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Assessment of the distribution and conservation status of the viviparous toad *Nimbaphrynoides occidentalis* on Monts Nimba, Guinea‡

A. Hillers[1], N.-S. Loua[2], M.-O. Rödel[3,*]

[1]Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Kruislaan 318, 1098 SM Amsterdam, The Netherlands

[2]Guinée Ecologie, Bâtiment 210, rue DI 501, Dixinn, BP 3266, Conakry, Guinea

[3]Humboldt University, Museum of Natural History, Herpetology, Invalidenstr. 43, 10115 Berlin, Germany

ABSTRACT: We investigated the distribution of the viviparous Nimba toad *Nimbaphrynoides occidentalis* throughout its potential range, the montane grasslands of the Monts Nimba massif, West Africa. Although predominantly part of a World Heritage Site, the Monts Nimba also comprise a mining enclave in the northwestern part of the mountain massif. The present study revealed that the Nimba toad seems to have its most viable populations within the mining enclave (Mont Sempéré) or directly adjacent to it (Grands Rochers). These 2 populations and a third, presumably isolated one (Mont Richard Molard), may be source populations, whereas other smaller populations are likely to be sinks. We generally recorded lower toad densities than in earlier studies and failed to confirm the toads' presence in parts of their former known range. Some of these changes might be due to an increased frequency of fires in recent years, resulting in the loss of a thick layer of grass roots on the rocky underground. However, the most imminent threat to the toads' survival at present is the proposed mining project in the core area of their range. It is thus imperative that the Critically Endangered status of the Nimba toad be retained for the present. However, a broader and more in-depth study of the population sizes, population genetics and the microhabitat needs is urgently needed.

KEY WORDS: Amphibia · Guinea · Iron ore · Mining exploration · Montane grassland · Monts Nimba · *Nimbaphrynoides occidentalis* · West Africa

INTRODUCTION

Areas of special conservation value, i.e. centers of imminent extinction risk for range-restricted species, are mainly concentrated in tropical forests, islands and especially mountain areas (Ricketts et al. 2005, Fa & Funk 2007). The Upper Guinea forest region of West Africa is one of the world's most important biodiversity hotspots (Myers et al. 2000, Bakarr et al. 2004) and one that is seriously threatened by deforestation (Chatelain et al. 1996, 2004, Bakarr et al. 2001), forest degradation and fragmentation (Beier et al. 2002, Ernst & Rödel 2005, Ernst et al. 2006, Hillers et al. 2008), and more recently mining activities in many mountain areas (McCullough 2004, McCullough et al. 2007). One of the major elevations and diversity centers in West Africa, and hence of particular conservation concern, is the Monts Nimba massif on the border of Guinea, Liberia and Ivory Coast (Bakarr et al. 2001, Ricketts et al. 2005). These mountains are dominated by rainforests on the foothills and ravines, and montane grasslands at higher elevations, the latter probably being the rarest West African habitat type (Lamotte 1998, Lamotte & Roy 2003).

The Monts Nimba massif is known to be generally very rich in terms of diversity and endemism (Lamotte & Roy 2003 and papers cited therein) and this is also true of the herpetofauna, i.e. at least 66 frog and 52

*Corresponding author. Email: mo.roedel@museum.hu-berlin.de
‡This study is dedicated to Prof. Maxime Lamotte, who recently passed away.

snake species are known from the massif, making it the most diverse frog and snake area in West Africa (summarized in Ineich 2003, Rödel et al. 2004). The high species richness of Monts Nimba is mainly due to the huge variety of different habitats (Lamotte & Roy 2003), whereas the high number of endemic species may be attributed to the mountains' presumed history as a rainforest refugium in Pleistocene and pre-Pleistocene dry periods (e.g. UICN 1996, Poorter et al. 2004).

The Monts Nimba are home to several endemic frog species, one of which is the viviparous Nimba toad *Nimbaphrynoides occidentalis* Angel, 1943. This Critically Endangered species (IUCN, Conservation International Nature Serve 2004) has been the object of numerous studies in the past and is probably one of the best known African amphibians. However, most publications are quite old and mainly deal with the anatomy, embryology, physiology and, in particular, with the special reproduction strategy of this unique toad (summarized in Xavier 1986). Data on the toad's ecology and distribution are rare and exclusively based on older data (e.g. Lamotte 1959, Lamotte & Sanchez-Lamotte 1999). It is known that the toad is restricted to a few square kilometres of montane grassland on the Guinean part of Monts Nimba (Lamotte 1959). More recent data on the distribution pattern of *N. occidentalis* were collected in 1991, 1992 (Bangoura 1993) and in 2002 (Doumbia 2003) but remained unpublished. Hence, no recent information on the distribution of the toads is publicly available. This is problematic in the light of the current exploration activities for iron ore on Monts Nimba. In the present study we report on the current distribution of *N. occidentalis* and compare our recent data with previous studies (Lamotte 1959, Bangoura 1993, Doumbia 2003).

