

# Anuran habitat selection and temporal partitioning in a montane and submontane rainforest in Southwestern Cameroon – first results

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## Abstract

Spatial and temporal partitioning of an anuran assemblage in a montane and in a submontane habitat at Mt. Nlonako, Southwestern Cameroon, were studied by visual encounter surveys along transects. Qualitative and quantitative data on anuran community structure at two different altitudes are provided as are data on habitat selection (creek vs. forest habitats), seasonal patterns (beginning of dry season vs. beginning of rainy season), activity patterns (diurnal vs. nocturnal) and substrate preference. The communities showed high species richness with a general low abundance per species with the exception of *Phrynobatrachus auritus* which represented 36% of all specimens; this dominance was especially pronounced in the rainy season. The high altitude study site assemblage was characterized by montane species. Most specimens were found at night perching on vegetation along the sides of creeks. A cluster analysis involving the twenty-one most abundant species resulted in one cluster representing all species but *Bufo latifrons* thus showing an unexpected proximity in the ecological variables studied.

Keywords: Anura: Amphibia; Mt. Nlonako; Southwestern Cameroon; species diversity; spatial partitioning; temporal partitioning; perching sites.

## 1 Introduction

Although the anuran fauna of Cameroon has been studied periodically by a number of authors (MERTENS 1938, 1939, 1940, 1968; MONARD 1951; PERRET & MERTENS 1957; PERRET 1959, 1960a, 1961, 1966; EISENTRAUT 1963, 1973; PERRET & AMIET 1971; AMIET 1971, 1978, 1989; BÖHME 1975; JOGER 1982; GARTSHORE 1986; BÖHME & SCHNEIDER 1987; LAWSON 1993; HERRMANN et al. 2000) and detailed studies on the biology of specific anuran species exist (PERRET 1962, 1977, AMIET 1977, 1980), only two studies have focused on the ecology and spatial partitioning of an anuran assemblage (SANDERSON 1936, AMIET 1975).

Anurans have been identified as sensitive bio-indicators which can provide important data critical for the evaluation of the condition of their habitats (SCHIØTZ 1999, RÖDEL 2000).

Anuran population declines are recognized in many areas worldwide (ALFORD & RICHARDS 1999, HOULAHAN et al. 2000). To determine the cause of such declines long term studies of anuran species assemblages are necessary (PECHMANN et al. 1991, BLAUSTEIN et al. 1994). Few such studies have been carried out (JAEGER 1980, PECHMANN et al. 1991) and are entirely lacking for most of tropical Africa and especially for Cameroon.

Here we describe anuran assemblages at a montane and submontane rainforest in Southwestern Cameroon and provide first qualitative and quantitative data on habitat selection and temporal partitioning within these assemblages. Our aim is to shed light on these anuran communities and their ecology and provide a basis for future studies, which may assist in detecting long-term trends in amphibian population fluctuations.

## 2 Materials and methods

### 2.1 Study area

All field work was carried out at Mt. Nlonako which is of volcanic origin, rising up to 1825 m above sea level and is situated in Southwest Cameroon (Fig. 1a). From 21 to 26 November 2000 and 31 March to 5 April 2001 transects ( $4^{\circ}51'N$ ,  $9^{\circ}54'E$ , 450 m altitude) were sampled in the vicinity of the village Ekomtolo at the southwestern foot of Mt. Nlonako. From 24 - 27 March 2001 transects at the higher altitude of 1140 m ( $4^{\circ}55'N$ ,  $9^{\circ}59'E$ ) were sampled in the vicinity of the village Nguengue on the northeastern flanks of the mountain (Fig. 1b).

The temperature during the time period of 21 November 2000 to 30 December 2001 varied from a minimum of 16.4 °C to a maximum of 29.5 °C at the Ekomtolo study site and 12.9 °C to 23.6 °C at the Nguengue study site respectively. The relative humidity during that time period was between 48.7 % and 100 % at Ekomtolo and 23.5 % and 100 % at Nguengue. For climatic details during the study periods refer to Figures 2 and 3. All temperature and relative humidity data were recorded with Onset Hobo® 08 t/rh data loggers with measuring intervals set to one hour. Temperature and relative humidity data were processed with the Onset BoxCar® version 4.2 program. Precipitation occurs throughout the year with a maximum during the peak rainy season from August to October. The study period from the end of November 2000 coincided with the beginning of the dry season which lasts from December to February. The studies during March/April 2001 were carried out when the first heavy rain showers were falling after a long dry period.

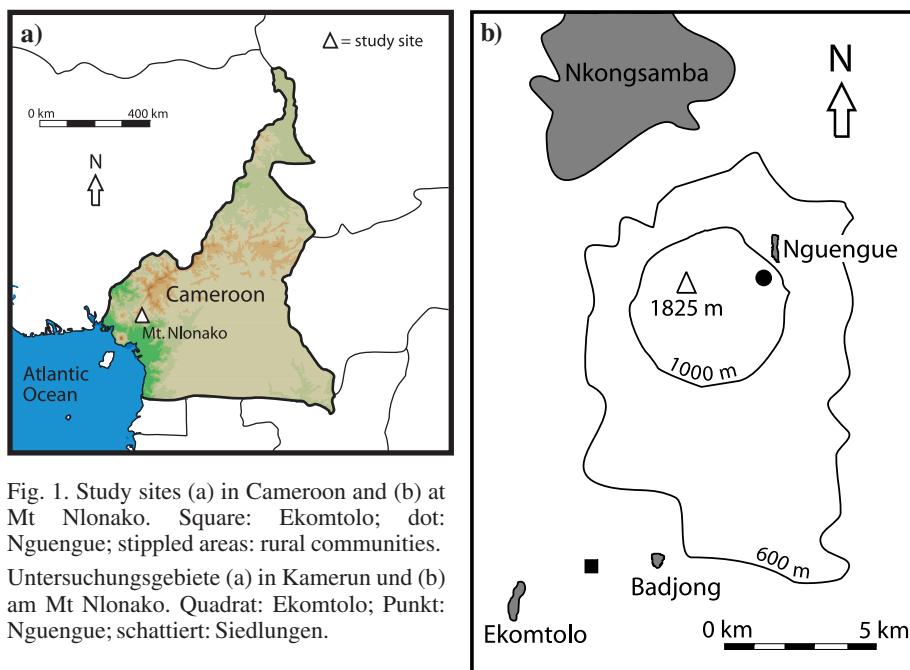


Fig. 1. Study sites (a) in Cameroon and (b) at Mt. Nlonako. Square: Ekomtolo; dot: Nguengue; stippled areas: rural communities.  
Untersuchungsgebiete (a) in Kamerun und (b) am Mt. Nlonako. Quadrat: Ekomtolo; Punkt: Nguengue; schattiert: Siedlungen.

