve is situated in the wet semi-equatorial climatic zone, with two wet seasons from May to July and from September to October/November with an annual precipitation of about 1650 mm. In addition to the upland forest, seasonal marshy grasslands, swamps and thickets are also thought to be nationally unique (Hall and Swaine 1981). Although most parts of the forest reserve are still in good condition, disturbance-indicating invasive species like *Chromolaena odorata* can be found along roads or other artificial openings of the forest.

This survey focused on the amphibians of Atewa, as this group generally seems to allow for a reliable judgment of the status of West African forests (Rödel and Branch 2002, Ernst and Rödel 2005, Ernst et al. 2006). Because standardized methods exist for estimating amphibian species richness, they are accurately assessable in a short time and with comparatively less effort (Heyer et al. 1994, Rödel and Ernst 2004). Furthermore, in tropical forests throughout the world, amphibians (i.e. anurans) comprise a significant portion of the vertebrates, and in these ecosystems they are important, both as predators and as prey (Inger 1980a, b; Duellman 1990). The whole taxonomic group is especially threatened by habitat degradation and conversion (Stuart et al. 2004). Recent amphibian surveys in Ghana revealed much higher species diversity than expected, including various recently or still undescribed taxa (Rödel and Agyei 2003, Rödel et al. 2005a, Leaché et al. 2006). Prior to our survey, the Atewa Range had not previously been sampled for amphibians.

METHODS

Our survey was undertaken from 6-22 June 2006 and covered three different areas within the Atewa range: Atiwiredu (06º12'22.7" N, 0º34'39.2" W, 817 m a.s.l.) was visited from 7-10 June, Asiakwa South (06º15'44.3" N, 0º33'18.8" W, 783 m a.s.l.) from 11-16 June, and Asiakwa North (06º16'16.1" N, 0º33'52.7" W, 814 m a.s.l.) from 17-22 June. Amphibians were mainly located opportunistically during day and night by visual and acoustic encounter surveys (Heyer et al. 1994, Rödel and Ernst 2004) of all habitats by two people (NGK, COB). Additional search techniques included refuge examination and dip-netting in all types of waters. As our sampling design provides only qualitative and semi-quantitative data we calculated the estimated species richness (and hence our sampling efficiency) with the Chao2 and Jack-knife 1 estimators (software: EstimateS, Colwell 2005). These estimators are incidence based, with calculations made using the presence/absence data of the daily species lists (13 days) for 32 species. To avoid order effects we performed 500 random runs of the daily species lists. Some voucher specimens were collected and killed using 1,1,1-Trichloro-2-methyl-2-propanol hemihydrate and preserved in 70 % ethanol. Vouchers and tissue samples are currently deposited in the research collection of M.-O. Rödel at Würzburg University, Germany and will be inventoried in the collection of the Natural History Museum Berlin later on (Table 9.1). Specimens not retained as vouchers were released at their original sites. The taxonomy is according to Frost et al. (2006).

RESULTS

Species richness

We recorded a total of 32 amphibian species, comprising one caecilian, *Geotrypetes seraphini*, and 31 anurans (Table 9.1). Richness of recorded species was highest in Atiwiredu (26 spp.), followed by Asiakwa South (23 spp.). Species richness was lowest in Asiakwa North (6 spp.). The overall species richness of Atewa hence was higher than that of known sites in the Volta-Togo region (Rödel and Agyei 2003, Leaché et al. 2006), but lower than in the Ankasa Conservation Area in western Ghana (Rödel et al. 2005a) and various other sites in Côte d'Ivoire and Guinea (Rödel and Branch 2002, Rödel et al. 2004). Although there seems to be a real gradient in amphibian species richness, with species numbers rising from the eastern to the western part of the Upper Guinean forests (Rödel and Agyei 2003; Rödel et al. 2004, 2005a), it can be taken as certain that we have not yet comprehensively assessed the Atewa amphibians. More intensive surveys, especially in areas and microhabitats not yet investigated, will result in an increasing number of species. Further species likely to be recorded in Atewa are *Leptopelis occidentalis*, *Amietophrynus superciliaris, Hydrophylax albolabris, Afrixalus dorsalis, Hyperolius concolor* and *H. laurenti*. The occurrence of *Astylosternus* sp., *Cardioglossa leucomystax, Leptopelis macrotis*, *Hyperolius viridigulosus, H. torrentis, Phlyctimantis boulengeri*, *Hydrophylax occidentalis*, *Phrynobatrachus annulatus*, *P. liberiensis* and *P. villiersi* also seems possible. We therefore estimate that the real number of amphibian species living in Atewa will probably be 40-50. This is also supported by our two species richness calculations (Figure 9.1). According to the Jack-knife 1 estimator 44.0 ± 4.7 species should occur in the area. The Chao2 estimator calculated 43.3 ± 8.8 species for Atewa. We hence recorded about 72.7% or 73.9% of the local species pool, respectively.

