CHAPTER 5. AMPHIBIANS OF THE AFROTROPICAL REALM

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THE GEOGRAPHIC AND HUMAN CONTEXT

The Afrotropical Realm includes all of mainland Sub-Saharan Africa and the southern Arabian Peninsula[1], as well as several large offshore islands: Zanzibar and Pemba; Madagascar; the western Indian Ocean islands of the Seychelles (including Aldabra), Mauritius (including Rodrigues), Réunion, Mayotte, and the Comoros; the Gulf of Guinea islands (Bioko, Príncipe, São Tomé and Pagalu); Socotra; and the Cape Verde Islands. Although Africa finally separated from the rest of the southern land-mass of Gondwanaland some 100 Ma, the African, Arabian and Eurasian plates abutted at least at the end of the Oligocene, and it is only from about 15-10 Ma that Africa has been an isolated land mass (when the African and Arabian land masses rifted apart; see Kingdon 1989; Goudie 2005). The island of Madagascar, on the other hand, separated from the African mainland between 165-140 Ma and has been isolated (as an island) from all other land masses for 87-91 million years (Storey *et al.* 1995; Torsvik *et al.* 2000).

An extensive process of rifting which began about 30 Ma has left mainland Africa very diverse topographically, with many high mountain ranges, especially on the east of the continent, and with rift valleys that include some of the deepest lakes in the world. Much of Africa is still volcanically active, including Mount Kilimanjaro, its highest peak, soaring some 5,895m above sea-level. A combination of intra-plate hotspots, extensive Cenozoic doming (45 Ma), vulcanism and coastal upwarp has created the world's largest plateau. This is characterized by a "basin and swell" topography unique to the interior of the African continent, and stretching from South Africa to East Africa, with high points including Mount Mulanje (3,002m) in southern Malawi and Mount Rungwe (2,691m) in southern Tanzania (Beentje *et al.* 1994; Goudie 2005). East and North-east Africa are bisected by the 6,000-km-long Great Rift (or Gregory Rift), the "passive" margin between the African and East African Plates. This massive feature is visible from space and runs from the Luangwa Valley in Zambia, northe-ast through Ethiopia, where it meets the Saudi Arabian Plate and continues north-west to the Caucasus Mountains.

Not surprisingly, the region is ecologically diverse, with an enormous range of vegetation types from deserts to woodlands and grasslands to rainforests. In West Africa, the agriculturally productive Guinea and Sudanese savannah regions slowly merge into the lowland forests stretching across West Africa. A little further to the east, the highly fragmented, lower Guinea rainforests of Nigeria and western Cameroon open into the vast, lush, relatively intact tropical rainforests of the Congo Basin. Apart from the chain of volcanic mountains centred on western Cameroon and extending into the sea as the Gulf of Guinea islands, West Africa has very few uplands (with the exception of Mount Nimba, and the Loma and other nearby mountains in Sierra Leone, Guinea and Liberia). The eastern edge of the Congo Basin is flanked by the Albertine Rift, a series of high, block-faulted mountain chains that separates the Congo Basin rainforest of Central Africa from the forest/savannah mosaic habitats of East Africa, most famous for their teeming herds of wildebeest and zebra.

To the north the Great Rift cuts through the Ethiopian Highlands, home to more than two-thirds of Africa's unique Afro-alpine habitat, while to the south-east of the Great Rift are the Eastern Arc Mountains that continue into the Southern Highlands of Tanzania south to Mount Mulanje in Malawi and the Chimanimani Highlands of Zimbabwe. Patches of forest (now highly fragmented) fringe the coast of much of eastern Africa, from the Juba and Shabelle River Valleys in Somalia south to south-eastern South Africa. In the south-western part of South Africa, the unique Mediterranean fynbos vegetation is dominant, with its remarkable floristic endemism, and further north the Succulent Karoo becomes dominant along the west coast of South Africa.

Africa has a low human population density (approximately 30 people per square kilometer in 2005), of which over 60% live in rural areas, but a high population growth rate (over 2.1% per annum, though this is decreasing). Historically, the region has been subject to relatively low levels of anthropogenic disturbance, related not only to low human population densities, but also to widespread poverty (gross income per capita was around US$600 in Sub-Saharan African in 2004). However, 35% of the continent's Gross Domestic Product is concentrated in South Africa, where the human impacts on natural ecosystems and biodiversity have been more severe than in most of the region. Economic growth rates in Africa have been amongst the lowest in the world and still are, though there has been a recent tendency for somewhat faster growth (4.5% in 2004). Although many of Africa's natural habitats are still intact, some parts of the continent have been affected much more than others. Deforestation has been particularly severe in the Upper Guinea forests of West Africa, in the mountains and lowlands of Nigeria and western Cameroon, in many of the mountainous regions of central and East Africa, and in the East African coastal lowlands. This forest loss has been driven largely by expanding subsistence agriculture to support the burgeoning human populations, but also by commercial agriculture and logging. As mentioned above, habitat loss and fragmentation has been particularly severe in South Africa, and above all in the fynbos vegetation of the extreme south and south-west (which has been heavily impacted by invasive species and fire, and well as by general urban and agricultural development). There has also been extensive habitat degradation in the semi-arid Sahel region, much of it driven by over-exploitation of resources for basic subsistence by growing human populations. However, in central and south-central Africa, extensive tracts of lowland forest, savannah and grassland remain largely intact. On Madagascar, habitat loss has been especially severe, with almost no natural habitat surviving on the central plateau, and much of the country characterised by very high levels of soil erosion.

GLOBAL CONSERVATION STATUS

A total of 969 amphibian species are recorded from the Afrotropical Realm, of which 240 (25%) are considered threatened (see Figure 1 for details). Although this is significantly less than the global average of 33%[2], it is still almost one-quarter of the overall amphibian fauna of the Afrotropics. As is the case globally, the percentage of threatened species is expected to increase as the status of DD species is clarified, as new species (many of which are likely to be rare, and have small ranges) are discovered, and as the taxonomic status of many species complexes is resolved.

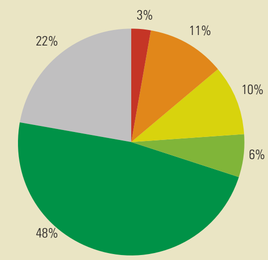
The Afrotropical realm currently accounts for about 13% (240) of all globally threatened amphibian species. When looking at the Red List Categories, the Afrotropics account for only 7% of CR species, but 14% of the EN species, and 15% of the VU species. Hence, on the basis of current knowledge, threatened Afrotropical amphibians are more likely to be in a lower category of threat, when compared with the global distribution of threatened species amongst categories. This might partly be explained by the fact that the amphibian fauna is very poorly known in many parts of the continent (for example the Albertine Rift, the Congo Basin, the Ethiopian plateau and the Upper Guinea forests of West Africa), and these are places that could have many threatened species. However, the lower than average level of threat is also likely to be genuine, in part because the fungal disease chytridiomycosis, although present in Africa (Weldon *et al.* 2004), is not so far believed to be a serious threat in the region (although there are few monitoring programmes, and further information could change this perception). Species that are threatened by this disease are more likely to experience sudden and dramatic declines, pushing them very quickly into the higher categories of threat.

Surprisingly, especially for such a poorly known region, the percentage of DD species (22%) is slightly lower than the global average (23%). As more African amphibian species are discovered and named, the percentage of DD species might increase for a period, at least until the conservation status of these species can be adequately assessed.

There have been no recorded recent extinctions of amphibians in the Afrotropical Realm. However, of the 33 CR species, three are flagged as Possibly Extinct: *Arthroleptides dutoiti* from Mount Elgon in Kenya, which has not been recorded since 1962, despite extensive searches (Lötters *et al.* 2003); *Nectophrynoides asperginis* from the Udzungwa Mountains in the Eastern Arc of Tanzania (which might have become extinct in the wild in 2004, though it still survives in captivity); and *Conraua derooi*, from the Togo-Volta Highlands of eastern Ghana and western Togo (previously not recorded since the 1960s[3]).

Figure 1. *Summary of Red List categories for amphibians in the Afrotropical Realm. The percentage of species in each category is also given.*

Red List Category	Number of species
Extinct (EX)	0
Extinct in the Wild (EW)	0
Critically Endangered (CR)	33
Endangered (EN)	107
Vulnerable (VU)	100
Near Threatened (NT)	53
Least Concern (LC)	467
Data Deficient (DD)	209
Total Number of Species	**969**



SPECIES RICHNESS AND ENDEMISM

Species Richness and Endemism Across Taxa

The 969 native amphibian species in the Afrotropical Realm represent 16% of the currently known global total of 5,915 species. Of these 969 species, 954 (or 98%) are endemic to the Afrotropics (Table 1). The overwhelming majority of African amphibians are frogs and toads (Anura), 98% of which are endemic. All 28 species of Afrotropical caecilian (Gymnophiona) occurring in the region are endemic. Members of the order Caudata (salamanders) are completely absent. A total of 618 species (64%) are members of families that are endemic to the region.

The amphibian fauna of the Afrotropical Realm has been relatively isolated from that of the rest of the world for much of its evolutionary history, and remains so today (the Saharan and Arabian deserts forming an effective, though fairly recent, barrier to most species). This isolation accounts for the high level of family and genus-level endemism within the region. For example, of the 16 families of amphibians found in the region, nine are also endemic. From the perspective of amphibian biogeography, the region is almost defined by the distribution of the African treefrogs and reed frogs (family Hyperoliidae) (Poynton 1999), which are present through nearly all of Sub-Saharan Africa, Madagascar, the Seychelles Islands, and the Gulf of Guinea islands (though absent from southern Arabia, the Comoros[4], the Mascarenes, and the Cape Verde Islands). The amphibian fauna comprises elements with both tropical and southern temperate origins (Poynton 1999).