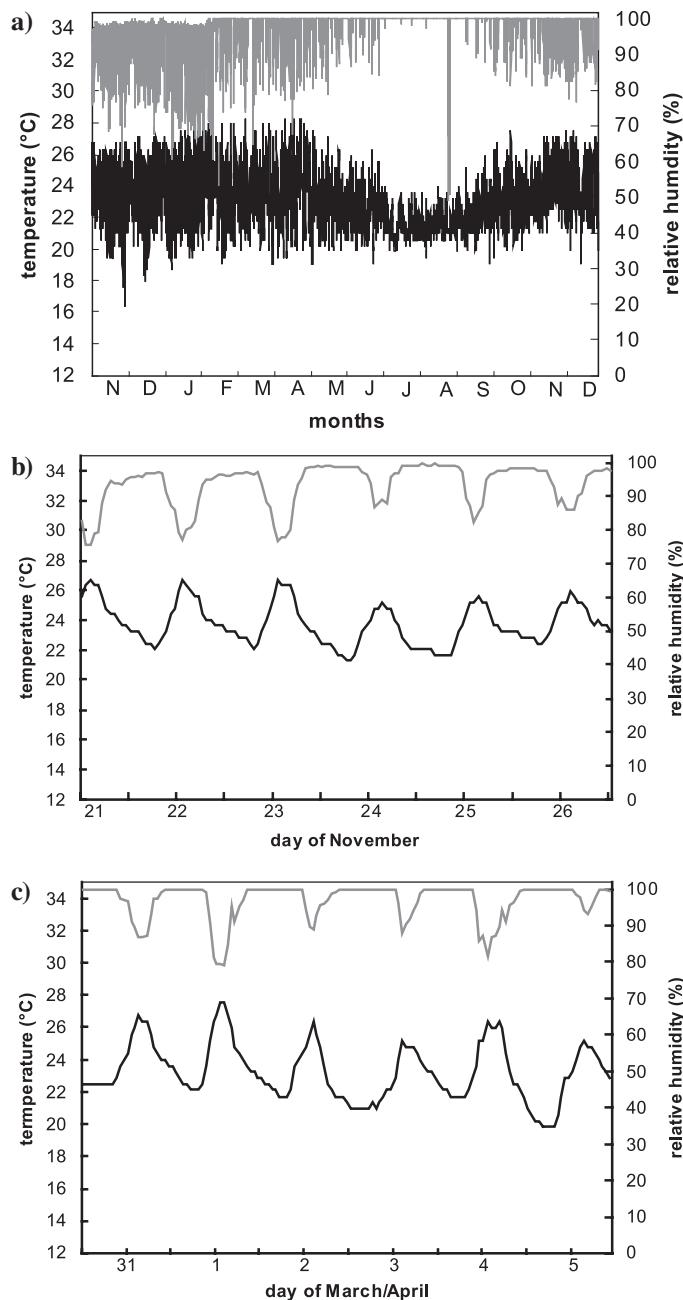


Fig. 2. Temperature and relative humidity at the Ekomtolo study site (a) from November 2000 to December 2001, (b) during the study period 21 to 26 November 2000 and (c) during the study period 31 March to 5 April 2001. Black: temperature; grey: relative humidity.

Temperatur und relative Luftfeuchtigkeit im Untersuchungsgebiet bei Ekomtolo (a) von November 2000 bis Dezember 2001, (b) während des Untersuchungszeitraums 21.-26. November 2000 und (c) während des Untersuchungszeitraums 31. März bis 05. April 2001. Schwarz: Temperatur; grau: relative Luftfeuchtigkeit.

The vegetation in areas below an altitude of 800 m consists of typical lowland rainforest followed by submontane rainforest up to an altitude of 1200 m. Above 1200 m montane rainforest and cloud forest exists at Mt. Nlonako. At the higher altitudes primary rain forest dominates whereas the lower altitudes are dominated by

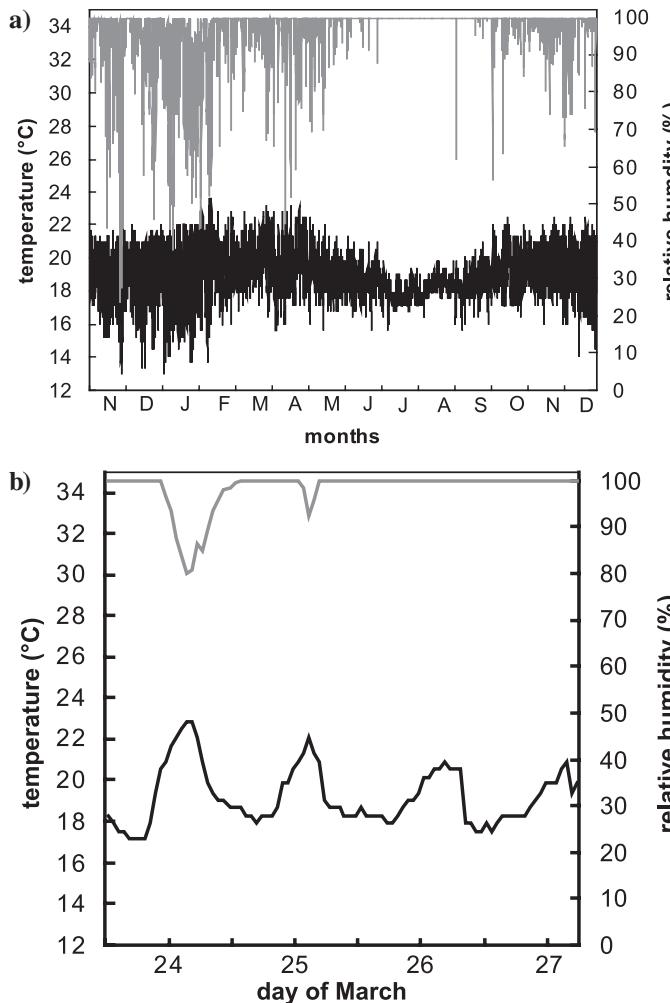


Fig. 3. Temperature and relative humidity at the Nguengue study site, a) from November 2000 to December 2001 and b) during the study period 24 to 27 March 2001.  
 Black: temperature; grey: relative humidity.  
 Temperatur und relative Luftfeuchtigkeit im Untersuchungsgebiet bei Nguengue, a) von November 2000 bis Dezember 2001 und b) während des Untersuchungszeitraums 24.-27. März 2001. Schwarz: Temperatur; grau: relative Luftfeuchtigkeit.

secondary forest interspersed with primary rainforest patches. Floristically Mt. Nlonako belongs to the Guinea Congo region.

The nomenclature follows FROST (2002) with the exception of *Arthroleptis poecilonotus*.

## 2.2 Transects

Visual encounter surveys along transects were carried out at the Ekomtolo site at around 450 m altitude from 21-26 November 2000 and 31 March to 5 April 2001 and at the Nguengue site at around 1140 m altitude from 24-27 March 2001. Each transect had a length of 400 m. Transects were located either along streams or in the forest occasionally crossing small streams (Fig. 4 and 5). Transects were sampled during the day ( $n = 20$ ) and during the night ( $n = 24$ , for details see Tab. 1). All transects were

study site	transect	n	November	2000	March/April	2001
			day	night	day	night
Ekomtolo	forest	16	4	2	4	6
Ekomtolo	creek	14	4	2	2	6
Nguengue	forest	7	0	0	3	4
Nguengue	creek	7	0	0	3	4

Tab. 1. Number of sampled transects and their distribution over research sites, periods, habitats and time.

Anzahl der untersuchten Transekte und deren Verteilung auf Untersuchungsgebiete, -zeiträume, -habitaten und -zeiten.

searched unidirectionally. The search direction within transects was alternated each 24 hrs period. Transects were sampled with two persons each searching one side of the transect. Sides searched were rotated nightly between persons to minimize sampling bias. All anurans sighted within five meters to either side of the transect were captured, identified and either released at the site of capture or preserved in 70 % ethanol and later deposited as voucher specimens at the Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn (ZFMK) (Appendix 1).

The following three habitat types were recognized in the stream transects: (a) dominated by sandy banks, middle density of stream bank vegetation, slow water flow, (b) very dense stream bank vegetation encroaching upon the stream area, very slow water flow, (c) shallow stream bed, highly structured by rocks of varying size, highly variable, sometimes fast water flow.

The forest transects were characterized by dense vegetation, clearings due to tree fall and areas with an abundance of old fallen logs as well as areas of new growth.

Perching height and substrate was recorded for each individual anuran. Table 2 shows the various categories for vegetation and substrate.

Nearest neighbor cluster analysis was performed using the Statgraphics® Plus version 5.0 software package.