The huge differences in species richness between the three RAP sites are most likely due to differences in habitat variability. Whereas we searched many different microhabitats suitable for amphibians in Atiwiredu and Asiakwa South (small puddles, larger ponds, rivers, waterfalls and dense vegetation as well as partly broken canopy), the sites investigated in Asiakwa North were generally more uniform and relatively dry (i.e. no rivers, ponds or puddles present and almost exclusively inhabited by the direct-developing *Arthroleptis* sp. A and *Phrynobatrachus tokba*). In only a few valleys

Table 9.1. List of all amphibian species recorded during the Atewa RAP survey. For every species we indicate whether records are supported by a voucher (JP number), photos, or only call records, and at which sites the respective species was recorded. *Amietophrynus* is a new name for some African *Bufo*, this name and family assignation is according to Frost et al. (2006).

Taxa	Voucher / photo / calls	Atiwiredu	Asiakwa South	Asiakwa North
Gymnophiona				
Caecilidae				
Geotrypetes seraphini	JP 0028		x	
Anura				
Arthroleptidae				
Arthroleptis sp. A	JP 0012	x	x	x
Arthroleptis sp. B	JP 0019, JP 0027	x	x	
Leptopelis spiritusnoctis	JP 0004	x	x	
Bufonidae				
Amietophrynus maculatus	acoustic	x		
Amietophrynus togoensis	JP 0026	x		
Dicroglossidae				
Hoplobatrachus occipitalis	visual	x		
Hemisotidae				
Hemisus sp.	JP 0030		x	
Hyperoliidae				
Acanthixalus sonjae	JP 0017	x		
Afrixalus nigeriensis	JP 0021, JP 0042	x	x	
Afrixalus vibekensis	JP 0048		x	
Hyperolius baumanni	JP 0008, JP 0018, JP 0020, JP 0043, JP 0044	x	x	
Hyperolius bobirensis	JP 0005, JP 0007, JP 0047, JP 0050	x	x	
Hyperolius fusciventris	JP 0009	x	x	
Hyperolius guttulatus	JP 0045			x
Hyperolius picturatus	JP 0010, JP 0011	x	x	
Hyperolius sylvaticus	JP 0006	x	x	
Kassina arboricola	JP 0049	x	x	
Petropetedidae				
Conraua derooi	JP 0041.1-3		x	x
Phrynobatrachidae				
Phrynobatrachus accraensis	JP 0023	x		
Phrynobatrachus alleni	JP 0013	x		
Phrynobatrachus calcaratus	JP 0024	x	x	x
Phrynobatrachus ghanensis	JP 0015	x		
Phrynobatrachus gutturosus	JP 0014	x	x	
Phrynobatrachus plicatus	JP 0016	x	x	
Phrynobatrachus tokba	JP 0022	x	x	x
Pipidae				
Silurana tropicalis	JP 0025	x	x	
Ptychadenidae				
Ptychadena aequiplicata	JP 0002, JP 0004	x	x	x
Ptychadena bibroni	JP 0001	x		
Ptychadena longirostris	JP 0003	x	x	
Ranidae				
Aubria subsigillata	JP 0051		x	
Rhacophoridae				
Chiromantis rufescens	photos	x	x	
Total species (32)		**26**	**23**	**6**

here, shallow rills flowed over a number of very large granite rocks. After rainfall the water level here increased considerably to fast flowing creeks. Then *Conraua derooi* could be captured near or under the rocks.