There are 112 amphibian genera in the Afrotropical Realm, of which 105 (94%) are endemic. These endemic genera represent nearly one-quarter (23%) of the 460 amphibian genera worldwide. The Afrotropics, therefore, account for a larger proportion of the overall diversity of amphibians at the generic level than at the species level. The most species-rich endemic genus in the region is *Hyperolius* (125 species). At the opposite end of the spectrum, there are 42 monotypic genera endemic to the Afrotropical Realm, which equates to exactly

Table 1. *The number of Afrotropical amphibians in each taxonomic Family present in the region.*

Family	Native species (endemics to region)	Percentage of species in region that are endemic	Percentage of species in family that are endemic to region	Native genera (endemics to region)	Percentage of genera in region that are endemic	Percentage of genera in family that are endemic to region
Anura						
Arthroleptidae	51 (51)	100	100	3 (3)	100	100
Astylosternidae	29 (29)	100	100	5 (5)	100	100
Bufonidae	105 (97)	92	20	15 (14)	93	41
Heleophrynidae	6 (6)	100	100	1 (1)	100	100
Hemisotidae	9 (9)	100	100	1 (1)	100	100
Hylidae	1 (0)	0	0	1 (0)	0	0
Hyperoliidae	253 (253)	100	100	18 (18)	100	100
Mantellidae	158 (158)	100	100	5 (5)	100	100
Microhylidae	87 (87)	100	20	18 (18)	100	26
Petropedetidae	102 (102)	100	100	13 (13)	100	100
Pipidae	23 (23)	100	77	4 (4)	100	80
Ranidae	109 (103)	94	15	14 (9)	64	23
Rhacophoridae	4 (4)	100	1	1 (1)	100	11
Sooglossidae	4 (4)	100	100	2 (2)	100	100
TOTAL ANURA	**941 (926)**	**98**	**18**	**101 (94)**	**93**	**26**
Gymnophiona						
Caeciliidae	22 (22)	100	19	9 (9)	100	100
Scolecomorphidae	6 (6)	100	100	2 (2)	100	100
TOTAL GYMNOPHIONA	**28 (28)**	**100**	**16**	**11 (11)**	**100**	**100**
TOTAL ALL AMPHIBIANS	**969 (954)**	**98**	**16**	**112 (105)**	**94**	**23**

Boophis luteus *(Least Concern) is a treefrog in the Family Mantellidae, which is endemic to Madagascar. This species is locally abundant along streams in both pristine and degraded rainforest. © Piotr Naskrecki*

one-third (33%) of the 126 monotypic genera of amphibians worldwide. This unexpectedly high percentage is probably a reflection of the poor state of knowledge of the Afrotropical amphibian fauna; it is likely that many of these genera will prove not to be monotypic as more species are discovered. For example, recent descriptions include a second species of the previously monotypic genus *Callulina* (De Sá *et al.* 2004), a second species of *Cophyla* (Vences *et al.* 2005), a second species of *Acanthixalus* (Rödel *et al.* 2003), and a second and third species of *Alexteroon* (Amiet 2000). The seven non-endemic genera in the Afrotropics include five ranid genera (*Euphlyctis*[5], *Hoplobatrachus, Ptychadena, Rana*[6], *Tomopterna*[7]) and the widespread genera *Bufo*[8] and *Hyla*[5].

As noted already, 16 of the world's 48 amphibian families (33%) occur in the Afrotropics. The nine endemic families to the region (Arthroleptidae, Astylosternidae, Heleophrynidae, Hemisotidae, Hyperoliidae, Mantellidae, Petropedetidae, Sooglossidae and Scolecomorphidae) represent 19% of the global level of diversity of amphibians at the family level[9]. The characteristics of these families are provided in Chapter 1.

Among the non-endemic families, the majority of Afrotropical species are in the Bufonidae, the Microhylidae and the Ranidae. Of the Afrotropical Bufonidae, 68 species (65% of those occurring in the region) are within the widespread genus *Bufo*[8]. The remaining 14 genera have mostly small numbers of species, with the exception of *Nectophrynoides* (11 species). The Afrotropical toad genera of *Nectophrynoides* (endemic to eastern Tanzania) and *Nimbaphrynoides* (endemic to Mount Nimba in Côte d'Ivoire, Guinea and Liberia) are remarkable in that they include 13 of the 14 known live-bearing anurans in the world[10] (with the possibility that the poorly known, monotypic Afrotropical bufonid genera, *Didynamipus* and *Laurentophryne*, might also be live-bearing).

The Afrotropical Microhylidae species are very unevenly distributed within the region, with 56 species endemic to Madagascar (10 genera, including *Plethodontohyla* – 15 species, *Platypelis* – 11 species, *Scaphiophryne* – 10 species, and *Stumpffia* – 8 species). On the African mainland, there are 29 species in eight genera. The largest concentrations of microhylids are in South Africa (15 species, eight of which are endemic) and Tanzania (12 species, nine of which are endemic, with four endemic genera). Microhylid diversity is low in the rest of Africa, with only one species in West Africa, and none at all in the equatorial rainforest belt. The largest genera on the African mainland are *Breviceps* (15 species) and *Phrynomantis* (5 species). The Afrotropical microhylids exhibit a wide diversity of reproductive modes, including both larval- and direct-developers.[11]

The Afrotropical Ranidae species are all larval-developers, and occur throughout the African mainland, with one species naturally occurring on Madagascar. There are 14 genera, the dominant genus being *Ptychadena* (47 species), with other notable genera including *Amnirana* (11 species), *Strongylopus* (11 species), *Afrana* (10 species), and *Tomopterna* (9 species). Among the Afrotropical ranids is the largest frog in the world, the Goliath Frog *Conraua goliath*, with some individuals recorded as weighing more than 3kg.[12]

Of the remaining families, the highly aquatic Pipidae, although small in number of species (but with more than 75% of the species in the family occurring in the Afrotropics), is a very visible and abundant component of the amphibian fauna, being dominated by the generally widespread and resilient genus *Xenopus* (16 species).

The caecilian family Caeciliidae is very poorly known in the Afrotropics, as in other parts of the world. Only 21 species (in nine genera) are known, of which six species are endemic to the granitic islands of the Seychelles, though strangely none at all occur in Madagascar. The Seychelles is the only country in the world in which the order Gymnophiona forms a majority of the amphibian fauna (and see Essay 5.1). One species in the Caeciliidae is endemic to the island of São Tomé. On the African mainland, members of this family appear to occur mainly in the West African forest belt, east to Cameroon and western Democratic Republic of Congo, and in the coastal areas of East Africa and the Eastern Arc Mountains, south to southern Malawi. There is a single species present in south-western Ethiopia, and a single species (known from just one specimen) is known from the Albertine Rift highlands. Caecilians are unknown from the Congo Basin, but this is probably due to lack of sampling, and they also appear to be absent from the Kenyan Highlands (except for the northern outliers of the Eastern Arc Mountains).

Not surprisingly, the larger families – Bufonidae, Hyperoliidae, Mantellidae, Microhylidae, Petropedetidae – have the largest absolute numbers of globally threatened species (Table 2). The percentage of threatened species ranges greatly between the families, from 0% for the Hylidae, Rhacophoridae and Scolecomorphidae to 100% for the endemic Sooglossidae of the Seychelles (all four of the species have tiny ranges). The percentage of threatened species is also very high in the Astylosternidae (73%), reflecting the poor state of forest conservation in the mountainous regions of Cameroon. The percentages are also high (>30%) in the Bufonidae, Heleophrynidae, and Microhylidae. In the Bufonidae, only 11 of the 68 species of Afrotropical *Bufo* (16%) are globally threatened, but 27 of the remaining 37 species in other genera (80%) are threatened. The Bufonidae are also noteworthy in that 30 of the 38 threatened species fall in the Critically Endangered and Endangered categories, underlining how urgent the conservation needs are in this family.

Certain families have lower levels of threat, notably the Pipidae, Hemisotidae and Ranidae[13], all of which have a high proportion of adaptable species in the Afrotropics. The results for the Arthroleptidae are hard to interpret because of the major taxonomic uncertainties in this family (31% of the species are DD). There is very little information on the threat levels to Afrotropical caecilians (39% DD); two of the three threatened species occur in Seychelles, and the other in Kenya, but almost nothing is known of the conservation status of most of the West African species.

Geographic Patterns of Species Richness and Endemism

A map of overall species richness of amphibians in the Afrotropical Realm (Figure 2) shows that species richness is lowest in arid regions, such as the Sahel, the Horn of Africa, and south-west Africa. However, the apparent region of species paucity on the southern Congo Basin is almost certainly an artefact reflecting the very limited herpetological work in that part of Africa.

Although the regions with the highest known species richness, such as south-western Cameroon and eastern Madagascar are genuine reflections of amphibian diversity, these are also the rainforest regions that have received the most research attention from herpetologists. Other regions, such as the high mountains of the Albertine Rift of eastern Democratic Republic of Congo, Rwanda, Burundi and south-western Uganda, are likely to be richer in species than the current data indicate. Some regions showing higher species richness, such as the Eastern Arc Mountains of Tanzania, and Mount Nimba in Liberia, Guinea and Côte d'Ivoire, are likely to represent genuine patterns, whereas others (for example, in the Upemba region of southern Democratic Republic of Congo and the Taï National Park in south-western Côte d'Ivoire) are probably a reflection of locally intensive survey efforts.

There are seven major concentrations of threatened species (Figure 3a): the Upper Guinea forests from Sierra Leone to Togo; south-eastern Nigeria and south-western Cameroon; the mountains of the Albertine Rift; the Ethiopian Highlands; the Eastern Arc Mountains; southern South Africa (especially in the south-western Cape); and eastern Madagascar (especially in the northern and southern extremities of the eastern rainforest zone). These concentrations of threatened species correlate with those for other taxa (Stuart and Collar 1988; Baillie *et al.* 2004). Smaller concentrations of threatened amphibians are found in: São Tomé, the Kenyan Highlands; southern Malawi (around Mount Mulanje); eastern Zimbabwe (the Chimanimani mountains, in particular) and adjacent Mozambique; and the Seychelles Islands. These geographic concentrations reflect the parts of the region where amphibians have naturally small ranges, and where habitat destruction is ongoing. However, at least some of the threatened species in the Upper Guinea forests were once more widespread, but have declined due to extremely severe habitat destruction. Because of the relatively small number of CR species, there are few significant concentrations of CR species, and the overall pattern is similar to that for threatened species (Figure 3b).

Species Richness and Endemism within Countries

Amphibians occur naturally in every mainland country in Sub-Saharan Africa and southern Arabia (Figure 4). They are also present on Madagascar, and are indigenous to the following

Table 2. *The number of species within each IUCN Red List Category in each Family and Order in the Afrotropical Realm. Introduced species are not included.*

Family	CR	EN	VU	NT	LC	DD	Total number of species	Number threatened or Extinct	% threatened or Extinct
Anura									
Arthroleptidae	3	9	2	3	18	16	51	14	27
Astylosternidae	2	11	8	2	5	1	29	21	72
Bufonidae	9	21	8	2	49	16	105	38	36
Heleophrynidae	2	0	0	0	4	0	6	2	33
Hemisotidae	0	0	1	0	4	4	9	1	11
Hylidae	0	0	0	0	1	0	1	0	0
Hyperoliidae	1	19	29	17	133	54	253	49	19
Mantellidae	7	12	16	12	77	34	158	35	22
Microhylidae	3	13	16	2	36	17	87	32	37
Petropedetidae	3	13	8	10	39	29	102	24	24
Pipidae	1	1	0	1	15	5	23	2	9
Ranidae	1	7	7	4	68	22	109	15	14
Rhacophoridae	0	0	0	0	4	0	4	0	0
Sooglossidae	0	0	4	0	0	0	4	4	100
TOTAL ANURA	**32**	**106**	**99**	**53**	**453**	**198**	**941**	**237**	**25**
Gymnophiona									
Caeciliidae	1	1	1	0	11	8	22	3	14
Scolecomorphidae	0	0	0	0	3	3	6	0	0
TOTAL GYMNOPHIONA	**1**	**1**	**1**	**0**	**14**	**11**	**28**	**3**	**11**
TOTAL ALL AMPHIBIANS	**33**	**107**	**100**	**53**	**467**	**209**	**969**	**240**	**25**