MATERIALS AND METHODS

Study site. The Monts Nimba massif (approx. surface area 12 540 ha) is situated in the trans-boundary region of Guinea, Ivory Coast and Liberia (7° 25'–7° 45' N, 8° 20'–8° 35' W) and has been most recently described by Lamotte (1998) and Lamotte et al. (2003b). The chain is orientated southwest–northeast and is approximately 40 km long and 8 to 12 km wide. Mean annual precipitation is 2093 mm (rainy season: May to October). Rainfall is generally higher in the montane grasslands than on the foothills (Lamotte 1959). Mean annual temperature on the foothills (450–550 m above sea level, a.s.l.) is 25°C; on the mountain ridge (1650–1750 m a.s.l.) it is 19°C (Lamotte 1998, Lamotte et al. 2003a). During the rainy season the higher parts of the mountains are covered in clouds and misty rain for a huge proportion of the day. The montane grasslands are a unique habitat in West Africa and extend from at least 900 m a.s.l., mostly from about 1300 m upward (Lamotte et al. 2003b). Only about 40 km^2 of the massif is above 1000 m, and less than 7 km^2 are above 1500 m (Lamotte 1959). The ground of the mountains consists mainly of iron-oxide quartzite (Lamotte et al. 2003b).

The scientific study of the Monts Nimba massif began in 1942. The Guinean part was protected as the Monts Nimba Strict Nature Reserve in 1944. From the 1960s Monts Nimba were prospected for iron ore. In 1981 and 1982 the Guinean and Ivorian parts were declared a World Heritage Site (WHS) and Biosphere Reserve. In 1989 Guinea announced plans to mine the iron ore of Monts Nimba but was requested by the World Heritage Committee (WHC) to abandon these plans. In 1990 Guinea stated that the proposed mining area was outside the WHS-boundaries. However, the WHC insisted that this was not the case and that 'mining will reduce the Reserve's area by 30 % and seriously endanger the integrity of the values for which Monts Nimba were originally granted World Heritage status' (WHC 1986–2007). WHC consequently declared Monts Nimba a 'World Heritage Site in Danger'. Guinea negotiated with the United Nations Development Program and the Global Environment Facility about a project to protect Monts Nimba by 'integrating mining as a motor for economic growth' in 1999, and prospecting activities for iron ore mining on Monts Nimba were re-started in 2005. The WHC, however, retained Monts Nimba on the list of 'World Heritage in Danger' in their 2006 and 2007 reports (WHC, 1986–2007).

Species distribution. The distribution pattern of the viviparous *Nimbaphrynoides occidentalis* (snout–vent length: 16 to 27 mm) is closely connected with its special life cycle. During the dry season (approx. November to March) the toads are dormant and hide underground, but they become active with the first rains. The gravid females (Fig. 1) are the first to emerge, followed by non-gravid females and finally the males. In June/July, after a gestation period of 9 mo, females give birth to 1–22, mostly 4–12, juveniles (7 mm). The mating period starts at the end of August, before toads again become dormant (Lamotte 1959).

Study plots. Our survey was carried out in the Guinean part of the Monts Nimba area from 7 to 26 May 2006. Following the method used by Lamotte (1959) and later studies (Bangoura 1993), modified by Doumbia (2003), who used 6 × 6 m squares, we randomly chose 5 × 5 m squares along the mountain ridge on which we searched for *Nimbaphrynoides occidentalis*. Unlike Lamotte (1959) and Bangoura (1993) we did not remove the vegetation within the