Habitat requirements

The vast majority of the recorded species were forest specialists or at least species that require forest conditions (Table 9.2), hence representing a typical and intact forest fauna (compare e.g. Rödel and Branch 2002, Ernst and Rödel 2005, Ernst et al. 2006). All four species that never occur in closed forest conditions, *Amietophrynus maculatus*, *Hoplobatrachus occipitalis*, *Phrynobatrachus accraensis* and *Ptychadena bibroni*, were only recorded in Atiwiredu, hence showing that this area has already partially suffered from habitat degradation. On the other hand Atiwiredu showed high potential for amphibian diversity by harboring the only records for such forest specialists as *Amietophrynus togoensis*, *Acanthixalus sonjae*, *Phrynobatrachus alleni* and *P. ghanensis*. The occurrence of species that are dependant on fast-flowing waters in intact forest (*Amietophrynus togoensis, Conraua derooi*) is encouraging, as similar habitats seem to be decreasing in the Volta-Togo region, and recently the respective species could not be recorded (Rödel and Agyei 2003, Leaché et al. 2006) or were only found to be present in isolated sites that are threatened by human activities (*Conraua derooi*: A. Hillers et al. unpubl data).

DISCUSSION

Most recorded species (75%) do not occur outside West Africa (defined as the area West of the Cross River in Nigeria, Table 9.2), and are often restricted to smaller parts of West Africa. Half of all recorded species are endemic to the Guinean Forest zone. This percentage of endemicity is well within the upper range of other West African sites of outstanding importance to amphibian diversity (Rödel and Branch 2002, Rödel et al. 2004), higher than in other Ghanaian sites (Rödel and Agyei 2003, Rödel et al. 2005a), and may even increase with an increasing completeness of the recorded fauna (compare above). Two taxa were previously known only from eastern Ghana and western Togo (*Hyperolius baumanni*, *Conraua derooi*), one was known only from Ghana and eastern Côte d'Ivoire (*Phrynobatrachus ghanensis*), and two others are endemic to Ghana (*Hyperolius bobirensis*, *H. sylvaticus sylvaticus*; Schiøtz 1964, 1967, 1999, Hulselmans 1971, Hughes 1988, Rödel and Agyei 2003, Rödel et al. 2005a, Assemian et al. 2006, Leaché et al. 2006).

Several species have their easternmost record in Atewa: *Acanthixalus sonjae*, *Afrixalus vibekensis*, *Hyperolius bobirensis*, *H. picturatus*, *Kassina arboricola*, *Phrynobatrachus ghanensis* and *P. tokba* (compare Perret 1985, 1988; Rödel et al. 2002, 2003, 2005b). This is the third record of *H. bobirensis* (see Photos), and the fifth record of *Afrixalus vibekensis* (Schiøtz 1967, Rödel and Branch 2002, Rödel et al. 2005a). For *Hyperolius baumanni* and *Conraua derooi,* Atewa represents the westernmost locality of their known range. For *Amietophrynus togoensis* the Atewa reserve is the closest known locality to the type locality in Togo and therefore the record likely will contribute to resolve the taxonomic situation of these forest toads (Rödel and Bangoura 2004). The *Arthroleptis* spp. might represent taxa endemic to the Atewa area but this needs further investigation (compare general comments on West African *Arthroleptis* in Rödel and Bangoura 2004). This also applies to the *Hemisus* sp. (compare Rödel and Agyei 2003). Atewa is the only known site were *H. baumanni* and *H. picturatus* live in syntopy, thereby confirming Rödel and Agyei (2003) that the first is not only a subspecies of the second (compare Schiøtz 1967, 1999).