Grandisonia sechellensis *(Least Concern) is known only from the islands of Mahé, Praslin and Silhouette in the Seychelles. The Seychelles is the only place in the world where caecilians form the majority of the amphibian fauna, and this species is sympatric with five other caecilian species. © Renaud Boistel*

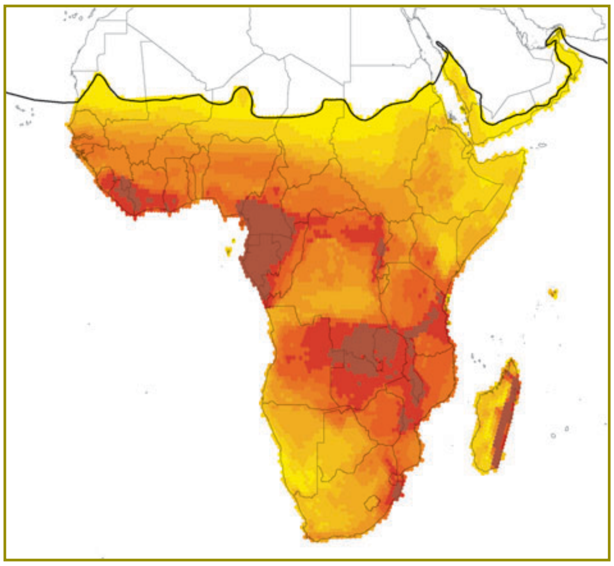


Figure 2. *The species richness of amphibians in the Afrotropical Realm, with darker colours corresponding to regions of higher richness. Colour scale based on 10 quantile classes; maximum richness equals 123 species.*

islands: Seychelles (on most of the granitic islands, but not on the coral atolls), Zanzibar, Pemba, Mafia, Bioko, Príncipe and São Tomé (but apparently not on Pagalu, Socotra, the Comoros[4], the Mascarenes or the Cape Verde Islands).

Madagascar has been intensively studied (Blommers-Schlösser and Blanc 1991; Glaw and Vences 1994; Andreone *et al.* 2005) and has the largest number of species of any country in the Afrotropical Realm (226 species), and 70% of these are in the endemic family Mantellidae (see also Essay 5.2). The only other country with more than 200 species is the Democratic Republic of Congo, and only four other countries have more than 100 species (Cameroon, Tanzania, South Africa, and Nigeria), although, if including species awaiting description, Cameroon has more than 200 species (J.-L. Amiet pers. comm.; see Essay 5.3).

However, these figures need to be treated with considerable caution. The rate of new species' descriptions in Madagascar has been very high over the last decade, with the number of described species from the country doubling since 1991 (compare Blommers-Schlösser and Blanc [1991] with Figure 4). However, the rate of species descriptions in recent years from the African mainland has been much slower than from Madagascar, and this is largely a reflection of the very limited amount of herpetological work that has been conducted on the continent in recent decades. Only the work of Schiøtz (1967, 1975, 1999) focusing on the Hyperoliidae, and that of Tandy and Keith (1972) focusing on African *Bufo*, has taken a continental approach to the amphibian fauna. In particular, there has been very limited work carried out in the Congo Basin since the late 1950s in what might be expected to be one of the most diverse parts of the region. Similarly, with the exception of a small amount of work in Uganda (Drewes and Vindum 1994; Vonesh 2001), the Albertine Rift has received no attention for a similar period of time, despite the fact that this area has higher species richness and endemism among vertebrates than any other part of mainland Africa (Stuart and Collar 1988; Brooks *et al.* 2001). There has been much greater focus on the amphibian fauna of Cameroon (Perret 1966; Amiet 1983, 1989), but serious exploration of the fauna of West Africa only resumed in the mid 1990s (Rödel 2000; see Essay 5.4). Apart from some

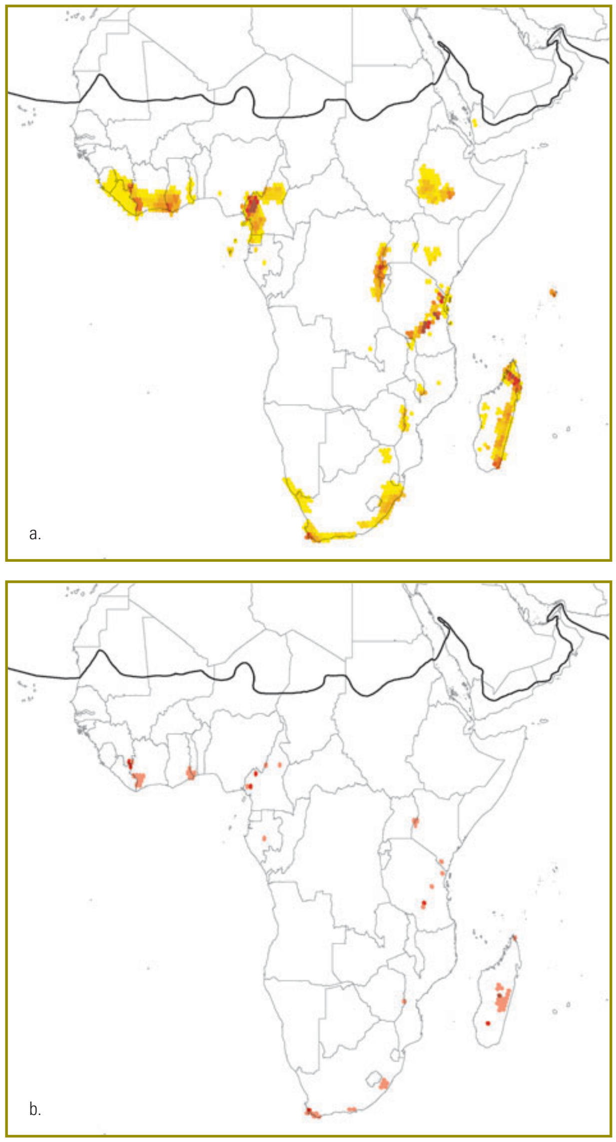


Figure 3. *a) The richness of threatened amphibians in the Afrotropical Realm, with darker colours corresponding to regions of higher richness. Colour scale based on 10 quantile classes; maximum richness equals 31 species. b) The richness of CR amphibians in the Afrotropical Realm, with darker colours corresponding to regions of higher richness. Maximum richness equals three species.*

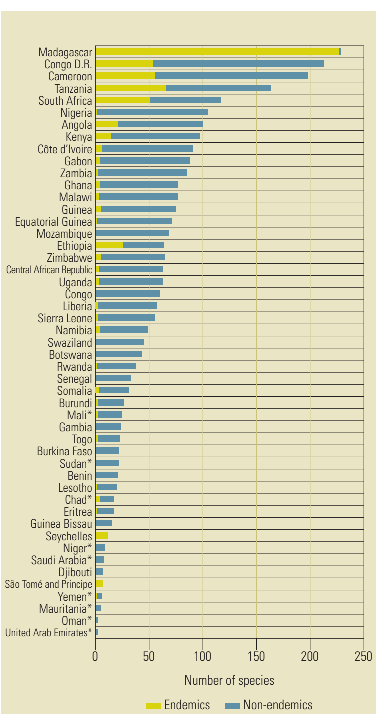
Bufo togoensis *(Near Threatened) is a toad from the Upper Guinea forests of West Africa, ranging from eastern Sierra Leone to western Togo. It lives only in primary forest, usually in close association with the streams in which it breeds, and is affected by ongoing deforestation throughout its range. © Piotr Naskrecki*

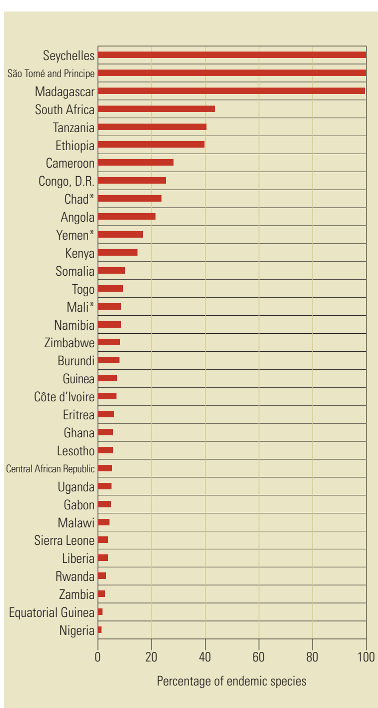
Figure 4. *The number of amphibians present in and endemic to each Afrotropical country. *denotes countries not entirely within the Afrotropical Realm, hence only the species whose ranges fall within the region are included.*

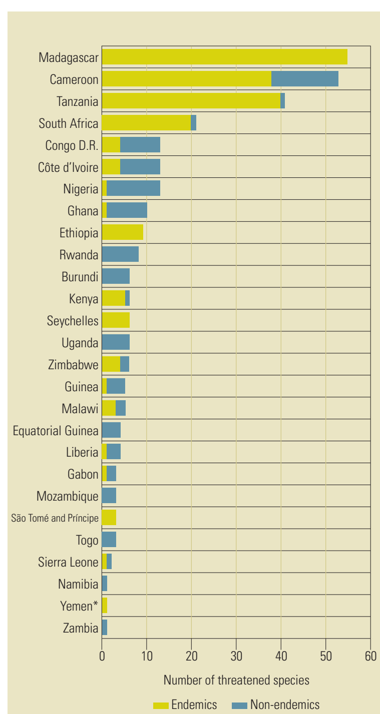
Figure 5. *Percentage of species endemic to each Afrotropical country. Countries with no endemic species are not included. *denotes countries not entirely within the Afrotropical Realm, hence only the species whose ranges fall within the region are included.*

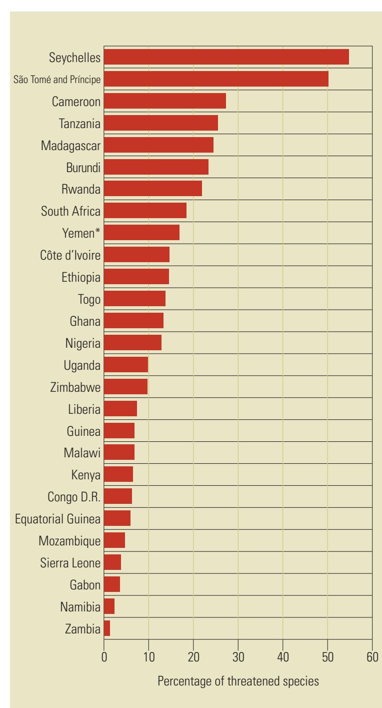
Figure 6. *The number of threatened amphibians present in and endemic to each Afrotropical country. Countries with no threatened species are not included in the diagram. *denotes countries not entirely within the Afrotropical Realm, hence only the species whose ranges fall within the region are included.*

Figure 7. *Percentage of native species that are threatened. Countries with no threatened species are not included in the diagram. *denotes countries not entirely within the Afrotropical Realm, hence only the species whose ranges fall within the region are included.*









Kassina cochranae *(Near Threatened) is in the endemic Afrotropical Family Hyperoliidae. It is an arboreal, forest-dwelling species known from the forest zone of Sierra Leone, Liberia and Guinea. Certain populations are probably suffering from severe deforestation as a result of agricultural expansion, logging and growing human settlements. © Piotr Naskrecki*

preliminary work in Ethiopia (Largen 2001) and Somalia (Lanza 1990), work in eastern Africa has been very limited, although there has been some recent attention on Tanzania (e.g., Poynton 2003), and a field guide to the amphibians of East Africa, covering Kenya, Tanzania and Uganda (Channing and Howell 2006).