### 3 Results

A total of 46 species with 456 individuals were recorded. Nine species were found only at the Nguengue transects, 28 species only at the Ekomtolo transects. Nine species occurred at both sites. 54 % (n = 25) of the species were represented by less than four specimens each. Examples are *Acanthixalus spinosus* (BUCHHOLZ & PETERS, 1875), *Leptodactylodon boulengeri* NIEDEN, 1910, *Opisthothylax immaculatus* (BOULENGER, 1903), *Petropedetes parkeri* AMIET, 1983, *Werneria mertensiana* (AMIET, 1976) and *Xenopus fraseri* BOULENGER, 1905. *Phrynobatrachus auritus* BOULENGER, 1900 (Fig. 6) was the most abundant anuran species in the study with 165 specimens (36 % of all specimens) followed by *Amnirana asperima* PERRET, 1977 (8 %, Fig. 7), *Phrynodon cf. sandersoni* PARKER, 1935 (7 %), *Dimorphognathus africanus* (HALLOWELL, 1858 "1857") (5 %) and *Amnirana amnicola* PERRET, 1977 (5 %). Figure 8 shows all species and provides numbers as well as localities, whereas Figure 9 shows the abundance of species and families. Ranidae clearly dominate the anuran assemblage with 69 % of all specimens. Relative to species diversity, no family exhibited a pronounced high diversity. Pipidae and Rhacophoridae were represented by only one species each.



Fig. 4. Section of the stream transect at the Ekomtolo study site.  
Photo: H.-W. HERRMANN.

Ausschnitt des Bachtranseks im Untersuchungsgebiet bei Ekomtolo.



Fig. 5. Section of the forest transect at the Ekomtolo study site.  
Photo: H.-W. HERRMANN.

Ausschnitt des Waldtranseks im Untersuchungsgebiet bei Ekomtolo.

Fig. 6. *Phrynobatrachus auritus* male.  
Photo: H.-W. HERRMANN.

*Phrynobatrachus auritus*-Männchen.



Fig. 7. *Amnirana asperrima* male.  
Photo: H.-W. HERRMANN.

*Amnirana asperrima*-ma-Männchen.



### 3.1 Seasonal partitioning

Only the Ekomtolo site was visited during two different seasonal periods, namely November 2000 which represents the beginning of the dry season and March/April 2001 which represents the end of the dry season/beginning of the rainy season. Variation in species composition is shown in Figure 10. From a total of 37 species found at Ekomtolo, 16 species were exclusively found during the March/April period. Species found with fewer than four specimens (and thus not represented in Fig. 10) are *Afrixalus paradorsalis* PERRET, 1960b, *Hyperolius* cf. *sylvaticus* SCHIØTZ, 1967, *H. kuligae* MERTENS, 1940, *Leptopelis omissus* AMIET, 1992 “1991” (Fig. 11), *L. rufus* REICHENOW, 1874, *Opisthothylax immaculatus*, *Cardioglossa elegans* BOULENGER, 1906, *Petropedetes* cf. *newtoni* (BOCAGE, 1895), *Phrynobatrachus batesi* (BOULENGER, 1906), *Phrynodon* cf. *sandersoni*, *Nectophryne afra* BUCHHOLZ & PETERS, 1875 (Fig. 12), *N. batesii* BOULENGER, 1913, *Xenopus fraseri*. Only three species, *Acanthixalus spinosus*, *Cardioglossa gracilis* BOULENGER, 1900 and *Astylosternus fallax* AMIET, 1978 “1977”, were exclusively found in November. All these species were represented by only one specimen. The abundance of individuals within most species encountered during both study periods varied little with the exception of *Phrynobatrachus auritus* (beginning/

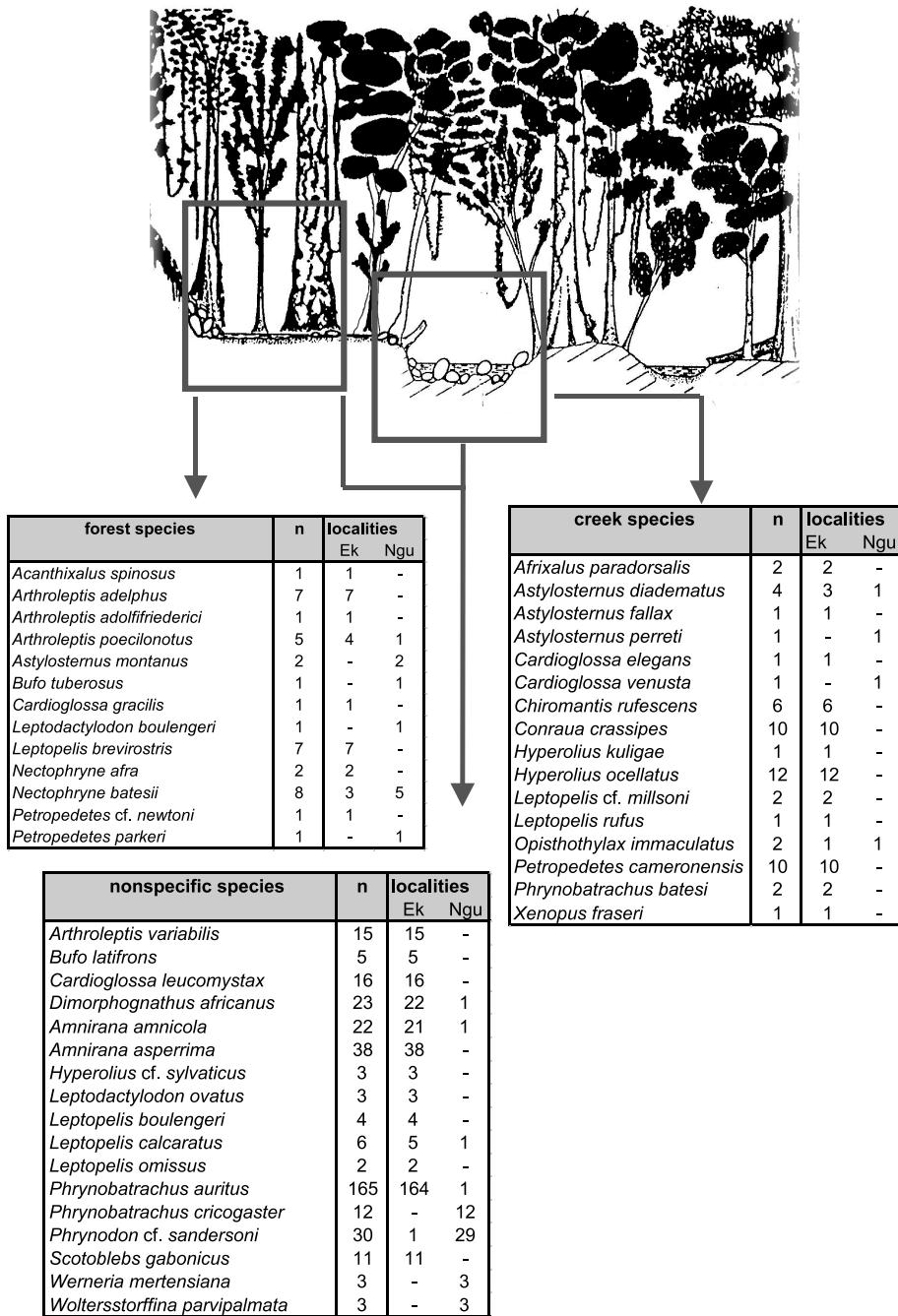


Fig. 8. List of all species found ordered by habitat and study site (adapted after AMIET 1975). Ek: Ekomtolo, Ngu: Nguengue.

Liste aller gefundenen Arten geordnet nach Habitat und Untersuchungsgebiet (verändert nach AMIET 1975). Ek: Ekomtolo, Ngu: Nguengue.