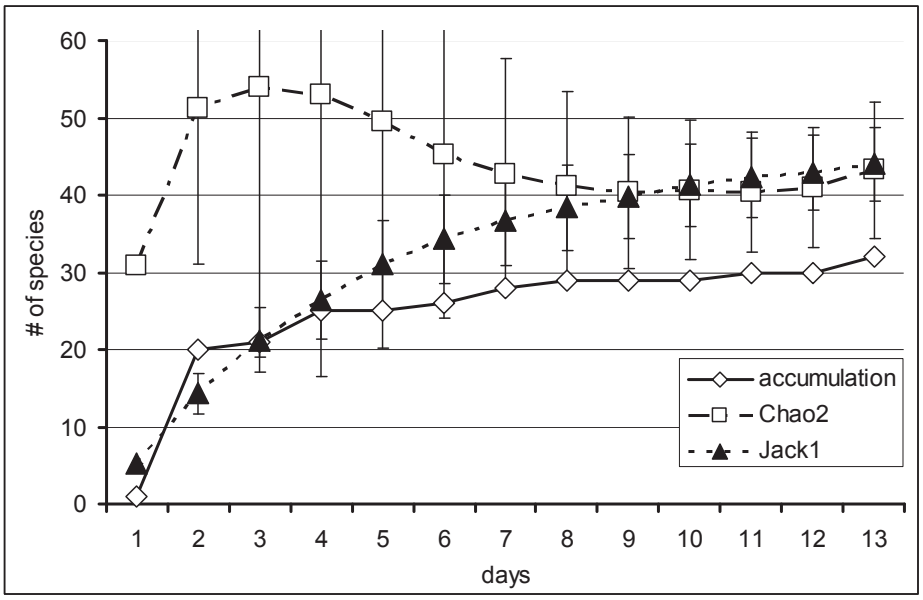

Figure 9.1. Species accumulation curve and estimated amphibian species richness of the Atewa Range Forest Reserve, Ghana. We recorded 32 different species in the course of 13 survey days and calculated that about 44 species can be expected for this forest reserve.

The amphibian species composition of the Atewa Range, comprising both species usually restricted to western or eastern parts of the Guinean Forest zone, is unique.

THREATENED SPECIES

Almost one-third of the recorded species (28%) fall into one of four IUCN Red List categories (Table 9.2). Five species are Near Threatened, one is Vulnerable, two are Endangered and one is Critically Endangered (*Conraua derooi*). Such a high percentage of threatened amphibian species is outstanding for West Africa. As the fauna can be assumed to be incompletely known and unrecorded species (see above) most likely comprise rarer species, the real percentage of threatened species may be even higher. For at least one species (*Conraua derooi*, see Photos), Atewa might harbor the most important remaining populations. This may also apply for *Hyperolius bobirensis*. *Conraua derooi* was originally described

Table 9.2. Distribution, habitat association and IUCN Red list categories (according to the Global Amphibian Assessment; 28 October 2006) of the Atewa amphibian species. Distribution: A = distributed also outside West Africa; WA = only in West Africa West of the Cross River; UG = endemic to the Upper Guinea forest zone (rainforest West of the Dahomey Gap); EGT = endemic to eastern Ghana and western Togo; EG = endemic to Ghana; Habitat: F = forest; FS = forest and secondary growth; S = savanna; Red list: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; ? = taxonomy not clarified and respective placement hence not certain, but likely.