The frogs of the southern third of the African continent are probably somewhat better known, thanks to a number of detailed studies, for example: Poynton (1964) and Channing (2001) covering the whole region; Wager (1986), Lambiris (1989a), Passmore and Carruthers (1995), and Minter *et al.* (2004) in South Africa, Lesotho and Swaziland; Channing and Griffin (1993) in Namibia; Lambiris (1989b) in Zimbabwe; Broadley (1971) in Zambia; Stewart (1967) in Malawi; Poynton (1966) in Mozambique; and the classic *Amphibia Zambesiaca* works of Poynton and Broadley (1985ab, 1987, 1988, 1991). However, even in South Africa, which is by far the most studied country in the region, new species continue to be described (for example, Turner *et al.* 2004).

In reality, our understanding of the country-level species richness of amphibians in the Afrotropics is still very incomplete. Future investigations will doubtless result in increases in the numbers of species in every country; however, based on the known species richness of other groups such as birds, these increases are likely to be greatest for the Democratic Republic of Congo, Nigeria, Angola, Côte d'Ivoire, Gabon, Ghana, Guinea, Equatorial Guinea, Mozambique, Ethiopia, Central African Republic, Uganda, Congo, Liberia, Sierra Leone, Rwanda, Burundi, Togo, Sudan, Benin[14], and Chad. Meanwhile, Madagascar, Cameroon and Tanzania, which have received the most herpetological attention (after South Africa) in recent years, show no signs of slowing in their rates of new species' descriptions.

Not surprisingly, endemism (in terms of relative proportions; Figure 5) is much higher in island nations. Madagascar has far more endemics than any other country, with all but one of the native species, the Mascarene Ridged Frog *Ptychadena mascareniensis* (LC), being found nowhere else[15]. In both Seychelles and São Tomé and Príncipe, the level of endemism is 100%.

Habitat type	Number of species in each habitat	% of all species occurring in the habitat	Threatened and Extinct species	% of species occurring in habitat that are Threatened or Extinct
Forest	648	67	208	32
All tropical forest	624	64	201	32
Lowland tropical forest	495	51	114	23
Montane tropical forest	322	33	137	43
Savannah	227	23	7	3
Grassland	267	28	52	19
Shrubland	213	22	29	14
Secondary terrestrial habitats	415	43	74	18
Flowing freshwater	380	39	112	29
Marsh/swamp	223	23	38	17
Still open freshwater	375	39	53	14
Arid and semi-arid habitats	41	4	1	2

Table 3. *The habitat preferences of amphibians in the Afrotropical Realm.*

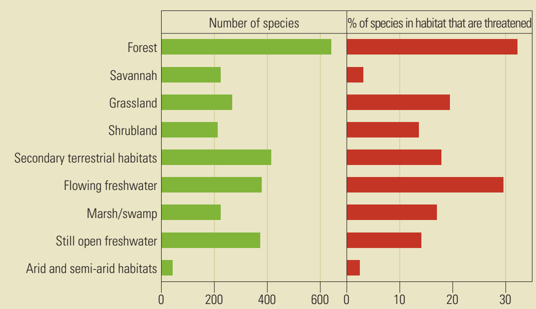


Figure 8. *The habitat preferences of Afrotropical amphibians. The plot on the left-hand side shows the number of species in the region in each habitat type. On the right-hand side, the percentage of these species which are threatened is given.*

Hyperolius puncticulatus *(Least Concern), one of at least 125 treefrogs in the genus* Hyperolius*, ranges from coastal Kenya, through eastern and southern Tanzania (including the island of Zanzibar) to the highlands of Malawi. The males of this species call from vegetation around pools, where they breed. © Alan Channing*

On the African mainland, Tanzania has more endemic species than any other country (see Essay 5.5). More than 50 endemic species are also known from Cameroon, the Democratic Republic of Congo, and South Africa. In terms of percentage of the fauna being endemic, the highest endemism on the African mainland is found in South Africa, Tanzania and Ethiopia (all have around 40% of species endemic). Although the actual numbers and percentages will change as new information becomes available, the overall patterns are concordant with those of other taxonomic groups, and are almost certainly real.

Threatened species occur in 27 of the 49 countries in which there are native amphibians (Figure 6). In fact, threatened species are concentrated in relatively few countries. Only four countries, Madagascar, Cameroon, Tanzania and South Africa, have more than 20 globally threatened species. The top three countries, Madagascar, Cameroon and Tanzania, are undoubtedly genuine centres of threatened species, but the number is almost certainly grossly under-estimated for the Democratic Republic of the Congo. Here there are likely to be many threatened species, probably many of them still undescribed, in the mountains around the Albertine Rift (where there is also severe forest loss due to expanding subsistence agriculture). The percentage of threatened amphibian species is highest in the island nations of Seychelles and São Tomé and Príncipe (Figure 7). The highest percentage on the African mainland is 27% for Cameroon, a reflection of the poor state of forest conservation in the mountainous regions of the country. In many countries, the percentage of threatened species can be expected to rise as new species discoveries are made or crucial habitats are destroyed.

Assessments of the conservation status of Afrotropical amphibians at national level have been carried out only for South Africa, Lesotho and Swaziland (Branch 1988; Monadjem *et al.* 2003; Minter *et al.* 2004).

There are only 33 Critically Endangered Afrotropical species, nine of which occur in Madagascar, seven in Cameroon and five in Tanzania. Outside these three countries, there are three Critically Endangered species in South Africa, two each in Côte d'Ivoire and Kenya, and one each in Gabon, Ghana, Guinea, Liberia, Togo and Zimbabwe. However, the numbers in West Africa are very likely to increase during the coming years, both because of newly discovered species and because of destruction of forest and mountain habitats.

HABITAT AND ECOLOGY

Habitat Preferences

Two-thirds of Afrotropical amphibians occur in forests, and over 40% are believed to be able to survive in secondary terrestrial habitats (Table 3; Figure 8). Similar percentages make use of flowing water and of standing, open water habitats, but marshes and swamps appear to be used by fewer species. Forest-dwelling amphibians are more likely to be threatened than those occurring in any other habitats, with almost one-third of them being globally threatened. Almost 30% of amphibians associated with flowing water (generally streams) are threatened. Consequently, forest-associated amphibians that live along streams are particularly likely to be threatened, a combination that has also been associated with rapid declines worldwide (Stuart *et al.* 2004).

For tropical forests overall, 32% of Afrotropical species are globally threatened. However, in montane tropical forest, 43% of known species are threatened, compared with 23% in lowland tropical forest. These figures probably reflect smaller range sizes of montane species, and the lack of effective habitat conservation measures in many mountainous parts of the region.

Amphibians occurring in savannah and arid habitat are particularly unlikely to be threatened. Africa has 47% of the world's 484 savannah-associated amphibians, and 44% of the world's 94 arid-habitat species, but only 14% of the global total of 4,712 forest-dwelling species. Many of these "species" are in fact complexes of several species, and when these are disaggregated, the number of savannah amphibians will increase. In addition, the number of threatened savannah species can also be expected to increase as their habitats shrink and dry out (these habitats are especially vulnerable to climate change) and their ranges become smaller.

Reproductive Modes

Larval development is by far the most common reproductive mode in the Afrotropics (85% of species), compared with 10% for direct development and 2% live-bearing (this compares with the global picture of 68% larval development, 30% direct development, and 1% live-bearing) (Table 4). Although live-bearing is uncommon, the Afrotropics account for 36% of the world's known live-bearing amphibians, and all but one of the world's known live-bearing frogs and toads. However, it should be noted that the reproductive mode of many species is unknown, and more terrestrial breeders are likely to be identified (Rödel and Ernst 2002; Rödel *et al.* 2002).

In the Afrotropics, the percentage of globally threatened direct-developing amphibians is only slightly higher than for larval-developing species (at a global level, direct-developing species are much more likely to be threatened). The high percentage of threatened live-bearing species in the Afrotropics is a reflection of the high levels of threat to species in the genera *Nectophrynoides* and *Nimbaphrynoides*, many of which have very small ranges in fragile, primarily montane, and poorly protected, habitats.

MAJOR THREATS

As in other parts of the world, habitat loss is overwhelmingly the major threat to amphibians in the Afrotropics (Table 5; Figure 9), affecting over 90% of the threatened species. Other commonly recorded threats include invasive species, fire and pollution. Over-utilization appears to be a minor threat in the region (at least based on current knowledge), and disease, which is a very important factor in other parts of the world, is cited as a threat to only 2% of threatened species in the Afrotropics (although the amount of information on the chytrid fungus, and its pathogenicity, is very limited in the region).

In terms of the types of habitat loss that are impacting threatened amphibians in the Afrotropics, expanding croplands, vegetation removal (mainly logging), and urbanization / industrial development are approximately equivalent, and each is affecting more than 70% of threatened species. Livestock grazing has less impact (probably because it is more prevalent in regions of lower amphibian species richness, and in any case much of Africa has long been grazed by large wild mammals), and tree plantations also appear not to be a significant threat in most places (although this is a serious threat in South Africa and Swaziland). In

Reproductive mode	All Species	Threatened or Extinct Species	% Threatened or Extinct
Direct development	100	26	26
Larval development	819	190	23
Live-bearing	21	10	48
Not known	29	14	48

Table 4. *Afrotropical amphibians categorized by reproductive mode.*

Threat type	Threatened species	% Threatened species
Habitat loss	221	92
Agriculture – Crops	191	80
Agriculture – Tree plantations	18	8
Agriculture – Livestock	79	33
Timber and other vegetation removal	179	75
Urbanization and industrial development	177	74
Invasive species	52	22
Utilization	15	6
Accidental mortality	1	0.4
Pollution	30	13
Natural disasters	3	1
Disease	4	2
Human disturbance	1	0.4
Changes in native species dynamics (excluding disease)	2	1
Fire	50	21

Table 5. *The major threats to globally threatened amphibians in the Afrotropical Realm. Only present threats to species are tallied.*

parts of West Africa, planned mining activities might become increasingly serious as threats to important sites for amphibians (for example, in Guinea and Ghana).