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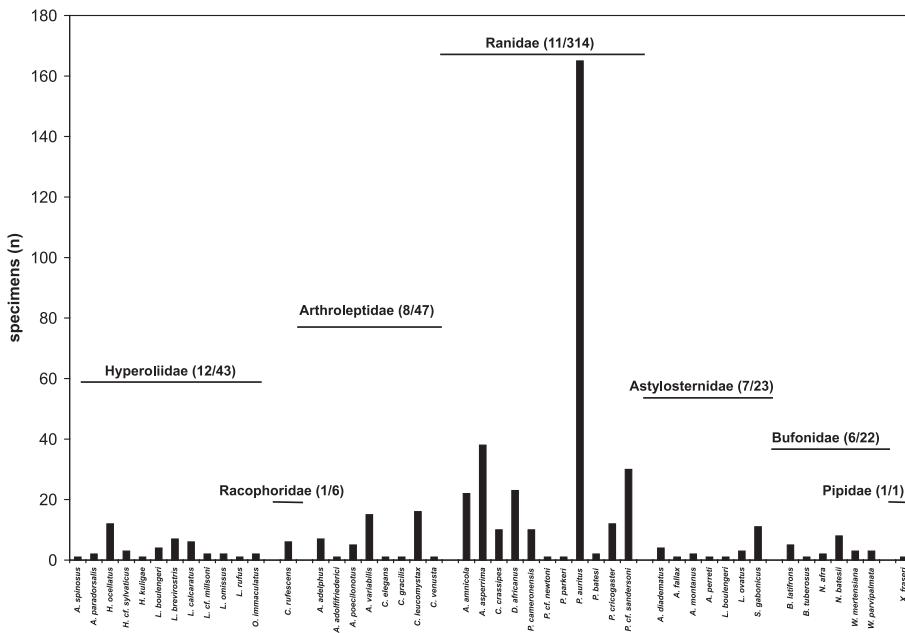


Fig. 9. Abundance of species and families. Parentheses: number of species/number of specimens.  
Abundanz der Arten und Familien. Klammern: Anzahl der Arten/Anzahl der Individuen.

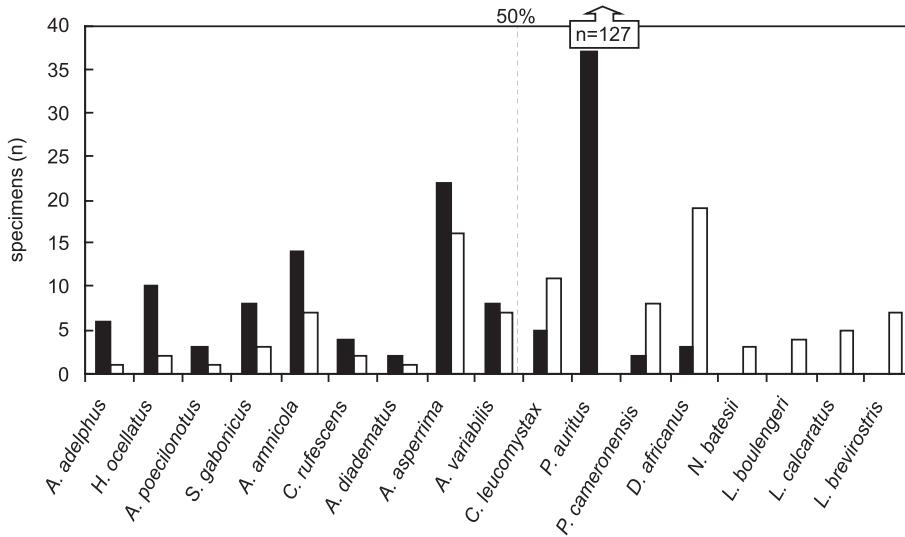


Fig. 10. Comparison of the number of specimens of species ( $n = 4$  specimens) found at Ekomtolo for November 2000 (black) and March/April 2001 (white). The dotted line marks equal specimen numbers during both periods.

Vergleich der Individuenzahlen der Arten ( $n = 4$  Individuen), die bei Ekomtolo im November 2000 (schwarz) und März/April 2001 (weiß) gefunden wurden. Die gestrichelte Linie markiert gleiche Anzahl von Individuen während beider Zeiträume.



Fig. 11. *Leptopelis omissus* male. Photo: H.-W. HERRMANN  
Fig. 12. *Nectophryne afra*. Photo: H.-W. HERRMANN

*Leptopelis omissus*-Männchen.

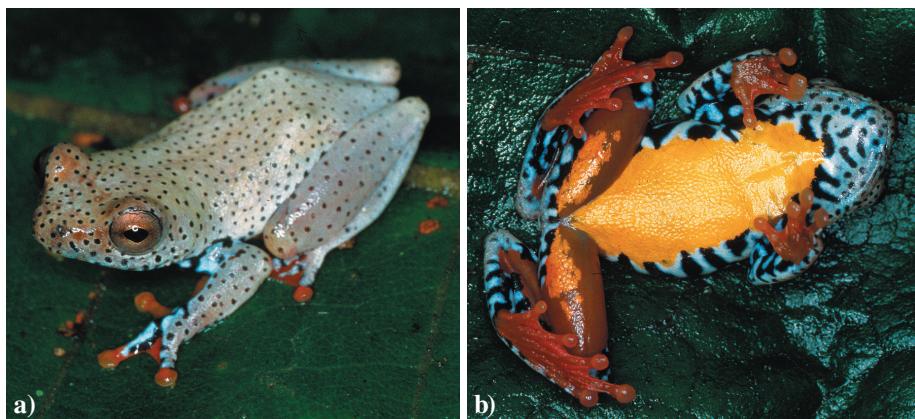


Fig. 13. *Hyperolius ocellatus* female. a) dorsal; b) ventral. Photo: H.-W. HERRMANN  
*Hyperolius ocellatus*-Weibchen. a) dorsal; b) ventral.

end of dry season: 37/127), *Dimorphognathus africanus* (3/19), *Hyperolius ocellatus* GÜNTHER, 1858 (10/2) (Fig. 13) and *Arthroleptis adelphus* PERRET, 1966 (6/1).

### 3.2 Altitudinal partitioning

Of the nine species found exclusively in Nguengue, *Phrynobatrachus cricogaster* PERRET, 1957 was represented by more than three specimens (Fig. 14). *Phrynodon* cf. *sandersoni* was mostly found in Nguenge ( $n = 29$ ) although one specimen was found in Ekomtolo. Other species found in small numbers only in Nguengue are *Astylosternus montanus* AMIET, 1978 “1977”, *A. perreti* AMIET, 1978 “1977”, *Bufo tuberosus* GÜNTHER, 1858, *Cardioglossa venusta* AMIET, 1972, *Leptodactylodon boulengeri*, *Petropedetes parkeri*, *Werneria mertensiana*, *Wolterstorffina parvipalmata* (WERNER, 1898). Vice versa, a number of species mostly found in Ekomtolo were found with only one specimen in Nguengue. Examples are *Phrynobatrachus auritus*, *Dimorphognathus africanus*, *Amnirana amnicola* and *Leptopelis calcaratus* (BOULENGER, 1906).

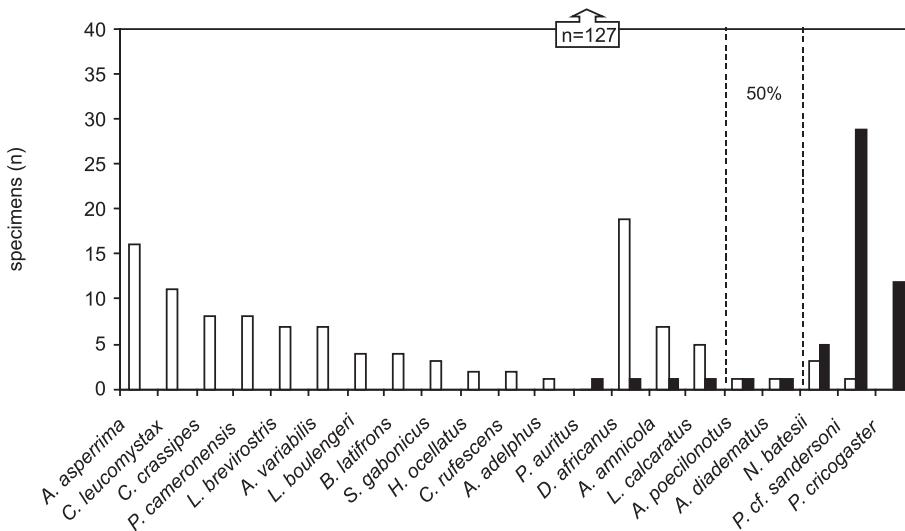


Fig. 14. Comparison of the number of specimens of species ( $n = 4$  specimens) found at Ekomtolo 450 m altitude (white) and Nguengue 1140 m altitude (black) in March/April 2001. The area between dotted lines marks equal specimen numbers at both altitudes.