Taxa	Distribution	Habitat			Red List
		F	FS	S	
Geotrypetes seraphini occidentalis	UG	x	x		
Arthroleptis sp. A	UG?	x?	x?		
Arthroleptis sp. B	UG?	x?	x?		
Leptopelis spiritusnoctis	WA	x	x		
Amietophrynus maculatus	A		x	x	
Amietophrynus togoensis	UG	x			NT
Hoplobatrachus occipitalis	A		x	x	
Hemisus sp.	UG?	x?			
Acanthixalus sonjae	UG	x	x		NT
Afrixalus nigeriensis	WA	x			NT
Afrixalus vibekensis	UG	x			NT
Hyperolius baumanni	EGT		x		
Hyperolius bobirensis	EG	x			EN
Hyperolius fusciventris burtoni	WA	x	x		
Hyperolius guttulatus	A		x		
Hyperolius picturatus	UG	x	x		
Hyperolius sylvaticus sylvaticus	EG	x			
Kassina arboricola	UG	x	x		VU
Conraua derooi	EGT	x	(x)		CR
Phrynobatrachus accraensis	WA		x	x	
Phrynobatrachus alleni	UG	x			NT
Phrynobatrachus calcaratus	A		x		
Phrynobatrachus ghanensis	UG	x			EN
Phrynobatrachus gutturosus	WA	x	x	x	
Phrynobatrachus plicatus	WA	x	x		
Phrynobatrachus tokba	UG	x	x		
Silurana tropicalis	WA	x	x		
Ptychadena aequiplicata	A	x			
Ptychadena bibroni	A		x	x	
Ptychadena longirostris	WA	x	x		
Aubria subsigillata	A	x			
Chiromantis rufescens	A	x	x		
Total (32 species)	**A = 8; WA = 8; UG = 12; EGT = 2; EG = 2**	**22 (25)**	**19 (22)**	**5**	**9**

from western Togo (Hulselmans 1971) and apart from there is only known from a few Ghanaian sites, close to the Togolese border (Schiøtz 1964 as *C. alleni*). Until very recently it had never been found again, although numerous suitable habitats were searched (Rödel and Agyei 2003, Leaché et al. 2006). Sites at which this species has previously been recorded are all close to human settlements and hence the persistence of the species in these areas is uncertain (A. Hillers et al. unpubl. data). Atewa seems to still hold large and viable populations of this Critically Endangered species in the fast flowing forest streams. Preliminary analyses showed that these are genetically distinct from those in the Volta region, again underlining the uniqueness of the Atewa range.

CONSERVATION RECOMMENDATIONS

Atewa is one of Ghana's few remaining intact forests which has survived the recent onslaught of forest destruction and degradation throughout the country as a whole (FAO 2006). It is recognized to hold one of the highest levels of biodiversity in Ghana, for some taxa even the highest (Larsen 2006). Similar results were obtained for amphibians throughout this survey. The overall composition of amphibians in Atewa is exceptional, because of a) the presence of species that have their center of distribution in eastern or western Ghana, b) the very high percentage of species that are restricted to forest environments and c) the outstanding percentage of threatened species, including some that most likely have their highest population numbers within Atewa.

It has been shown that amphibians are very sensitive to comparatively minor forest degradation, such as selective logging, with reactions including altered species composition, changes to community structure and the loss of particular functional groups (Ernst and Rödel 2005, Ernst et al. 2006). Ghanaian studies revealed dramatic negative effects of forest fragmentation on bird species composition (Beier et al. 2002) and local climatic conditions (Hill and Curran 2003). We observed similar effects on amphibian communities in forest fragments in western Côte d'Ivoire (A. Hillers et al. unpubl. data). All these studies underline the importance of maintaining larger intact forest blocks. Losses of particular species, and more importantly losses of particular functional groups, most likely also result in a decrease of resistance of a given ecosystem to disturbances, such as invasive species (Symstad 2000, Xu et al. 2004, Ernst et al. 2006).

In addition, mountain ranges are known to have played a significant role in maintaining biodiversity throughout times of higher temperature and drought (Amiet 1987, Moritz et al. 2000, Plana et al. 2004, Wieringa and Poorter 2004). They could also most likely play this role as refugias in the future. The Atewa Range holds the only larger Upland Evergreen Forest between the Upper Guinea Highlands and the Cameroon Mountains. The forests of Atewa hold large numbers of endemic and threatened species (e.g. the data presented herein, Swaine and Hall 1977, Larsen 2006, Weber and Fahr 2007 – see Chapter 11 of this report). If the Atewa Range were to be subject to development activities involving the wholesale removal of vegetation or riparian habitat, it is certain that the majority of specialized forest amphibians would be lost. We therefore recommend the following for long-term protection of Atewa's exceptional biodiversity:

- Undertake further surveys of Atewa to complete the amphibian inventory;
- Conduct in-depth studies focusing on threatened, rare and endemic species, i.e. *Conraua derooi* and *Hyperolius bobirensis*;
- Involve local communities in the management and conservation of the Atewa Range, including intensive capacity building in the knowledge of local biodiversity and sustainable use of forest resources;
- Prevent further illegal logging through involvement with local authorities;
- Strictly protect the watersheds of Atewa in order to secure water quality for the local biodiversity and water supply for surrounding communities as well as for Accra;
- Upgrade the protection status of Atewa, preferably to a national park, in recognition of Atewa's global significance for biodiversity conservation, as shown by its status as both a Globally Significant Biodiversity Area and as a result of the findings of the RAP survey;
- Decline all plans for the future development of Atewa in recognition of the outstanding nature of Atewa's biodiversity as, in the case of Atewa, impacts from development cannot be adequately mitigated (Phillips 2001, Dudley and Stolton 2002, Abu-Juam et al. 2003).

REFERENCES

Abu-Juam, M., E. Obiaw, Y. Kwakye, R. Ninnoni, E.H. Owusu and A. Asamoah. 2003. Biodiversity management plan for the Atewa Range Forest Reserve. Forestry Commission, Accra.

Amiet, J.-L. 1987. Aires disjointes et taxons vicariants chez les Anoures du Cameroun: implications paléoclimatiques. Alytes 6: 99–115.

Assemian, N.E., N.G. Kouamé, B. Tohé, G. Gourène and M.-O. Rödel. 2006. The anurans of the Banco National Park, Côte d'Ivoire, a threatened West African rainforest. Salamandra 42: 41-51.

Bakarr, M., B. Bailey, D. Byler, R. Ham, S. Olivieri and M. Omland. 2001. From the forest to the sea: Biodiversity connections from Guinea to Togo. Conservation International, Washington, DC.

Bakarr, M., J.F. Oates, J. Fahr, M. Parren, M.-O. Rödel and R. Demey. 2004. Guinean forests of West Africa. Pp.

123-130. *In*: Mittermeier, R.A., P.R. Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoreux and G.A.B. da Fonesca (eds.). Hotspots Revisited: Earth's biologically richest and most endangered terrestrial ecoregions, Conservation International and CEMEX, Washington, DC.

Beier, P., M. van Drielen and B.O. Kankam. 2002. Avifaunal collapse in West African forest fragments. Conservation Biology 16: 1097-1111.

Collwell, R.K. 2005. EstimateS Version 6.0b. Statistical estimation of species richness and shared species from samples. Online. Available: http://viceroy.eeb.uconn.edu/
estimates (last inquiry date: 9 January 2006).

Dudley, N. and S. Stolton. 2002. To dig or not to dig? WWF International and WWF UK, Gland.

Duellman, W.E. 1990. Herpetofauna in neotropical rainforests: comparative composition, history, and resource use. pp. 455-505. *In:* Gentry, A.H. (ed.). Four neotropical rainforests. Yale University Press, Yale.

Ernst, R., K.E. Linsenmair and M.-O. Rödel. 2006. Diversity erosion beyond the species level: Dramatic loss of functional diversity after selective logging in two tropical amphibian communities. Biological Conservation 133: 143-155.

Ernst, R. and M.-O. Rödel. 2005. Anthropogenically induced changes of predictability in tropical anuran assemblages. Ecology 86: 3111–3118.

FAO. 2006. Global forest resources assessment 2005. Progress towards sustainable forest management. FAO Forestry Paper N° 147. Rome. xxvii+320 pp.

Frost, D.R., T. Grant, J. Faivovich, R.H. Bain, A. Haas, C.F.B. Haddad, R.O. De Sá, A. Channing, M. Wilkinson, S.C. Donnellan, C.J. Raxworthy, J.A. Campbell, B.L. Blotto, P. Moler, R.C. Drewes, R.A. Nussbaum, J.D. Lynch, D.M. Green and W.C. Wheeler. 2006. The Amphibian tree of life. Bulletin of the American Museum of Natural History 297: 1-370.