A total of 84 species (18 of which are threatened) are recorded as being used for some or other purpose in the region (Table 6). The most commonly recorded reason for harvesting Afrotropical amphibians is for the international pet trade (especially in Madagascar), followed by human consumption (although the number of species used as human food is probably greatly under-recorded). Much of the harvesting of amphibians in the region is not considered to constitute a major threat to the species. Of the 84 species being harvested, utilization is considered to be a threat for 32 (of which only 15 are threatened species for which harvesting is believed to be contributing to deterioration in their status).

POPULATION STATUS AND TRENDS

Estimates of Population Trends

A summary of the inferred population trends of Afrotropical amphibians is presented in Table 7. For nearly all species, these trends are inferred from trends in the state of the habitats on which the species depend. Species with decreasing populations are typical forest-dependent species that can tolerate little disturbance to their habitats. The percentage of decreasing and increasing species in the Afrotropics is very similar to the global results. However, the percentage of species where the situation is stable is slightly lower, and the percentage for which it is unknown is slightly higher than the global averages (27% and 30%, respectively).

"Rapidly Declining" Species

The Afrotropics appears to have been shielded to some extent from the amphibian declines that are taking place in some other regions, with only 30 (6%) of the 470 globally "rapidly declining" species occurring within the region (a full list of all "rapidly declining" species is provided in Appendix IV and includes their occurrence within each of the realms). Most of the "rapidly declining" species are threatened primarily by the reduction of suitable habitat. Twelve of these are forest-obligate species from the Upper Guinea region of West Africa (see Essay 5.4), where habitat loss has been particularly severe. Another six are endemic to South Africa, where urbanization and agricultural intensification in key habitats has been relatively more severe than on the rest of the continent (see Essay 5.6). The remaining eight species are scattered widely across the continent in Cameroon, Gabon, Kenya, Madagascar (two species), São Tomé and Príncipe, Tanzania, and Zimbabwe.

The Afrotropics have three "rapidly declining" species, affected by severe over-harvesting. Two of these, *Mantella cowanii* (CR) and *Scaphiophryne gottlebei* (CR), both from Madagascar, appear to have declined due to over-collection for the international pet trade (Andreone *et al.* 2006). In the case of *Mantella cowanii*, it declined initially because of the loss of most of its habitat, but subsequently the remnant populations were hit by over-harvesting. The third species, the Goliath Frog *Conraua goliath* (EN) from Cameroon and Equatorial Guinea, has declined mainly due to over-harvesting for human consumption, though there is also some international trade.

So far, only one "rapidly declining" species undergoing an enigmatic decline has been recorded in the Afrotropics, namely the Kihansi Spray Toad *Nectophrynoides asperginis* (CR). This species, endemic to the spray zone of one waterfall in Tanzania, decreased initially because of the damming of an upstream river. However, its final catastrophic decline to probable extinction is believed to have been caused by the fungal disease chytridiomycosis (Krajick 2006), which has been implicated or suspected in most of the enigmatic declines worldwide. Globally, enigmatic declines account for 48% of the "rapid declines" worldwide, but for only 3% so far in the Afrotropics, though it is possible that additional enigmatic declines have not yet been detected. One suspected case concerns *Arthroleptides dutoiti* (CR) in Kenya. This species has the ecological characteristics of other species that have succumbed to chytridiomycosis elsewhere in the world, and now appears to be absent from former sites, even though suitable habitat remains. It is not listed as an enigmatic decline species here, as its decline might have taken place prior to 1980.

Leptopelis parkeri *(Vulnerable), a treefrog in the Family Hyperoliidae, is endemic to several mountain blocks in the Eastern Arc chain of Tanzania. It is a species of closed, intact rainforest, not surviving in seriously disturbed habitats outside forest, and is threatened by habitat loss as a result of expanding human settlements and agriculture, and the harvesting of wood. © David Moyer / Wildlife Conservation Society*

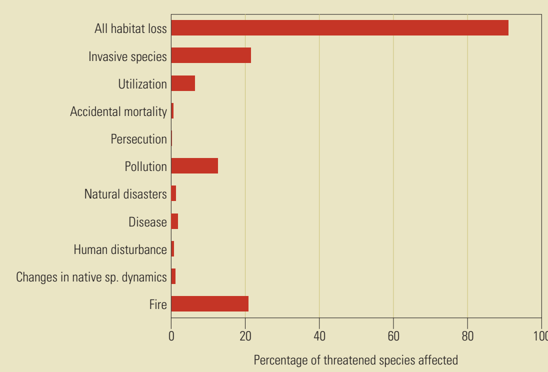


Figure 9. *The major threats impacting threatened amphibians in the Afrotropical Realm.*

Purpose	Subsistence	Sub-national/ National	Regional/ International	Number of species
Food – human	24 (4)	5 (2)	1	25 (4)
Medicine – human and veterinary	3	1	1	3 (0)
Pets, display animals	0	1	61 (15)	61 (15)
Research	0	1	1	2 (0)

Table 6. *The purposes for which amphibians are used in the Afrotropical Realm. The numbers in brackets are the number of species within the total that are threatened species.*

Population Trend	Number of species	% of species
Decreasing	425	44
Stable	221	23
Increasing	8	1
Unknown	315	33

Table 7. *The population trends for all extant Afrotropical amphibians.*

Family	Number of species in "rapid decline"	Percentage of species in family in "rapid decline"
Arthroleptidae	3	6
Bufonidae	5	5
Hemisotidae	1	11
Hyperoliidae	6	2
Mantellidae	1	6
Microhylidae	2	2
Petropedetidae	7	7
Ranidae	5	5

Table 8. *The number of species in "rapid decline" in the Afrotropical Realm by Family .*

The aptly named Tomato Frog Dyscophus antongilii *(Near Threatened) of the Family Microhylidae is endemic to north-eastern Madagascar. Although it is an adaptable species, being found in a variety of habitats from primary rainforest to disturbed urban areas, the pollution of waterbodies is a potential threat to this species. © Russell A. Mittermeier*

Endnotes

1 We follow the WWF biogeographic realms in this chapter, but recognize that this is not ideal for amphibians, especially with regard to the inclusion of the Arabian Peninsula within the Afrotropical Realm. The small Arabian amphibian fauna is generally of Palaearctic origin.

2 P<0.01 (binomial test)

3 At the time of writing, this species had been rediscovered in the Togo Hills (Leache *et al.* 2006), and been found outside its former range in the Atewa mountains (M.-O. Rödel, pers. comm.).

4 Although no amphibians have been found on the islands that make up the country Comoro, two undescribed species are present on the French island of Mayotte, which is part of the Comoro Archipelago (Vences *et al.* 2003). Because they are undescribed, they are not included in this analysis.

5 The genera *Euphlyctis* and *Hyla* occur only in the southern Arabian peninsula within the Afrotropical Realm, and not on the African continent south of the Sahara.

6 The only evidence for the occurrence of the genus *Rana* in Africa is the doubtfully valid *Rana demarchii* of unknown provenance in Ethiopia (Largen 2001).

7 The genus *Tomopterna* occurs marginally in the Palaearctic, as it is present in parts of the Sahara region; the genus is, however, essentially Afrotropical.

8 Frost *et al.* (2006) split the genus *Bufo* in Africa.

9 Frost *et al.*'s (2006) rearrangement results in 19 families in the Afrotropics, of which nine are endemic: Arthroleptidae; Brevicipitidae; Heleophrynidae; Hemisotidae; Hyperoliidae; Mantellidae; Ptychadenidae; Phrynobatrachidae; and Pyxicephalidae. However, in this section we follow the former taxonomic arrangement of families based on Frost (2004).

10 The only other species is the apparently extinct *Eleutherodactylus jasperi* from the Neotropics.

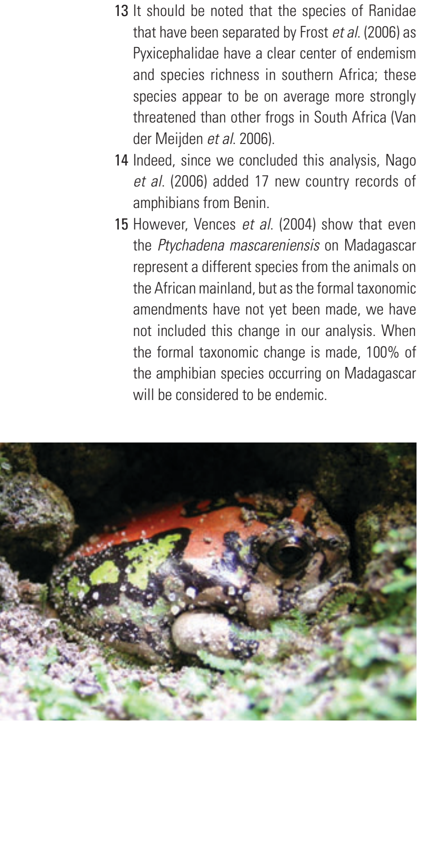
11 Frost *et al.* (2006) separate the genera *Breviceps*, *Balebreviceps*, *Callulina* and *Probreviceps* into a new family endemic to the Afrotropics: Brevicipitidae. Loader *et al.* (2004) consider that the genus *Spelaeophryne* also belongs with the brevicipitine group. Under this arrangement, all the African mainland species remaining in Microhylidae are larval developers.

12 Under the new arrangement by Frost *et al.* (2006), the genus *Amnirana* is the only remaining member of the Ranidae in the Afrotropics. The genus *Conraua* is moved to Petropedetidae, and *Euphyctis* and *Hoplobatrachus* are transferred to the predominantly Indomalayan Dicroglossidae. *Ptychadena*, *Hildebrandtia* and *Lanzarana* are transferred to a new endemic Afrotropical family, Ptychadenidae, and the remaining Afrotropical genera previously considered to be in Ranidae are transferred to the endemic new family Pyxicephalidae.

13 It should be noted that the species of Ranidae that have been separated by Frost *et al.* (2006) as Pyxicephalidae have a clear center of endemism and species richness in southern Africa; these species appear to be on average more strongly threatened than other frogs in South Africa (Van der Meijden *et al.* 2006).

14 Indeed, since we concluded this analysis, Nago *et al.* (2006) added 17 new country records of amphibians from Benin.

15 However, Vences *et al.* (2004) show that even the *Ptychadena mascareniensis* on Madagascar represent a different species from the animals on the African mainland, but as the formal taxonomic amendments have not yet been made, we have not included this change in our analysis. When the formal taxonomic change is made, 100% of the amphibian species occurring on Madagascar will be considered to be endemic.



Unlike most other regions, the Afrotropical "rapidly declining" species show no distinct taxonomic pattern (see Table 8), with small percentages (less than 7% of the species) in all of the larger families.