Vergleich der Individuenzahlen der Arten ( $n = 4$  Individuen), die bei Ekomtolo 450 m Höhe (weiß) und Nguengue 1140 m Höhe (schwarz) gefunden wurden. Der Bereich zwischen den gestrichelten Linien markiert gleiche Individuenanzahl in beiden Höhen.

### 3.3 Daily partitioning

From a total of 44 transects searched, 20 were worked during the day and 24 during the night; this may result in a sampling bias towards nocturnality (Table 1). *Bufo tuberosus*, *Leptodactylodon ovatus* ANDERSSON, 1903 and *Xenopus fraseri* were only found diurnally, as well as two of the three specimens of *Werneria mertensi* (Fig. 15). Specimens of *L. mertensi* and *X. fraseri* were hiding under stones and under leaf litter respectively on a sandy bank. Many more species were exclusively seen at night such as *Hyperolius ocellatus*, *Chiromantis rufescens* (GÜNTHER, 1869), *Astylosternus diademaetus* WERNER, 1898 as well as all members of the genus *Leptopelis* with the exception of *L. brevirostris* (WERNER, 1898) of which only three of a total of seven specimens were found active nocturnally. Similar ratios of diurnal versus nocturnal activity could be found in *Arthroleptis variabilis* MATSCHIE, 1893 (10/5) and *Scotobleps gabonicus* BOULENGER, 1900 (4/7) (Fig. 16). 13 more species with a total of more than three specimens were found active during the day and at night but showed a much stronger tendency towards nocturnality. For example, only five individuals of *Phrynobatrachus auritus* were active during the day whereas 155 specimens (97 %) showed nocturnal activity. A similar pattern was found for *Amnirana asperrima* with 97 % of all individuals observed at night.

### 3.4 Habitat partitioning

17 species (37 %) were found in both habitats, along the stream and in the forest (Fig. 8). Both species of *Nectophryne*, *N. afra* and *N. batesii*, were found only in the forest (Fig. 17). Most specimens and all species of *Arthroleptis* were found in the forest

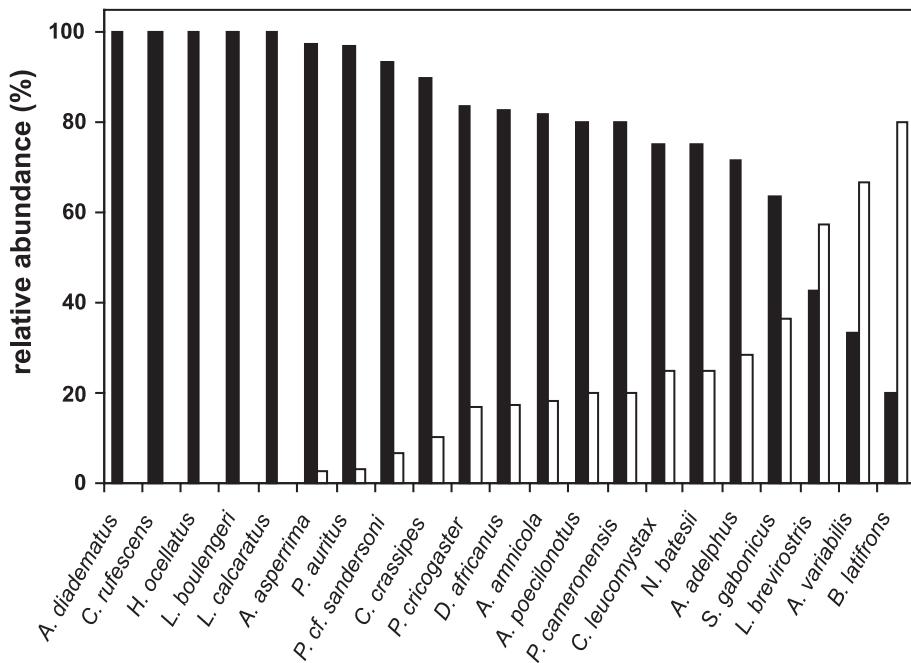


Fig. 15. Relative abundance of species ( $n = 4$  specimens) found at night (black) and/or during the day (white).

Relative Abundanz der Arten ( $n = 4$  Individuen), die nachts (schwarz) und/oder tags (weiß) gefunden wurden.

(partially: *A. variabilis* (73 %); exclusively: *A. adelphus*, *A. adolfifriederici* NIEDEN, 1911 “1910”, *A. poecilonotus*). Within *Astylosternus* only *A. montanus* was found exclusively in the forest. *Astylosternus diadematus*, *A. fallax* and *A. perreti* were all found only in the stream transects. Other species found only along the stream were *Conraua crassipes* (BUCHHOLZ & PETERS, 1875), *Chiromantis rufescens*, *Hyperolius ocellatus* and *Petropedetes cameronensis* REICHENOW, 1874. 20 specimens (96 %) of all *Dimorphognathus africanus* were found along the stream transects. The genus *Amnirana* shows remarkably different habitat preferences with *A. asperima* being found almost exclusively along the streams (97 %) and *A. amnicola* predominately in the

right page: Tab. 2. Perching sites. Numbers in site categories indicate number of specimens found. Numbers in parentheses indicate specimens found in day retreats. Bold: species with more than 50 % of the specimens found on the ground in day retreats. Underlined: species with at least 80 % of the specimens found on the ground in day retreats.

rechte Seite: Sitzwarten. Zahlen entsprechen der Anzahl der gefunden Individuen. Zahlen in Klammern entsprechen der Anzahl der Individuen, die in Tagverstecken gefunden wurden. Fett: Arten mit mehr als 50 % der Individuen auf dem Boden in Tagverstecken. Unterstrichen: Arten mit mindestens 80 % der Individuen auf dem Boden in Tagverstecken.

species	total	vegetation		substrate					
		leaf	branch	root	logs	leaf litter	rocks	soil	water
<i>Acanthixalus spinosus</i>	1	1							
<i>Afrixalus pardorsalis</i>	2	2							
<i>Hyperolius ocellatus</i>	12	5	5						2
<i>Hyperolius cf. sylvaticus</i>	3	2	1						
<i>Hyperolius kuligae</i>	1	1							
<i>Leptopelis boulengeri</i>	4		4						
<i>Leptopelis brevirostris</i>	7	5	2						
<i>Leptopelis calcaratus</i>	6	2	4						
<i>Leptopelis cf. millsoni</i>	2		2						
<i>Leptopelis omissus</i>	2	1	1						
<i>Leptopelis rufus</i>	1		1						
<i>Opisthothylax immaculatus</i>	2	2							
<i>Chiromantis rufescens</i>	6	1	5						
<i>Arthroleptis adelphus</i>	7	5				1(1)		1(1)	
<i>Arthroleptis adolfifriederici</i>	1	1							
<i>Arthroleptis poecilonotus</i>	5	4	1						
<i>Arthroleptis variabilis</i>	15	6			1(1)	5(5)	2(2)	1(1)	
<i>Cardioglossa elegans</i>	1		1						
<i>Cardioglossa gracilis</i>	1					1			
<i>Cardioglossa leucomystax</i>	16	7	4	1(1)		2(2)		2(1)	
<i>Cardioglossa venusta</i>	1	1							
<i>Amnirana amnicola</i>	22	10	4			4(3)		3	1(1)
<i>Amnirana asperrima</i>	38	10	10	7	1		4	6(1)	
<i>Conraua crassipes</i>	10	2		1	1			3	3(1)
<i>Dimorphognathus africanus</i>	23	19			1(1)				3(2)
<i>Petropedetes cameronensis</i>	10	8		1(1)			1(1)		
<i>Petropedetes cf. newtoni</i>	1				1				
<i>Petropedetes parkeri</i>	1					1			
<i>Phrynobatrachus auritus</i>	165	148	10		1(1)	4(3)		2(1)	
<i>Phrynobatrachus batesi</i>	2	2							
<i>Phrynobatrachus cricogaster</i>	12	9				1(1)		2(1)	
<i>Phrynodon cf. sandersoni</i>	30	28				1(1)		1(1)	
<i>Astylosternus diadematus</i>	4	1							3
<i>Astylosternus fallax</i>	1					1			
<i>Astylosternus montanus</i>	2	1	1						
<i>Astylosternus perreti</i>	1						1		
<i>Leptodactylodon boulengeri</i>	1							1	
<i>Leptodactylodon ovatus</i>	3					2(2)			1(1)
<i>Scotobleps gabonicus</i>	11			1(1)	1(1)	1	1(1)	6	1(1)
<i>Bufo latifrons</i>	5	1			1(1)	1(1)		2(2)	
<i>Bufo tuberosus</i>	1					1(1)			
<i>Nectophryne afra</i>	2	2							
<i>Nectophryne batesii</i>	8	8							
<i>Werneria mertensiana</i>	3	1				1(1)		1(1)	
<i>Wolterstorffina parvipalmata</i>	3	3							
<i>Xenopus fraseri</i>	1					1(1)			