Fig. 1. *Nimbaphrynoides occidentalis.* Gravid female

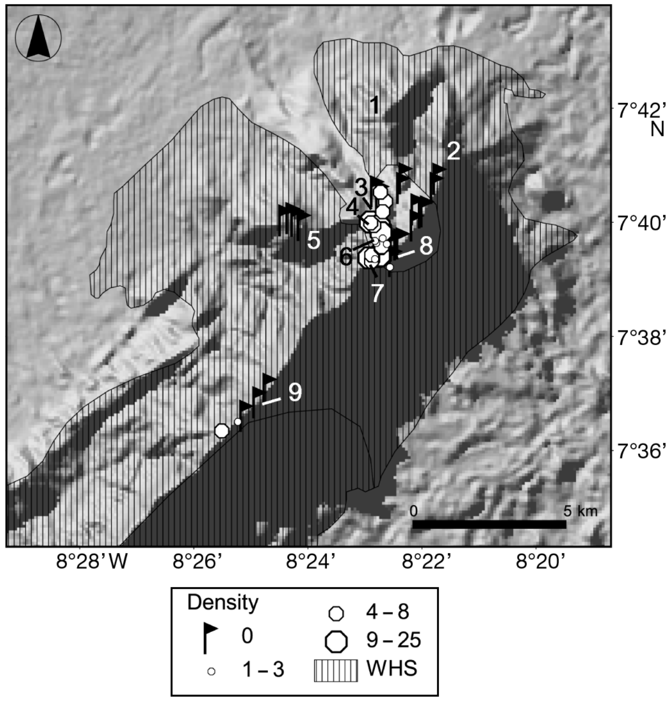

Fig. 2. Monts Nimba World Heritage Site (WHS, striped area) and the mining enclave (gap in the upper centre part of the WHS) with the position of plot sites and toad densities encountered. 1 = Monts des Génies, 2 = Pierré Richaud, 3 = Château, 4 = Sempéré, 5 = Mont Leclerc, 6 = Mare d'hivernage, 7 = Grands Rochers, 8 = Mont Tô, 9 = Mont Richard Molard. Flags indicate plots with no record of a Nimba toad. Circles show plots where toads were recorded; size of circles indicates the relative density of toads on the respective plot (for further detail see Table 1). The dark grey shaded area is the east flank of the mountain; the line beneath Site 9 denotes the border between Guinea and Ivory Coast

25 m^2 plots, but carefully checked through the vegetation and under stones and rocks as well as within crevices. Searches were standardized to 1.5 observer hours $plot^{-1}$. Plots were investigated between 9:00 and 14:30 h, during which period most plots were still covered in mist.

Methods of capture. All Nimba toads encountered on a plot were captured and held in plastic boxes for the duration of the searches. They were subsequently released to their original places. Although all frogs so far tested from east of the Dahomey Gap were *Batrachochytrium dendrobatidis* (Bd) negative (C. Weldon & M.-O. Rödel unpubl. data), we exclusively used new equipment to avoid the risk of accidentally transporting chytrid to the study area and species. We did not explicitly test for sampling efficiency, but sampling time most often allowed us to check the plot completely twice. As the second trial did not usually reveal additional specimens, we assume that our approach allowed for an almost complete assessment of the toads on a particular plot.

To characterize the plots we noted the presence of particular vegetation and soil types and took photographs of every plot. Geographic position and altitude of each plot was taken with a handhold GPS receiver (Garmin 12 XL), and study localities were plotted on the SRTM90 digital elevation model (90 m resolution; Version 3, http://srtm.csi.cgiar.org). The boundaries of the WHS were taken from the World Database on Protected Areas (UNEP & WDPA 2006; www. unep-wcmc.org/wdpa). All our plots were located higher than 1200 m a.s.l. as the Nimba toad is known to build populations only above this altitude (Lamotte 1959). In total we checked 50 plots (1250 m^2) spread along the whole area of montane grassland, from the northern Pierré Richaud to the southern side of Mont Richard Molard (Fig. 2). A list of all plots is given in Table 1. Geographic names differ slightly between studies. Lamotte (1959) and Bangoura (1993) use the name Mont Tô for an area that is now regarded as part of Grands Rochers, while the Mont Tô is now applied to a location east of Grands Rochers. We herein follow the most current terminology (Fig. 2).

RESULTS

In total, we detected 179 *Nimbaphrynoides occidentalis* on the 50 plots. All records were in the montane grasslands, and the vast majority of toads were recorded above 1600 m a.s.l. The toad densities on the various plots were very heterogeneous, ranging from 0 to 25 toads (mean ± SD: 3.6 ± 5.8 toads per 25 m^2). No toads were found on 26 of the plots. On the remaining 24 sites we recorded 7.5 ± 6.3 ind. per 25 m^2 (Tables 1 & 2).