KEY FINDINGS

- A total of 969 species are recorded from the Afrotropical Realm, of which 240 (nearly 25%) are considered threatened.
- At the species level, 954 amphibians (99% of those present) are endemic to the Afrotropics; of the 16 families found in the region, nine are endemic, and of 112 amphibian genera occurring, 105 are endemic.
- The percentage of threatened species is very high in the family Astylosternidae (72%), reflecting the poor state of forest conservation in the mountainous regions of Cameroon. On the other hand, certain families have lower levels of threat (Pipidae, Hemisotidae and Ranidae), all of which have a high proportion of adaptable species in the Afrotropics.
- Geographic concentrations of threatened species occur in the Upper Guinea forests from Sierra Leone to Togo; south-eastern Nigeria and south-western Cameroon; the mountains of the Albertine Rift; the Ethiopian Highlands; the Eastern Arc Mountains; eastern and southern South Africa (especially in the south-western Cape); and eastern Madagascar (especially at the northern and southern tips).
- Madagascar has the largest number of species of any country in the Afrotropical Realm (226 species). Only five other countries have more than 100 species (Democratic Republic of Congo, Cameroon, Tanzania, South Africa, and Nigeria), with all except Nigeria having more than 50 endemics. Madagascar, Cameroon, Tanzania and South Africa each have more than 20 globally threatened species. Madagascar has many more endemics than any other country.
- Among species occurring in tropical forests, 43% of species in montane tropical forest are threatened, compared with 23% in lowland tropical forest, probably reflecting smaller range sizes of montane species, and the lack of effective habitat conservation in montane regions. Africa has 47% of the world's 484 savannah-associated amphibians (yet only 3% of these species are threatened) and 44% of the world's 94 arid-habitat species (2% threatened).
- Habitat loss, primarily due to expanding croplands, vegetation removal (mainly logging), and urbanization/industrial development, is affecting over 90% of the threatened species in the region. Other commonly recorded threats include invasive species, fire and pollution; disease is cited as a threat to only 2% of threatened species.
- Only 6% of the 470 globally "rapidly declining" species occur within the region; 12 of these species are forest-obligate species from the Upper Guinea region of West Africa, where habitat loss has been especially severe.
- No amphibian extinctions have yet been recorded from the Afrotropics, but three species are possibly extinct.

REFERENCES

Amiet, J.-L. 1983. Un essai de cartographie des anoures du Cameroun. *Alytes* **2**:124-146.

Amiet, J.-L. 1989. Quelques aspects de la biologie des Amphibiens Anoures du Cameroun. *Année Biologique* **28**:73-136.

Amiet, J.-L. 2000. Les *Alexteroon* du Cameroun (Amphibia, Anura, Hyperoliidae). *Alytes* **17**:125-164.

Andreone, F., Cadle, J.E., Cox, N., Glaw, F., Nussbaum, R.A., Raxworthy, C.J., Stuart, S.N., Vallan, D. and Vences, M. 2005. A species review of amphibian extinction risks in Madagascar: results from the Global Amphibian Assessment. *Conservation Biology* **19**:1790-1802.

Andreone, F., Mercurio, V. and Mattioli, F. 2006. Between environmental degradation and international pet trade: conservation strategies for the threatened amphibians of Madagascar. *Natura - Soc. it. Sci. nat. Museo civ. Stor. nat. Milano* **95**:81-96.

Baillie, J.E.M., Hilton-Taylor, C. and Stuart, S.N. (eds). 2004. *2004 IUCN Red List of Threatened Species. A Global Species Assessment*. IUCN, Gland, Switzerland and Cambridge, UK.

Beentje, H.J., Adams, B. and Davis, S.D. 1994. Regional Overview: Africa. In: S.D. Davis, V.H. Heywood and A.C. Hamilton (eds), *Centres of Plant Diversity: A guide and strategy for their conservation*. Vol. 3., pp. 101-48. IUCN Publication Unit, Cambridge, U.K.

Blommers-Schlösser, R.M.A. and Blanc, C.P. 1991. *Amphibiens* (première partie). Vol. 75 of Faune de Madagascar. Muséum national d'Histoire naturelle, Paris.

Broadley, D.G. 1971. The reptiles and amphibians of Zambia. *Puku* **6**:1-143.

Branch, W.R. 1988. *South African Red Data Book – Reptiles and Amphibians*. South African National Scientific Programmes Report No. 51. CSIR, Pretoria, South Africa.

Brooks, T., Balmford, A., Burgess, N., Fjeldsaa, J., Hansen, L. A., Moore, J., Rahbek, C. and Williams, P. 2001. Toward a blueprint for conservation in Africa. *Bioscience* **51(8)**:613-624.

Channing, A. 2001. *Amphibians of Central and Southern Africa*. Cornell University Press, Ithaca, New York, USA and London, UK.

Channing, A. and Griffin, M. 1993. An annotated checklist of the frogs of Namibia. *Madoqua* **18**:101-116.

Channing, A. and Howell, K.M. 2006. *Amphibians of East Africa*. Cornell University Press, Ithaca, New York, USA.

Collar, N.J. and Stuart, S.N. 1988. Key forests for threatened birds in Africa. *ICBP Monograph* **3**:1-102.

De Sá, R.O., Loader, S.P. and Channing, A. 2004. A new species of *Callulina* (Anura: Microhylidae) from the West Usambara Mountains, Tanzania. *Journal of Herpetology* **38**:219-224.

Drewes, R.C. and Vindum, J.V. 1994. Amphibians of the Impenetrable Forest, Southwest Uganda. *Journal of African Zoology* **108**:55-70.

Frost, D.R. 2004. Amphibian Species of the World: an Online Reference. Version 3.0 (22 August, 2004). Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/index.html. American Museum of Natural History, New York, USA.

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

Glaw, F. and Vences, M. 1994. *A Field Guide to the Amphibians and Reptiles of Madagascar*. Second Edition. Zoologisches Forschunginstitut und Museum Alexander Koenig, Bonn

Goudie, A.S. 2005. The drainage of Africa since the Cretaceous. *Geomorphology* **67**:437-456.

Kingdon, J. 1989. *Island Africa: The Evolution of Africa's Rare Animals and Plants*. Princeton University Press, Princeton, New Jersey, USA.

Krajick, K. 2006. The lost world of the Kihansi toad. *Science* **311**:1230-1232.

Lambiris, A.J.L. 1989a. A review of the amphibians of Natal. *Lammergeyer* **39**:1-210.

Lambiris, A.J.L. 1989b. The frogs of Zimbabwe. *Museo Regionale di Scienze Naturali Torino, Monografia* **10**:1-247.

Lanza, B. 1990. Amphibians and reptiles of the Somali Democratic Republic: checklist and biogeography. *Biogeographica* **14**:407-465.

Largen, M.J. 2001. Catalogue of the amphibians of Ethiopia, including a key for their identification. *Tropical Zoology* **14**:307-402.

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

Loader, S.P., Gower, D.J., Clarke, B.T., Howell, K.M., Doggart, N., Rödel, M.-O., de Sá, R.O., Cohen, B.L. and Wilkinson, M. 2004. Phylogenetic relationships of African microhylid frogs inferred from DNA sequences of mitochondrial 12S and 16S ribosomal rRNA genes. *Organisms Diversity and Evolution* **4**:227-235.

Lötters, S., Rotich, D. and Veith, M. 2003. Non-finding of the Kenyan endemic frog *Arthroleptides dutoiti*. *Froglog* **60**:3.

Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J. and Knoepfer, D. 2004. *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland*. SI/MAB Series No. 9. Washington, D.C., USA

Monadjem, A., Boycott, R.C., Parker, V. and Culverwell, J. 2003. *Threatened Vertebrates of Swaziland. Swaziland Red Data Book: Fishes, Amphibians, Reptiles, Birds and Mammals*. Ministry of Tourism, Environment and Communications, Swaziland.

Nago, S.G.A., Grell, O., Sinsin, B. and Rödel M.-O. 2006. The amphibian fauna of the Pendjari National Park and surroundings, northern Benin. *Salamandra* **42**:93-108.

Passmore, N.I. and Carruthers, V.C. 1995. *South African Frogs*, 2nd Edition. Southern Book Publishers and Witwatersrand University Press, Johannesburg, South Africa.

Perret, J.-L. 1966. Les amphibiens du Cameroun. *Zoologische Jahrbücher. Abteilung für Systematik, Ökologie und Geographie der Tiere* **8**:289-464.

Poynton, J.C. 1964. The amphibia of southern Africa: a faunal study. *Annals of the Natal Museum* **17**:1-334.

Poynton, J.C. 1966. Amphibia of northern Mozambique. *Memorias do Instituto de Investigacão Cientifica de Moçambique, Ser. A Ciencas B* **8**:13-34.

Poynton, J.C. 1999. Distribution of amphibians in Sub-Saharan Africa, Madagascar, and Seychelles. In: W.E. Duellman (ed.), *Patterns of Distribution of Amphibians: A Global Perspective*, pp. 483-539, Johns Hopkins University Press, Baltimore, Maryland, USA.

Poynton, J.C. 2003. Altitudinal species turnover in southern Tanzania shown by anurans: some zoogeographical considerations. *Systematics and Biodiversity* **1**:117-126.

Poynton, J.C. and Broadley, D.G. 1985a. Amphibia Zambesiaca. 1. Scolecomorphidae, Pipidae, Microhylidae, Hemisidae, Arthroleptidae. *Annals of the Natal Museum* **26**:503-553.

Poynton, J.C. and Broadley, D.G. 1985b. Amphibia Zambesiaca. 2. Ranidae. *Annals of the Natal Museum* **27**:115-181.

Poynton, J.C. and Broadley, D.G. 1987. Amphibia Zambesiaca. 3. Rhacophoridae and Hyperoliidae. *Annals of the Natal Museum* **28**:161-229.

Poynton, J.C. and Broadley, D.G. 1988. Amphibia Zambesiaca. 4. Bufonidae. *Annals of the Natal Museum* **29**:447-490.

Poynton, J.C. and Broadley, D.G. 1991. Amphibia Zambesiaca. 5. Zoogeography. *Annals of the Natal Museum* **32**:221-277.

Rödel, M.-O. 2000. *Herpetofauna of West Africa. Volume 1. Amphibians of the West African Savannas*. Edition Chimaira, Frankfurt am Main, Germany.

Rödel, M.-O. and Ernst, R. 2002. A new reproductive mode for the genus *Phrynobatrachus*: *Phrynobatrachus alticola* has nonfeeding, nonhatching tadpoles. *Journal of Herpetology* **36**:121-125.

Rödel, M.-O., Kosuch, J., Veith, M. and Ernst, R. 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.

Rödel, M.-O., Krätz, D. and Ernst, R. 2002. The tadpole of *Ptychadena aequiplicata* (Werner, 1898) with the description of a new reproductive mode for the genus (Amphibia, Anura, Ranidae). *Alytes* **20**:1-12.

Schiøtz, A. 1967. The treefrogs (Rhacophoridae) of West Africa. *Spolia Zoologica Musei Hauniensis* **25**:1-346.

Schiøtz, A. 1975. *The Treefrogs of Eastern Africa*. Steenstrupia, Copenhagen, Denmark.