Fig. 16. *Scotobleps gabonicus* male.  
Photo: H.-W. HERRMANN.  
*Scotobleps gabonicus*-Männchen.

forest (59 %). Similarly, *Phrynobatrachus auritus* was found predominately in forest habitat (61 %). Another species of *Phrynobatrachus*, *P. cricogaster* was also found in both habitats with a trend towards the forest (67 %, 8 out of 12 specimens). Remarkably, *Leptopelis brevirostris* was the only species within the genus found only along forest transects. *Cardioglossa leucomystax* (BOULENGER, 1903) (Fig. 18) is an example of a species which occurs in both habitats but is predominant in streams.

### 3.5 Perching site partitioning

21 of all 46 species (46 %) were found only on plants (Tab. 2); the treefrogs *Chiromantis rufescens*, *Leptopelis boulengeri* (WERNER, 1898) (Fig. 19), *L. brevirostris*, *L. calcaratus* and the dwarf toad *Nectophryne batesii* for example. On the contrary, ten species (22 %) were encountered only on the ground (6 of these species were represented by only one specimen). 15 species (32 %) were found on the ground and in vegetation. Nine of these 15 species showed a strong link between their microhabitat (ground/vegetation) and their temporal activity pattern (diurnal/nocturnal). In *Arthroleptis adelphus*, *A. variabilis*, *Cardioglossa leucomystax*, *Petropedetes cameronensis* and *Phrynodon cf. sandersoni* all specimens encountered during the day were found in retreats such as crevices, under rocks or logs or hidden in leaf litter. With the exception of *Arthroleptis variabilis* more than half of the specimens of these species were found active (not in retreats) during the night. This suggests that in most if not all of these five species specimens found during the day were encountered in their day retreats. In *Dimorphognathus africanus*, *Amnirana amnicola*, *Phrynobatrachus auritus* and *P. cricogaster* a similar pattern is observed, though not as substantiated, 50-75 % of the specimens found during the day were in retreats.

*Leptodactylodon ovatus*, *Bufo latifrons* BOULENGER, 1900, *B. tuberosus*, *Werneria mertensiana* and *Xenopus fraseri* were also predominately found in retreats during the

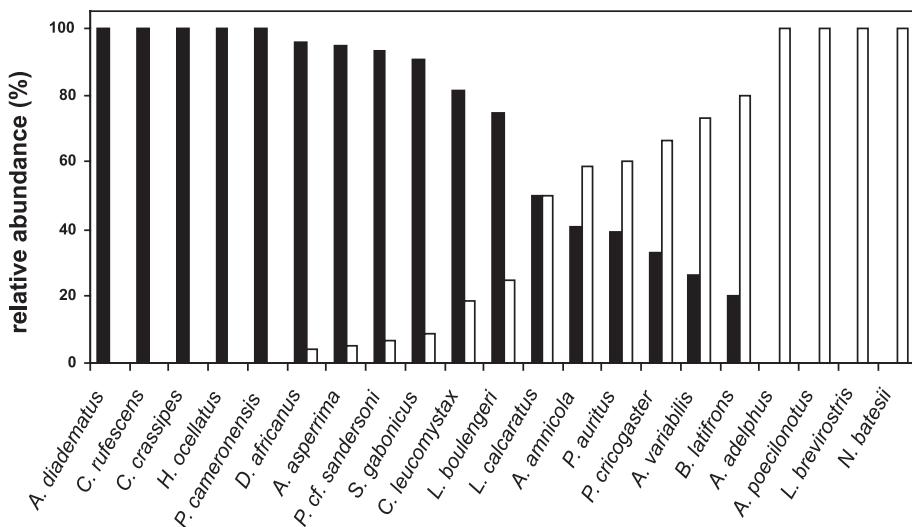


Fig. 17. Relative abundance of species ( $n = 4$  specimens) found along the creek (black) and/or the forest (white) transects.

Relative Abundanz der Arten ( $n = 4$  Individuen), die entlang von Bach- (schwarz) und/oder Waldtransekten (weiß) gefunden wurden.

day, however, with the distinction that there were no majorities of specimens found active during the night.

All but two *Hyperolius ocellatus* were found at night in vegetation. The two specimens on the ground were found in amplexus.

Of all species found in vegetation only *Leptopelis boulengeri*, *L. cf. millsoni* (BOULENGER, 1895) and *L. rufus* were exclusively found perching on branches. All other species were found perching on leaves as well or showed a marked preference for the latter. Ten species showed a remarkably narrow substrate preference, found only on leaves.

In contrast *Amnirana asperrima* and *Conraua crassipes* were the only species found on a variety of different substrates in the vegetation as well as on the ground.

### 3.6 Ecological relationships between species

A cluster analysis with the variables altitude (Ekomtolo/Nguengue), habitat (creek/forest), activity pattern (nocturnal/diurnal) and perching site distribution (vegetation/ground) (for data matrix see Appendix 2) was conducted (Fig. 20). Species with more than 50 % of specimens found during the day in retreats on the ground were treated as operational units only found in vegetation. Thereby we tried to avoid bias resulting from possible retreats being scored as perching sites. Only species with four or more specimens were included in the analysis. A second such cluster analysis excluding specimens found in Nguengue was performed to check for cluster robustness by avoiding bias from unequal study periods and unequal numbers of transects searched.

The analysis resulted in one large cluster representing all species except *Bufo latifrons*. This dominant pattern was supported in the second analysis for specimens

from Ekomtolo only. Within the cluster of the remaining species, two well defined groups were determined: one consisting of the species *Leptopelis brevirostris* and *Arthroleptis variabilis* and one represented by *Arthroleptis adelphus* and *A. poecilostomus*. The former is supported by the Ekomtolo-specimens-alone analysis. A less defined subgroup consisting of *Hyperolius ocellatus*, *Chiromantis rufescens*, *Leptopelis boulengeri*, *Cardioglossa leucomystax*, *Dimorphognathus africanus*, *Petropedetes cameronensis*, *Leptopelis calcaratus*, *Phrynobatrachus auritus*, *Amnirana asperrima*, *Conraua crassipes* and *Astylosternus diadematus* exists within the main cluster.

#### 4 Discussion

The high species diversity, 46 species from seven different families, found in two localities at Mt. Nlonako while working only 24 transects is characteristic for ancient tropical rainforests. The Southwest-Cameroonian mountain chain called “Dorsale Camerounaise”, beginning with Mt. Cameroon in the South and ending with Tchabal Mbabo in the North, of which Mt. Nlonako is part, is possibly the area with the highest anuran species diversity in Africa (POYNTON, 1999). Another typical pattern for rainforests is that more than half of all species are represented by very low numbers of specimens. The high species diversity found is possibly also based on the location of the transects in an ecotone area with secondary and primary forest patches. For Mt. Nlonako and adjacent areas data suggests that the total species count will be considerably higher than that for the transects sampled in this study (H.-W. HERRMANN et al., unpublished data).