Gartshore, M. 1986. The status of the montane herpetofauna of the Cameroon Highlands. Pp. 1-263. *In*: Stuart, S.N. (ed.). Conservation of Cameroon Montane Forests. International Council for Bird Preservation, London.

Guibé, J. and M. Lamotte. 1958. La réserve naturelle intégrale du Mont Nimba. XII. Batraciens (sauf *Arthroleptis, Phrynobatrachus* et *Hyperolius*). Mémoires de l'Institut fondamental d'Afrique noire 53: 241–273.

Guibé, J. and M. Lamotte. 1963. La réserve naturelle intégrale du Mont Nimba. XXVIII. Batraciens du genre *Phrynobatrachus*. Mémoires de l'Institut fondamental d'Afrique noire 66: 601–627.

Hall, J.B. and M.D. Swaine. 1981. Distribution and ecology of vascular plants in a tropical rain forest. Forest vegetation in Ghana. Junk Publishers, The Hague.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.-A.C. Hayek and M.S. Foster. 1994. Measuring and monitoring biological diversity, standard methods for amphibians. Smithsonian Institution Press, Washington, DC.

Hill, J. L. and P.J. Curran. 2003. Area, shape and isolation of tropical forest fragments: Effects on tree species diversity and implications for conservation. Journal of Biogeography 30: 1391-1403.

Hughes, B. 1988. Herpetology in Ghana (West Africa). British Herpetological Society Bulletin 25: 29-38.

Hulselmans, J.L.J. 1971. Contribution à l'herpétologie de la République du Togo, 4. Description de *Conraua derooi*, n. sp. (Amphibia). Revue Zoologique Botanique Africaine 84: 153-159.

Inger, R.F. 1980a. Densities of floor-dwelling frogs and lizards in lowland forests of Southeast Asia and Central America. American Naturalist 115: 761-770.

Inger, R.F. 1980b. Relative abundances of frogs and lizards in forests of Southeast Asia. Biotropica 12: 14-22.

Lamotte, M. 1971. Le Massif des Monts Loma (Sierra Leone), Fasciule I; XIX. Amphibiens. Mémoires de l'Institut fondamental d'Afrique noire 86: 397-407.

Larsen, T.B. 2006. The Ghana butterfly fauna and its contribution to the objectives of the Protected Areas System. WDSP Report no. 63. Wildlife Division (Forestry Commission) and IUCN (World Conservation Union).

Laurent, R.F. 1958. Les rainettes du genre *Hyperolius*. Mémoires de l'Institut fondamental d'Afrique noire 53: 275–299 + 3 plates.

Leaché, A.D., M.-O. Rödel, C.W. Linkem, R.E. Diaz, A. Hillers and M.K. Fujita. 2006. Biodiversity in a forest island: reptiles and amphibians of the West African Togo Hills. Amphibian and Reptile Conservation 4: 22-45.

Mayaux, P., E. Bartholomé, S. Fritz and A. Belward. 2004. A new land-cover map of Africa for the year 2000. Journal of Biogeography 31: 861-877.

Moritz, C., J.L. Patton, C.J. Schneider and T.B. Smith. 2000. Diversification of rainforest faunas: an integrated molecular approach. Annual Review of Ecology and Systematics 31: 533-563.

Perret, J.-L. 1985. Description of *Kassina arboricola* n. sp. (Amphibia, Hyperoliidae) from the Ivory Coast and Ghana. South African Journal of Science 81: 196–199.

Perret, J.-L. 1988. Les espèces de *Phrynobatrachus* (Anura, Ranidae) à éperon palpébral. Archives des Sciences 41: 275-294.

Phillips, A. 2001. Mining and protected areas. Mining, Minerals and Sustainable Development 62: 1-19.

Plana, V., A. Gascoigne, L.L. Forrest, D. Harris and R.T. Pennington. 2004. Pleistocene and pre-Pleistocene *Begonia* speciation in Africa. Molecular Phylogenetics and Evolution 31: 449-461.