Schiøtz, A. 1999. *Treefrogs of Africa*. Edition Chimaira, Frankfurt am Main, Germany.

Stewart, M.M. 1967. *Amphibians of Malawi*. State University of New York Press, Albany, New York, USA.

Storey, M., Mahoney, J.J., Saunders, A.D., Duncan, R.A., Kelly, S.P. and Coffins, M.F. 1995. Timing of hot spot-related volcanism and the breakup of Madagascar and India. *Science* **267**:852-855.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischman, D.L. and Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* **306**:1783-1786.

Tandy, M. and Keith, R. 1972. African *Bufo*. In: Blaire, W.F. (ed.) *Evolution in the Genus Bufo*, pp. 119-170, University of Texas Press, Austin, Texas, USA.

Torsvik, T.H., Tucker, R.D., Ashwal, L.D. Carter, L.M., Jamtveit, B., Vidyadharan, K.T. and Venkataramana, P. 2000. Late Cretaceous India-Madagascar fit and timing of break-up related magmatism. *Terra Nova* **12**:220-225.

Turner, A.A., de Villiers, A.L., Dawood, A. and Channing, A. 2004. A new species of *Arthroleptella* Hewitt, 1926 (Anura: Ranidae) from the Groot Winterhoek Mountains of the Western Cape Province, South Africa. *African Journal of Herpetology* **53**:1-12.

Van der Meijden, A., Vences, M., Hoegg, S. and Meyer, A. 2005. A previously unrecognized radiation of ranid frogs in southern Africa revealed by nuclear and mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution* **37**:674-685.

Vences, M., Andreone, F. and Glaw, F. 2005. A new microhylid frog of the genus *Cophyla* from a transitional forest in northwestern Madagascar. *African Zoology* **40**:143-149.

Vences, M., Kosuch, J., Rödel, M.-O., Lötters, S., Channing, A., Glaw, F. and Böhme, W. 2004. Phylogeography of *Ptychadena mascareniensis* suggests transoceanic dispersal in a widespread African-Malagasy frog lineage. *Journal of Biogeography* **31**:593-601.

Vences, M., Vieites, D.R., Glaw, F., Brinkmann, H. Kosuch, J. Veith, M. and Meyer, A. 2003. Multiple overseas dispersal in amphibians. Proceedings of the Royal Society B 270:2435-2442.

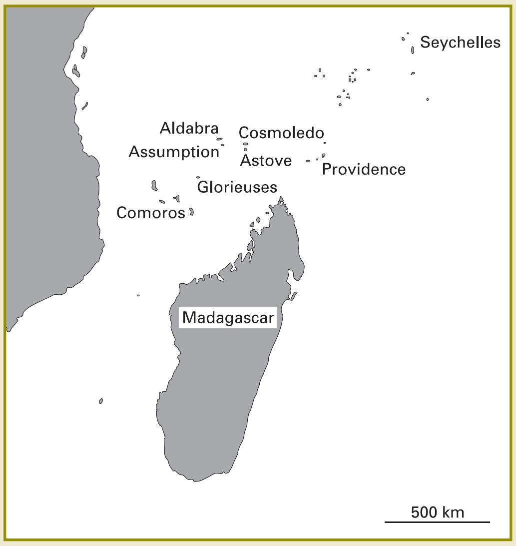
Vonesh, J. 2001. Natural history and biogeography of the amphibians and reptiles of Kibale National Park, Uganda. Contemporary Herpetology. 4. http://research.calacademy.org/herpetology/herpdocs/2001/4/index.htm.

Wager, V.A. 1986. *Frogs of South Africa*. 2nd edition. Delta Books, Craighall, South Africa.

Weldon, C., du Preez, L.H., Hyatt, A.D., Muller, R. and Speare, R. 2004. Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* **10**:2100-2105.

Scaphiophryne gottlebei *(Critically Endangered) is restricted to two localities near Isalo in south-central Madagascar. Like other members of the Family Microhylidae, it digs itself into the ground, as shown in this photograph. Over collection for the international pet trade could be a significant threat to this restricted-range species. © Franco Andreone*

ESSAY 5.1. SEYCHELLES AMPHIBIANS



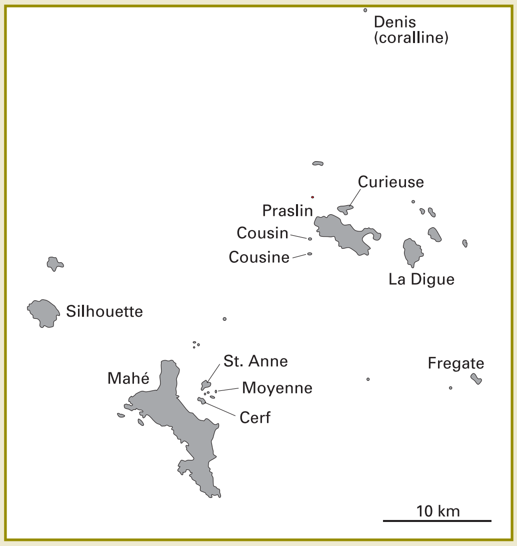


Figure 1. *Map of the Seychelles Islands.*

Due to their permeable skin few amphibians are able to tolerate dry or salty conditions, a characteristic that has prevented most species from colonising oceanic islands. The most diverse oceanic island amphibian fauna is found in the Seychelles, an archipelago of about 115 granitic and coralline islands in the Indian Ocean, some 1,600km east of mainland Africa, and northeast of the island of Madagascar (Figure 1). Eleven native amphibian species have been recorded from the Seychelles islands, comprising both recent colonists and ancient endemics. Recent colonization by one species, the Mascarene Grass Frog *Ptychadena mascareniensis* (LC), is probably the result of human introduction (Vences *et al.* 2004) in the 1800s, whilst the endemic Seychelles Treefrog *Tachycnemis seychellensis* (LC) is believed to be descended from a natural colonist from Madagascar (Vences *et al.* 2003). The remaining species are all ancient endemics that have probably existed on the island since their isolation from the Indian landmass some 65 million years ago. These species comprise the endemic frog family Sooglossidae and seven species of burrowing caecilians (Order Gymnophiona).

Sooglossidae are an exceptional family in several respects. Four species are currently recognized in two genera, although recent morphological and molecular data suggests that a further three species remain to be described and that the genera need to be redefined. They are all small frogs, with Gardiner's Frog *Sooglossus gardineri* (VU) among several species up for contention as the world's smallest frog (with adults being as small as 9mm in length). All sooglossids are found in the damp forests of the two highest islands, Mahé and Silhouette. These habitats have only seasonal or fast-flowing stems, and the sooglossids have abandoned the normal frog life-cycle in favour of terrestrial development. The Seychelles Frog *Sooglossus sechellensis* (VU) lays its eggs on land and the female carries the tadpoles until they develop into frogs. *Sooglossus gardineri* is even more specialized, with the male guarding terrestrial eggs that hatch into 3-mm long froglets; the entire tadpole stage is passed within the egg. Thomasset's Seychelles Frog *Nesomantis thomasseti* (VU) has recently been discovered to have a very similar breeding strategy, but nothing is known of the reproductive behaviour of the Seychelles Palm Frog *S. pipilodryas* (VU). This latter species is the most recently described of the Seychelles amphibian species, having been discovered in 2000 (Gerlach and Willi 2002). It lives in the axils of endemic palms where it lay protected from discovery by the dense spines of the palm leaves. It is the only arboreal sooglossid, the other species all being associated with crevices in boulder fields or the leaf-litter and root-mat of the forest floor.

The caecilian fauna of the Seychelles islands comprises six species in three endemic genera. Not surprisingly, and as with caecilians in general (see Essay 1.3), these are the least well known of all Seychelles amphibians. Their burrowing habits make them difficult to locate and study. For most species, their distributions are reasonably well defined and there are some observations of breeding habits. Different species appear to show the full range of reproductive strategies, form aquatic larvae, thorough to terrestrial larvae and direct development. The limited ecological data available indicate that *Grandisonia alternans* (LC) is a widespread species occurring in all habitats and *Hypogeophis rostratus* (LC) is a similar generalist, although more associated with lowland habitats. In contrast, *Praslina cooperi* (VU) and some of the small *Grandisonia* species appear to be specialists of the high forest. Current research into this group is attempting to develop monitoring methods and to identify aspects of their ecology that are of importance to their conservation.

Half of Seychelles amphibians are threatened due to their naturally restricted ranges and deteriorating habitats (five species are categorised as Least Concern, 5 Vulnerable and one Endangered). The sooglossid frogs and the caecilian *Praslina cooperi* have particularly restricted ranges, being associated only with the damper rain-forests. Habitat deterioration is a significant threat to the caecilian *Grandisonia brevis* (EN), which has a restricted range and occurs in habitats that are suffering from ongoing invasion by alien plant species. In addition, there is some suggestion that changes in rainfall patterns may have impacts on some species, which may result from mid-year declines in rainfall restricting the activity and distribution of the rain-forest specialists (Gerlach 2000). Losses of several areas of marsh habitats have probably caused population declines in some species, such as another caecilian *Grandisonia alternans* (Gerlach 2000).

There have been a number of successful conservation programmes in Seychelles, concentrating mainly on birds. Critically Endangered species have been rescued from extinction by limited habitat management, but mostly by inter-island transfers. These programmes have been to the benefit of species such as the Seychelles Magpie-robin *Copsychus seychellarum* and the Seychelles White-eye *Zosterops modesta*. Such options are not available for the amphibians due to their close dependence on their high forest or marsh-land habitats. Consequently, preservation of their habitat is essential; most species are present in protected areas, although habitat management is still required to control the spread of invasive plant species. The island with the highest diversity of amphibians (Silhouette) is currently unprotected and designation of this island as a national park would significantly enhance amphibian conservation in Seychelles.

To date, there has been no evidence of any sudden amphibian decline in Seychelles, although the potential impact of an invasion by chytridiomycosis would be considerable. Monitoring programmes are in place for the frogs, and are being developed for the caecilians. Updates on research and conservation progress can be found at http://members.aol.com/jstgerlach/herps.htm

Justin Gerlach

References

Gerlach, J. 2000. Seychelles Amphibia – a mixture of secure and declining species. *Froglog* 40(5).

Gerlach, J. and Willi, J. 2002. A new species of *Sooglossus* frog (Sooglossidae). *Amphibia-Reptilia* **23**:445-498.

Vences, M., Kosuch, J., Glaw, F., Bohme W. and Veith, M. 2003. Molecular phylogeny of hyperoliid treefrogs: biogeographic origin of Malagasy and Seychellean taxa and re-analysis of familial paraphyly. *Journal of Zoology and Systematic Evolutionary Research* **41**:205-215.