Table 1. Plots investigated on Monts Nimba with geographic coordinates, altitude and number of Nimba toads *Nimbaphrynoides occidentalis* observed

Plot no.	Location	Latitude (°N)	Longitude (°W)	Altitude (m)	No. of toads
1	Sempéré	7° 39.938′	8° 22.850′	1639	8
2	Sempéré	7° 39.996′	8° 22.912′	1586	25
3	Sempéré	7° 39.813′	8° 22.724′	1672	11
4	Grands Rochers/Mare d'hivernage	7° 39.620′	8° 22.712′	1635	0
5	Pierré Richaud	7° 40.604′	8° 21.734′	1581	0
6	Pierré Richaud	7° 40.763′	8° 21.688′	1553	0
7	Pierré Richaud	7° 40.190′	8° 21.906′	1593	0
8	Pierré Richaud	7° 40.227′	8° 22.071′	1549	0
9	Grands Rochers	7° 39.308′	8° 22.888′	1678	6
10	Grands Rochers	7° 39.369′	8° 22.935′	1655	11
11	Grands Rochers	7° 39.420′	8° 22.885′	1665	4
12	Grands Rochers	7° 39.402′	8° 22.751′	1693	16
13	Grands Rochers	7° 39.549′	8° 22.724′	1673	4
14	Mare d'hivernage	7° 39.634′	8° 22.803′	1607	3
15	Mare d'hivernage/Sempéré	7° 39.669′	8° 22.829′	1616	1
16	East of Grands Rochers	7° 39.209′	8° 22.567′	1484	3
17	Valley between Grands Rochers/Mont Tô	7° 39.322′	8° 22.465′	1412	0
18	Mont Tô	7° 39.610′	8° 22.375′	1673	0
19	Mont Tô	7° 39.630′	8° 22.331′	1645	0
20	Mont Tô	7° 39.656′	8° 22.565′	1654	0
21	Mont Tô	7° 39.684′	8° 22.629′	1643	0
22	Monts des Génies	7° 40.604′	8° 22.325′	1252	0
23	Monts des Génies	7° 40.771′	8° 22.281′	1267	0
24	Mont Leclerc	7° 39.952′	8° 24.067′	1577	0
25	Mont Leclerc	7° 40.026′	8° 24.181′	1534	0
26	Mont Leclerc	7° 40.072′	8° 24.265′	1467	0
27	Mont Leclerc	7° 40.035′	8° 24.390′	1366	0
28	Sempéré/Château	7° 40.457′	8° 22.690′	1362	0
29	Château	7° 40.543′	8° 22.783′	1356	0
30	Château	7° 40.521′	8° 22.733′	1323	4
31	Mont Richard Molard	7° 37.082′	8° 24.665′	1752	0
32	Mont Richard Molard	7° 36.846′	8° 24.845′	1636	0
33	Mont Richard Molard	7° 36.609′	8° 25.073′	1530	0
34	Mont Richard Molard	7° 36.501′	8° 25.231′	1503	1
35	Mont Richard Molard	7° 36.337′	8° 25.514′	1389	7
36	Grands Rochers	7° 39.352′	8° 22.827′	1686	3
37	Grands Rochers	7° 39.394′	8° 22.785′	1694	20
38	Grands Rochers/Mont Tô	7° 39.563′	8° 22.710′	1660	4
39	Grands Rochers/Mont Tô	7° 39.614′	8° 22.620′	1649	3
40	Mont Tô	7° 39.661′	8° 22.621′	1649	0
41	Mont Tô	7° 39.593′	8° 22.444′	1654	0
42	Pierré Richaud	7° 40.173′	8° 21.941′	1597	0
43	Pierré Richaud	7° 39.945′	8° 22.086′	1650	0
44	Sempéré/Château	7° 40.357′	8° 22.642′	1474	7
45	Sempéré/Château	7° 40.179′	8° 22.692′	1498	4
46	Sempéré	7° 39.983′	8° 22.904′	1600	4
47	Sempéré	7° 39.927′	8° 22.753′	1682	14
48	Sempéré	7° 39.873′	8° 22.732′	1673	15
49	Sempéré/Mare d'hivernage	7° 39.777′	8° 22.735′	1651	0
50	Sempéré/Mare d'hivernage	7° 39.714′	8° 22.693′	1635	1

Occurrence of toads was very unevenly distributed along the mountain chain (Fig. 2). No toads were recorded on Monts des Génies (2 plots), Mont Leclerc (4 plots), Mont Tô (7 plots) or on Pierré Richaud (6 plots). On Mont Richard Molard we found toads (n = 8) on only 2 out of 5 plots searched. In contrast, we recorded toads (n = 74) on 9 out of 10 plots on Grands Rochers and towards Mont Tô. We found a total of 77 ind. on the 6 plots on Sempéré. On the ridge between Sempéré and the Château we found toads (n = 11) on 2 out of 3 plots, and on the Château we found 4 ind. in one of the 2 investigated plots. Around the Mare d'hivernage we checked 5 plots but found only a total of 5 toads on 3 plots (Table 1).