The very high abundance of *Phrynobatrachus auritus* was somewhat surprising. As the study period was very short, this pattern could possibly be explained by a seasonality of the species which may have been triggered by the first heavy rain showers after the dry season. This view is supported by the disproportion of specimens found at the beginning (November 2000) and the end of the dry season (March/April 2001). This observation is in disagreement with MERTENS (1938) and LARGEN & DOWSETT-LEMAIRE (1991) who found reproductive behavior in *P. auritus* at the end of the rainy season (November) and during the dry season (January). A similar reproductive pattern was found for *Dimorphognathus africanus*. In both species this pattern may be related to reproductive activity synchronized by the first rains at the beginning of the rainy season. 16 of all the species found in Ekomtolo were found only at the end of the dry/rainy season transition. This could indicate a seasonal reproductive period.

The altitudinal pattern observed with some species found only in the Nguengue transects is based on the high abundance of montane species such as *Phrynobatrachus cricogaster*, *Arthroleptis adolfifriederici*, *Astylosternus montanus*, *A. perreti*, *Cardioglossa venusta*, *Phrynodon cf. sandersoni*, *Werneria mertensiana* and *Wolterstorffina parvipalmata* (SCHMITZ, 1998, GARTSHORE, 1986, PERRET 1966, 1977, AMIET, 1975). Other species such as *Bufo tuberosus*, *Phrynobatrachus auritus*, *Dimorphognathus africanus* and *Amnirana amnicola* show a more submontane or lowland distribution and may reach their upper limits around the Nguengue transects as only one specimen per species was found at this higher altitude (1140 m).

The majority of all species showed a marked nocturnal activity. The few specimens that were found during the day were often in places which suggested day retreats. Such specimens can be considered to have been found “by accident” – not active – thereby negating the conclusion of diurnality (see Tab. 2). In cases where more than half of

such “diurnal” specimens were found in day retreats the diurnal data was excluded from later analysis, i. e. the cluster analysis. A number of species such as *Bufo latifrons*, *B. tuberosus*, *Leptodactylodon ovatus* and *Xenopus fraseri* were found exclusively or mainly during the day, however, always in retreats. Due to the lack of data on nocturnal activity in these species, no conclusions can be drawn relative to activity patterns.

From the “forest species”, i. e. species found exclusively or mostly within the forest transects (species of the genera *Nectophryne* and *Arthroleptis* as well as *Leptopelis brevirostris* and *Astylosternus montanus*), all but *Astylosternus montanus* are independent from open water (streams or ponds) for their reproduction (MERTENS 1938, AMIET & PERRET 1969, SCHEEL 1970, AMIET 1975, 1989, 1991, BARBAULT & TREFOUT RODRIGUEZ 1979, FISCHER & HINKEL 1992); their eggs develop without a free larval stage. *Astylosternus montanus* deposits its eggs in streams or temporal water bodies. The eggs develop into tadpoles (AMIET 1977, 1989) which GARTSHORE (1986) found in February. Two specimens of *A. montanus* were found in our forest transect at the end of March. This suggests that the period of reproduction had already passed and may be at the beginning of the dry season with larvae found later during that season. *Scotobleps gabonicus* was found mainly in the stream transects with more specimens in November than in March/April. This may indicate a reproductive activity peak at the beginning of the dry season which is supported by the observations by LARGEN & DOWSETT-LEMAIRE (1991) and LAWSON (1993) who observed calling males in November. *Dimorphognathus africanus*, another species found almost entirely in the stream habitat, was found much more often in March-April. Whether this is related to reproduction remains unknown as information on the reproductive biology of *D. africanus* is widely lacking. The increased occurrence of *Leptopelis boulengeri* at the stream in March/April suggests reproduction at the beginning of the rainy season.

That most species were found primarily active on vegetation is expected for treefrogs such as species of *Acanthixalus*, *Afrixalus*, *Hyperolius*, *Leptopelis*, *Opisthothylax* and *Chiromantis*. Of the species found in vegetation and on the ground a large number occupied day retreats thus suggesting that the species are mainly active on vegetation but retreat to the ground during the daily period of inactivity. After data correction for such phenomena (see Tab. 2) the large majority of all species were found on vegetation. Only *Conraua crassipes* and *Amnirana asperrima* show a broader acceptance of perching sites on different structures in the vegetation and different substrates on the ground. Six species were found exclusively active on the ground (not in retreats) of which all were represented by only one specimen. *Scotobleps gabonicus* was the only species with all eleven specimens encountered on the ground, four of which were found in day retreats, indicating a nocturnal terrestrial activity.

The 21 species in the cluster analysis result in a cluster with 20 species except for *Bufo latifrons* (Fig. 20). This is explained by the combination of diurnal activity, the forest habitat and frequent occurrence on the ground by *B. latifrons*. Only two sub-clusters of the main cluster formed by the remaining species showed a partial distinctiveness, namely *Leptopelis brevirostris* and *Arthroleptis variabilis* as well as *A. adelphus* and *A. poecilonotus*. These two groups together build another sub-cluster. The whole sub-group with all four species is characterized by a forest habitat which is directly linked to their reproductive mode. The two species subgroups are differentiated mostly by a nocturnal activity in the *A. adelphus-poecilonotus* group and predominately diurnal activity in the *A. variabilis-L. brevirostris*-group. Overall all species included in the cluster analysis, except *B. latifrons*, show a remarkable similarity within the ecological variables analyzed.



Fig. 18. *Cardioglossa leucomystax* female.  
Photo: H.-W. HERRMANN  
*Cardioglossa leucomystax*-Weibchen.



Fig. 19. *Leptopelis boulengeri* male. Photo: H.-W. HERRMANN  
*Leptopelis boulengeri*-Männchen.

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### Habitatwahl und zeitliche Aktivitätsmuster von Anuren in einem Montan- und Submontan-Regenwald im südwestlichen Kamerun – erste Ergebnisse

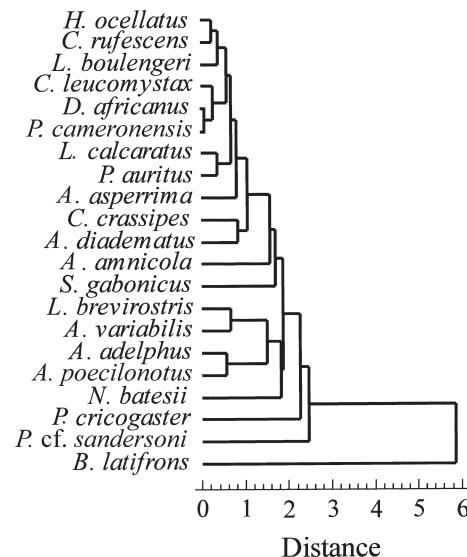
In Rahmen einer Untersuchung zur Anurenökologie im Südwesten Kameruns wurden vom 21. bis 26. November 2000 (Beginn der Trockenzeit) sowie vom 31. März bis 5. April 2001 (Beginn der Regenzeit) „visual encounter surveys“ entlang von Transekten in der Umgebung von Ekomtolo ( $4^{\circ}51'N$ ,  $9^{\circ}54'E$ , 450 m ü.NN) am Mt. Nlonako durchgeführt. Vom 24. bis 27. März 2001 wurden Transekten in der Umgebung von Nguengue ( $4^{\circ}55'N$ ,  $9^{\circ}59'E$ ) in 1140 m Höhe bearbeitet. Bei der qualitativen und quantitativen Arten-Erfassung wurden neben der Höhen- und der saisonalen Verteilung auch Habitatwahl (Bach-/Waldtransekten), Aktivitätsmuster (tag-/nachtaktiv) und Substratpräferenz für Sitzwarten untersucht.

Die 456 nachgewiesenen Anurenindividuen verteilten sich dabei auf insgesamt 46 Arten, von denen 54 % (n = 25) mit weniger als vier Individuen vertreten waren. Dominierende Art war *Phrynobatrachus auritus* (36 %), gefolgt von *Amnirana asperrima* (8 %) und *Phrynodon cf. sandersoni* (7 %), *Dimorphognathus africanus* (5 %) sowie *Amnirana amnicola* (5 %). Ranidae machten 69 % aller Funde aus.