Rödel, M.-O. and A.C. Agyei. 2003. Amphibians of the Togo-Volta highlands, eastern Ghana. Salamandra 39: 207-234.

Rödel, M.-O. and M.A. Bangoura. 2004. A conservation assessment of amphibians in the Forêt Classée du Pic

de Fon, Simandou Range, southeastern Republic of Guinea, with the description of a new *Amnirana* species (Amphibia Anura Ranidae). Tropical Zoology 17: 201-232.

Rödel, M.-O., M.A. Bangoura and W. Böhme. 2004. The amphibians of south-eastern Republic of Guinea (Amphibia: Gymnophiona, Anura). Herpetozoa 17: 99-118.

Rödel, M.-O. and W.R. Branch. 2002. Herpetological survey of the Haute Dodo and Cavally forests, western Ivory Coast, Part I: Amphibians. Salamandra 38: 245-268.

Rödel, M.-O. and R. Ernst. 2004. Measuring and monitoring amphibian diversity in tropical forests. I. An evaluation of methods with recommendations for standardization. Ecotropica 10: 1-14.

Rödel, M.-O., M. Gil, A.C. Agyei, A.D. Leaché, R.E. Diaz, M.K. Fujita and R. Ernst. 2005a. The amphibians of the forested parts of south-western Ghana. Salamandra 41: 107-127.

Rödel, M.-O., T.U. Grafe, V.H.W. Rudolf and R. Ernst. 2002. A review of West African spotted *Kassina*, including a description of *Kassina schioetzi* sp. nov. (Amphibia: Anura: Hyperoliidae). Copeia 2002: 800-814.

Rödel, M.-O., J. Kosuch, N.G. Kouamé, R. Ernst and M. Veith. 2005b. *Phrynobatrachus alticola* Guibé & Lamotte, 1961 is a junior synonym of *Phrynobatrachus tokba* (Chabanaud, 1921). African Journal of Herpetology 54: 93-98.

Rödel, M.-O., J. Kosuch, M. Veith and R. Ernst. 2003. First record of the genus *Acanthixalus* Laurent, 1944 from the Upper Guinean rain forest, West Africa, with the description of a new species. Journal of Herpetology 37: 43-52.

Schiøtz, A. 1964. A preliminary list of amphibians collected in Ghana. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening 127: 1–17.

Schiøtz, A. 1967: The treefrogs (Rhacophoridae) of West Africa. Spolia zoologica Musei Haunienses 25: 1–346.

Schiøtz, A. 1999. Treefrogs of Africa. Edition Chimaira, Frankfurt/M.

Swaine, M.D. and J.B. Hall. 1977. Ecology and conservation of upland forests in Ghana. pp. 151-158. *In*: Laryea, A.M (ed.). Proceedings of Ghana SCOPE's Conference on Environment and Development in West Africa. Ghana Academy of Arts & Sciences, UNESCO and Ghana Environmental Protection Council, Accra.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 205: 1783-1786.

Symstad, A.J. 2000. A test of the effects of functional group richness and composition on grassland invisibility. Ecology 81: 99-109.

Weber, N. and J. Fahr. 2007. A rapid survey of small mammals from Atewa Range Forest Reserve, Eastern Region, Ghana. Pp. 90-98. *In*: McCullough, J., L.E. Alonso, P. Naskrecki and Y. Osei-Owusu (eds.) A Rapid Biological Assessment of the Atewa Range Forest Reserve, Eastern Ghana. RAP Bulletin of Biological Assessment 47. Conservation International. Arlington, VA.

Wieringa, J.J. and L. Poorter. 2004. Biodiversity hotspots in West Africa; patterns and causes. Pp. 61-72. *In*: Poorter, L., F. Bongers, F.N'. Kouamé and W.D. Hawthorne (eds.). Biodiversity of West African forests. An ecological atlas of woody plant species. CABI Publishing, Cambridge, Massachusetts.

Xu, K., W. Ye, H. Cao, X. Deng, Q. Yang and Y. Zhang. 2004. The role of functional traits of species in community invasibility. Botanical Bulletin of the Academia Sinica 45: 149-157.