Table 2. *Nimbaphrynoides occidentalis.* Importance of the various Guinean parts of Monts Nimba for the Nimba toad, showing number of plots investigated, number of toads found on 5 × 5 m plots and relative abundances (Lamotte 1959 does not provide exact toad numbers for all sites; 'important': significant part of the toad population). Note that Doumbia (2003) worked on 6 × 6 m plots. Study periods as follows: Lamotte (1959), April–May 1942, August–October 1946, July–December 1951, December 1953, September–October 1956; Bangoura (1993), April 1991, April–May 1992; Doumbia (2003), June, September, October 2002; present study May 2006. For Lamotte (1959) and Bangourra (1993) Grands Rochers was termed Mt. Tô. For the plots listed in the Lamotte (1959) column not all localities are assignable with certainty, as the study only cites exemplary plots; Lamotte & Sanchez-Lamotte (1999) present a map with 49 (=all?) sites investigated by Lamotte (1959); the former publication is based on data from Lamotte (1959). Blanks: no data available

Location	Lamotte (1959)		Bangoura (1993)			Doumbia (2003)			Present study		
	No. of plots	No. of toads	No. of plots	No. of toads	Relative %	No. of plots	No. of toads	Relative %	No. of plots	No. of toads	Relative %
Sempéré	?	Important	8	53	13.8	3	103	30.7	6	77	49.7
Mare d'hivernage	?	Important				3	27	8.1	5	5	3.9
Pierré Richaud	4	4.3 ± 7.8; 0–16[a]	8	1	0.3	3	10	3.0	6	0	0
Grands Rochers	12	62.9 ± 51.3; 2–135[a]	11	206	38.7	3	106	37.6	10	74	28.6
Tô	?	?							7	0	0
Leclerc	1	96	8	66	17.2	3	58	17.3	4	0	0
Château	?	?							5	15	11.6
Richard Molard	1	2; important	8	115	30.0	3	11	3.3	5	8	6.2
Génies	?	?							2	0	0
Total no. of toads; mean ± SDtoads per plot; range		0–148		441; 10.3 ± 20.2; 0–92			335; 18.6 ± 19.3; 0–70			179; 3.6 ± 5.8; 0–25	
Total no. of plots investigated		18		43			18			50	

[a]Data are mean ± SD; range

In summary, and with the exception of the few toads on the Mont Richard Molard, we detected *Nimbaphrynoides occidentalis* only on plots within or in close proximity to the mining enclave (Fig. 2).

DISCUSSION

The northern part of the Monts Nimba, and hence a huge proportion of the known range of *Nimbaphrynoides occidentalis*, is in the focus of prospecting activities for iron ore. As the current distribution and status of the Nimba toad was not known, we gathered up-to-date information about the species' distribution, relative abundance, and habitat requirements. The comparison of our data with the data provided by the studies of Lamotte (1959), Bangoura (1993) and Doumbia (2003) confirmed the known habitat preferences of the species but also revealed several changes that have occurred over the last 50 yr. Although we investigated sites over the whole accessible range of the Guinean part of Monts Nimba, we were unable to record any extension to the known distribution area of the Nimba toad. The toads were very unevenly distributed along the mountain chain and abundances were very heterogeneous on the study plots. A similar heterogeneity in abundance was observed by Bangoura (1993) and Doumbia (2003), whereas Lamotte (1959) reported more homogeneous toad densities.