16 der in Ekomtolo nachgewiesenen Arten wurden ausschließlich zu Beginn der Regenzeit gefunden; ein mögliches Indiz für eine saisonale Reproduktionsabhängigkeit. Bei Arten, die in beiden Untersuchungszeiträumen nachgewiesen wurden, zeigten nur *Phrynobatrachus auritus* (Beginn der Trocken-/Regenzeit: 37/127), *Dimorphognathus africanus* (3/19), *Hyperolius ocellatus* (10/2) und *Arthroleptis adelphus* (6/1) einen deutlichen Unterschied in der Individuenanzahl.

Fig. 20. Nearest neighbor cluster analysis including all species with  $n = 4$  specimens for the variables low/high altitude, creek/forest habitat, nocturnal/diurnal activity and vegetation/ground perching sites (for data matrix see Appendix 2). Vegetation/ground perching sites data corrected for day retreats (see text).

„Nearest neighbor“-Clusteranalyse mit allen Arten mit  $n = 4$  Individuen und den Variablen niedrige/hohe Höhenverteilung, Bach-/Waldhabitat, Nacht-/Tagaktivität und Vegetation-/Bodensubstratsitzwarten (für die Datenmatrix siehe Appendix 2). Vegetation-/Bodensubstratsitzwarten-Werte korrigiert für Tagverstecke (siehe Text).



Einige Arten, wie zum Beispiel *Phrynobatrachus cricogaster* (Nguengue/Ekomtolo: 12/0) und *Phrynodon cf. sandersoni* (29/1), wurden ausschließlich beziehungsweise fast ausschließlich bei Nguengue gefunden und können als Montanarten bezeichnet werden. Andere Arten wurden fast ausschließlich bei Ekomtolo gefunden und zeigen damit eine eher submontane Verbreitung; Beispiele sind *Phrynobatrachus auritus* (1/164) und *Dimorphognathus africanus* (1/22).

Die Mehrheit der nachgewiesenen Arten war nachtaktiv (z. B. *Hyperolius ocellatus*, *Chirormantis rufescens*, *Astylosternus diadematus* und alle *Leptopelis*-Arten mit Ausnahme von *L. brevirostris*). Bei einer Anzahl von Arten lagen sowohl Nacht- als auch Tagfunde vor. Am Tag gefundene Individuen wurden allerdings häufig in Verstecken gefunden und dann als „nicht tagaktiv“ interpretiert.

Viele Arten, die ausschließlich oder überwiegend im Waldhabitat nachgewiesen wurden, haben wahrscheinlich eine gewässerunabhängige Reproduktion ohne ein freies Larvenstadium (z. B. Arten der Gattung *Arthroleptis*, *Nectophryne* und *Leptopelis brevirostris*). Zwei *Astylosternus montanus*, eine Art, die in Bächen oder temporären Gewässern ablaicht, wurden Ende März im Waldtransekt gefundenen. Dies kann ein Hinweis dafür sein, dass die Reproduktionsphase bereits beendet war und wahrscheinlich am Anfang der Trockenzeit liegt. Ein verstärktes Auftreten von *Leptopelis boulengeri* im Bachtransekt im März/April lässt eine Reproduktion zu Beginn der Regenzeit vermuten.

Unabhängig vom Habitat wurde Vegetation in den meisten Fällen als Sitzwarte bevorzugt. Von den zehn ausschließlich am Boden gefundenen Arten (22 %) sind sechs nur mit einem Individuum vertreten. Hinzu kommt, dass bei neun der 15 Arten, die sowohl am Boden als auch in der Vegetation gefunden wurden, eine enge Korrelation zwischen Substratwahl und Aktivitätsmuster vorlag. So befanden sich alle am Tage gefundenen Individuen von *Arthroleptis adelphus*, *A. variabilis*, *Cardioglossa leucomystax*, *Petropedetes cameronensis* und *Phrynodon cf. sandersoni* in Verstecken, wie zum Beispiel in Spalten, unter Steinen oder im Laub. *Amnirana asperrima* und *Conraua crassipes* zeigten keine ausgeprägte Substratpräferenz. Eine „nearest neighbor“-Clusteranalyse mit den Variablen Höhenverteilung, Habitat, Aktivitätsmuster und Substrat ergab eine einzige Artengruppe mit Ausnahme von *Bufo latifrons*. Dies spricht für eine unerwartet große ökologische Ähnlichkeit der Arten.

Schlagwörter: Anura: Amphibia; Mt. Nlonako; Südwest-Kamerun; Artendiversität; räumliche Einnischung; zeitliche Aktivitätsmuster; Sitzwarten.

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### Appendix 1. ZFMK numbers of specimens collected

Species are listed in alphabetical order. Numbers after a slash indicate number of specimens under one collection number.

*Acanthixalus spinosus* (1 specimen): 78313. *Amnirana amnicola* (15 specimens): 78314, 78316-7, 78319-20, 78322-29, 78331-2. *A. asperrima* (21 specimens): 78321, 78333-45, 78346/2, 78348-52. *Arthroleptis adelphus* (6 specimens): 78417-21, 78657. *A. adolfifriedericii* (1 specimen): 78405. *A. poecilonotus* (5 specimens): 78424-5, 78427, 78431-2. *A. variabilis* (15 specimens): 78406-15, 78434, 78436, 78654-6. *Astylosternus diadematus* (4 specimens): 78303-6. *A. fallax* (1 specimen): 78310. *A. montanus* (1 specimen): 78308. *A. perreti* (1 specimen): 78309. *Bufo latifrons* (3 specimens): 78221-3. *Cardioglossa elegans* (1 specimen): 78256. *C. gracilis* (1 specimen): 78255. *C. leucomystax* (12 specimens): 78257-9, 78261-2, 78264-70. *C. venusta* (1 specimen): 78253. *Chiromantis rufescens* (6 specimens): 78245-50. *Conraua crassipes* (7 specimens): 78273-8, 78280. *Dimorphognathus africanus* (22 specimens): 78433, 78435, 78437/2, 78439-42, 78444-52, 78454-58. *Hyperolius* cf. *sylvaticus nigeriensis* (3 specimens): 78381-3. *H. kuligae* (1 specimen): 78367. *H. ocellatus ocellatus* (12 specimens): 78368-76, 78378-80. *Leptodactylodon boulengeri* (1 specimen): 78287. *L. ovatus orientalis* (2 specimens): 78284, 78423. *Leptopelis boulengeri* (3 specimens): 78399-401. *L. brevirostris* (6 specimens): 78392-6, 78398. *L. calcaratus* (6 specimens): 78386-91. *L. cf. millsoni* (2 specimens): 78403-4. *L. omissus* (2 specimens): 78311-2. *L. rufus* (1 specimen): 78402. *Nectophryne afra* (2 specimens): 78229-30. *N. batesii* (6 specimens): 78231-3, 78235, 78237-8. *Opisthothylax immaculatus* (2 specimens): 78384-5. *Petropedetes cameronensis* (8 specimens): 78355-9, 78361-3. *P. cf. newtoni* (1 specimen): 78354. *P. parkeri* (1 specimen): 78366. *Phrynobatrachus auritus* (133 specimens): 78286, 78351-7, 78426, 78505, 78507-24, 78527-30, 78538-59, 78561-84, 78586-601, 78603-25, 78627-41, 78653. *P. batesi* (2 specimens): 78503-4. *P. cricogaster* (11 specimens): 78460-7, 78469-71. *Phrynodon* cf. *sandersoni* (27 specimens): 78473-93, 78495-9, 78501. *Scotobleps gabonicus* (11 specimens): 78288-94, 78296, 78299-301. *Werneria mertensiiana* (3 specimens): 78243, 78251, 78253. *Wolterstorffina parvipalmata* (3 specimens): 78240-2). *Xenopus fraseri* (1 specimen): 78220.

### Appendix 2. Data matrix for cluster analysis

Vegetation/ground perching sites data corrected for day retreats (see text).

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