The number of toads observed in 2006 was lower than in all previous studies. It is possible that there has been a continuous decrease in toad densities from the 1940s and 1950s to the present day: whereas Lamotte (1959) reported up to 6 ind. m^{-2}, our maximum was 1 ind. m^{-2} (Table 2). However, this is not necessarily an indication of a decrease in population sizes over time. This could also be the result of methodological differences, resulting in particular from different study periods, as the life cycle of *Nimbaphrynoides occidentalis* results in very unequal abundances throughout the year (Lamotte 1959). For example, Lamotte (1959) reported approx. 40 ind. 25 m^{-2} in May, but more than 100 ind. 25 m^{-2} in August and September. The whole population was estimated to comprise approx. 6 million toads, which could increase to up to 15 million later in the year, due to the appearance of juveniles in August and September. In 5 consecutive years, 1951 to 1956, toad numbers remained more or less identical (Lamotte 1959). Our study covered a period in which population densities are always lowest (before the birth of the young). However, Doumbia's (2003) data show that although toad numbers change throughout the season, the relative abundances between sites remain constant. Whereas our abundance data thus might not be directly comparable to former studies, our distribution and relative abundances data should be.

So far, all studies reported highest toad abundance in the area of Grands Rochers (Lamotte 1959, Bangoura 1993, Doumbia 2003, present study). With the exception of Bangoura (1993), all studies also found *Nimbaphrynoides occidentalis* to be very abundant on Sempéré. On Pierré Richaud, all previous observers recorded toads, but in low abundances (Lamotte 1959, Bangoura 1993, Doumbia 2003). Older records on Mont Leclerc varied from records of individual toads (Lamotte 1959) to those showing abundant numbers of toads (Bangoura 1993, Doumbia 2003). We failed to confirm the presence of *N. occidentalis* on Pierré Richaud and on Mont Leclerc.

Due to the dry climatic conditions during part of our survey and the comparatively short study period, we possibly missed parts of the Nimba toad's distribution pattern. However, we did observe toads, sometimes very abundant and including adult males (which are the last to emerge after hibernation), in many plots. Hence, we conclude that the absence of toads in some regions of the mountain may be real or at least an indication of very low abundances.

If the distributional range of the Nimba toad is indeed smaller than in the 1940s and 1950s (Lamotte 1959), this could be due to climatic changes or, more likely, a higher frequency of fires in the montane grasslands. Dry season fires may result in toad populations that drop to half or even a quarter (Lamotte 1959). These fires have resulted, for example, in altered vegetation on the Mare d'hivernage, where Lamotte (1959) still found dense shrub and tree vegetation (see Fig. 3 in Lamotte et al. 2003a) and where nowadays only a low herb layer persists. Indeed, the vegetation and the ground cover now seem to have been altered by fires on almost all parts of the montane grasslands. This applies in particular to a formerly thick layer (>10 cm) of old grass roots that served as hiding sites for the toads (Lamotte 1959) and that has disappeared almost everywhere (M. A. Bangoura pers. obs.). Unfortunately, fire frequencies have never been documented scientifically. The effects savanna fires may have on habitats and fauna are, however, well known (Barbault 1976).

Why the populations on the Grands Rochers and Sempéré, which hold the vast majority of the toad populations, suffered less cannot be explained by our data. Toads of both areas may still be genetically connected and acting as a source population, whereas other populations might be sinks, as is indicated by low toad densities in areas near these 2 sites (e.g. Château, Mare d'hivernage, ridge between Grands Rochers and Mont Tô). The population on Mont Richard Molard might be separated from this core population. Taking into account the ongoing prospecting activities for iron ore in (Sempéré) or near (Grands Rochers) the core population's area, this may be a more severe danger to the survival of the Nimba toad than frequent fires. Destruction of the habitat and a possibly altered climate (less rainfall and less mist) due to the lowering of various parts of the mountain during the mining itself, might be the most important threat to the long-term survival of *Nimbaphrynoides occidentalis*.

The Nimba toad has a very small distribution range. It occurs exclusively on the montane grasslands of Monts Nimba and its main populations, confirmed by this study, have been reported to exist only above 1500 m. A mere 7 km^2 of the Nimba massif consists of such habitat, and a huge proportion is situated within or close to the proposed mining area. In the present study we showed that the overwhelming part of the Nimba toad population is concentrated in and around the mining enclave. The Nimba toad thus qualifies as a species of imminent extinction risk and as such should be in the focus of immediate and appropriate conservation measures (Ricketts et al. 2005).

These should include research to gain a more detailed knowledge about the exact habitat requirements and the population genetics of the species. We have initiated genetic sampling and a monitoring program that covers the different seasons throughout a year as well as the population fluctuations throughout preceding years, and this will hopefully provide data that can be used for reliable recommendations for the long-term survival of *Nimbaphrynoides occidentalis,* but also of other endangered and endemic species of the Nimba range (American Bird Conservancy 2006). Based on the current data the Red List status of *N. occidentalis* must be retained as Critically Endangered.

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