Vences, M., Kosuch, J., Rodel, M.-O., Channing, A., Glaw, F. and Bohme, W. 2004. Phylogeography of *Ptychadena mascareniensis* suggests transoceanic dispersal in a widespread African-Malagasy frog lineage. *Journal of Biogeography* **31**:593-601. ■

Nesomantis thomasseti *(Vulnerable) is restricted to Mahé and Silhouette Islands in the Seychelles, and has been recorded from the Morne Seychellois National Park. © Naomi Doak*

ESSAY 5.2. THE ENDEMIC AND THREATENED AMPHIBIANS OF MADAGASCAR

Separated from mainland Africa by a sea channel of about 300km, the biodiversity of Madagascar has experienced a distinct evolutionary trajectory that has resulted in a very high degree of endemism in both its fauna and flora. Among the vertebrates, the amphibians of this large island (around 580,000km^2, the fourth in the world for size) are currently represented by more than 230 frog species[1], a number that is still preliminary and tentative, since many more remain to be discovered or are awaiting description (see Essay 1.1) (Figure 1). Remarkably, out of the entire amphibian fauna, only two species, the adaptable and widely distributed *Ptychadena mascareniensis*, which is present also in mainland Africa, and *Hoplobatrachus tigerinus*, introduced to Madagascar from southern Asia, are not considered to be endemic. Interestingly, recent molecular studies have shown that the *P. mascareniensis* populations from Madagascar are already sufficiently differentiated from those from mainland Africa, and likely represent a different species (Vences *et al.* 2003, 2004).

Malagasy amphibians are represented by four families of frogs (Gymnophiones and Urodeles being absent): Mantellidae, Microhylidae, Hyperoliidae, and Ranidae[2], with ranids being represented only by the aforementioned non-endemic *Ptychadena mascareniensis* and *Hoplobatrachus tigerinus* (Glaw and Vences 1994). Mantellidae is the most speciose group and is endemic to Madagascar and the Comoro Islands. This family includes the highly diverse genus *Mantidactylus* (with nearly 90 species), the well-known genus *Mantella*

(15 species), *Boophis* (53 species), *Aglyptodactylus* (3 species), and the monospecific genus *Laliostoma*. At the time of writing, *Mantidactylus* has been split into several genera (Glaw and Vences 2006), which differ significantly in aspects of morphology, life history and distribution: *Wakea, Blommersia, Guibemantis, Spinomantis, Gephyromantis, Boehmantis,* and *Mantidactylus*. As a general trait, *Mantidactylus* (sensu lato) and the closely related *Mantella* show peculiar reproductive features, such as the absence of amplexus and of nuptial pads in males, with eggs laid outside water, and the presence (in most species) of femoral glands, which are glandular structures on the inside of the thighs, and related to reproductive behaviour. They also exhibit a variety of life history traits, with species adapted to terrestrial, aquatic, and arboreal habitats (Andreone and Luiselli 2003). The diurnal *Mantella* species are characterized mainly by their bright aposematic colouration, small size, and accumulations of alkaloids in the skin. The *Mantella* species are, therefore, toxic, and are apparently rarely predated upon by other species, a situation similar in many respects to that of the Neotropical dendrobatid frogs (Clark *et al.* 2005).

In contrast to these frogs, amphibians in the genus *Boophis* are mainly arboreal species, breed in water, and have a typical larval development. Egg-laying usually occurs in streams, except for some species that reproduce in lentic waters (Aprea *et al.* 2004; Glaw and Vences 2006). Two further genera, *Aglyptodactylus* and *Laliostoma,* are mainly terrestrial and breed in temporary ponds, often breeding explosively during which time they form large aggregations. The genus *Aglyptodactylus* is also peculiar in having the males that assume a somehow bright yellow colouration during the breeding season (Glaw and Vences 1994, 2006).

Microhylidae are represented by 10 genera and more than 50 species with a diverse life history. The cophyline microhylids (belonging to the genera *Cophyla, Platypelis, Anodonthyla, Plethodontohyla, Madecassophryne, Rhombophryne,* and *Stumpffia*) are closely tied to rainforest habitats and have a reproduction that is characterized by the presence of parental care (for example, both the parents, or at least one of them, remain with the tadpoles during their development) and non-feeding tadpoles (Andreone *et al.* 2004). The genera *Dyscophus, Paradoxophyla,* and *Scaphiophryne* are different in this habitat preference, living mainly in open areas, but sometimes in arid and sub-arid conditions (Andreone *et al.* 2006a). Most of them are mainly terrestrial, although some species, such as *S. gottlebei* are partly rupicolous and able to climb vertical walls within the narrow canyons of the Isalo Massif (Andreone *et al.* 2005a). In particular, *Scaphiophryne* species have tadpoles that are largely filter feeding, with some peculiar specializations (see Mercurio and Andreone 2005).

The Malagasy Hyperoliidae includes the single endemic genus *Heterixalus* comprising eleven species, which inhabit grasslands and forest edges. They are quite similar in habitat preferences and general behaviour to other hyperoliids from mainland Africa (Glaw and Vences 1994).

Nine species of Malagasy frogs have been categorized as Critically Endangered according to the IUCN Red List Categories and Criteria, namely: *Mantella aurantiaca, M. cowani, M. expectata, M. milotympanum, M. viridis, Scaphiophryne gottlebei, Mantidactylus pauliani, Boophis williamsi,* and *Stumpffia helenae* (Andreone *et al.* 2005b). A further 21 species were classed as Endangered and 25 as Vulnerable. In general, the main threat affecting the local amphibian fauna is the high rate of forest loss (just less than 1% per annum; Harper *et al.* 2007) (Figure 2). The different life history traits of the amphibians are consequently mirrored by their differential ecological sensitivity and conservation needs (Andreone and Luiselli 2003). In fact, most of the Malagasy frogs inhabit the eastern rainforest, an ecosystem that allowed the rapid diversification of some groups, such as *Boophis, Mantidactylus* (sensu lato), and cophyline microhylids. The original eastern rainforest block is now severely fragmented due to deforestation, and this fragmentation has often resulted in high levels of threats among the native amphibian fauna (Figure 3). However, in some cases this loss in amphibian species richness is not immediately evident, because species have differing sensitivities to habitat alterations (Andreone *et al.* 2005b).

In addition to the threat of habitat loss, some species (e.g. those belonging to *Mantella, Scaphiophryne,* and *Dyscophus*) have been highly sought after for the international pet trade due to their biological peculiarities and remarkable colouration (Raxworthy and Nussbaum 2001; Andreone *et al.* 2006b; Mattioli *et al.* 2006). There is still a paucity of reliable data on the impact of trade on wild populations, although in some cases it is evident that collecting represents a confounding threat when the habitat is already compromised and the populations are small. This is the case, for example, for the rare harlequin mantella, *Mantella cowani*, which was collected in high numbers and survived in a very degraded environment on the high plateau of Madagascar (Andreone and Randrianarina 2003; Chiari *et al.* 2005). Fortunately, the collecting and exportation of this species, classified as Critically Endangered, are now banned, a measure that should reinforce its protection (Andreone *et al.* 2006b). Due to concerns about overharvesting for commercial trade, all frogs in the genus *Mantella* as well as the species *Scaphiophryne gottlebei* are now included on CITES Appendix II. Other species are also of conservation concern, such as the Tomato Frog, *Dyscophus antongili,* the only native species included on CITES Appendix I. Although its distribution area is wider than formerly believed (Andreone *et al.* 2006b), the habitat degradation around the town of Maroantsetra, where most known populations occur, is high. There is also evidence that the populations have apparently declined in numbers, and the species appears to have vanished from sites at which it was formerly known to occur (Chiari *et al.* 2006).

Fortunately, field surveys conducted during the last 15 years have revealed no known extinctions of Malagasy amphibians resulting from habitat loss, disease or other agents (Andreone *et al.* 2005b), as has been reported elsewhere. On the other hand, 12 highly threatened species now have their last remaining populations confined to a single site (Ricketts *et al.* 2005), and several of these sites, such as the Ankaratra Massif and Fierenana, remain unprotected. In general, the two areas with the majority of threatened species are the northern Tsaratanana-Marojejy-Masoala highlands and the southeastern Anosy Mountains (Andreone *et al.* 2005b).

Following the remarkable declaration by Malagasy president Marc Ravalomanana to triple the existing coverage of the island's protected areas network (see Figure 2), amphibians are now beginning to be considered in the identification of globally important sites for conservation (see Essay 11.3). This is all the more important since, as already noted, several highly threatened species experience no protection whatsoever. For example, of the nine Critically Endangered amphibians, six are not recorded from any protected area (Andreone *et al.* 2005b, 2006b). Amphibians also represent an excellent candidate to become a symbol for the conservation strategies in Madagascar. Indeed, it is clear that, as with lemurs, the frogs of Madagascar have the potential to become an important tool for the conservation of wildlife in Madagascar. This aspect, as well as long-term conservation planning, was the focus of a workshop (*A Conservation Strategy for the Amphibians of Madagascar*) held in Antananarivo in September 2006 specifically dedicated to the amphibians of Madagascar, and attended by more than 80 scientists and conservation practitioners.

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References

Andreone F., Aprea G., Odierna G. and Vences M. 2006a. A new narrow-mouthed frog of the genus *Paradoxophyla* (Microhylidae: Scaphiophryninae) from Masoala rainforest, northeastern Madagascar. *Acta Herpetologica* **1**:15-27.

Andreone F., Mattioli F. and Mercurio V. 2005a. The call of *Scaphiophryne gottlebei*, a microhylid frog from the Isalo Massif, south-central Madagascar. *Current Herpetology* **24**:33-35.

Andreone, F. and Luiselli, L.M. 2003. Conservation priorities and potential threats influencing the hyper-diverse amphibians of Madagascar. *Italian Journal of Zoology* **70**:53-63.

Andreone F. and Randrianirina J.E. 2003. It's not carnival for the harlequin mantella! Urgent actions needed to conserve *Mantella cowani*, an endangered frog from the High Plateau of Madagascar. *Froglog* **59**:1-2.

Andreone, F., Cadle, J.E., Cox, N., Glaw, F., Nussbaum, R.A., Raxworthy, C.J., Stuart, S.N., Vallan, D. and Vences, M. 2005b. Species Review of Amphibian Extinction Risks in Madagascar: Conclusions from the Global Amphibian Assessment. *Conservation Biology* **19**:1790-1802.

Andreone, F., Mercurio, V. and Mattioli, F. 2006b. Between environmental degradation and international pet-trade: conservation strategies for the threatened amphibians of Madagascar. *Natura* **95**:81-96.

Andreone, F., Vences, M., Vieites, D.R., Glaw, F. and Meyer, A. 2004. Recurrent ecological adaptations revealed through a molecular analysis of the secretive cophyline frogs of Madagascar. *Molecular Phylogenetics and Evolution* **34**:315-322.

Aprea, G., Andreone, F., Capriglione, T., Odierna, G. and Vences, M. 2004. Evidence for a remarkable stasis of chromosome evolution in Malagasy treefrogs (*Boophis*: Mantellidae). *Italian Journal of Zoology,* Supplement **2**:237-243.

Chiari, Y., Andreone, F., Vences, M. and Meyer, A. 2005. Genetic variation of an endangered Malagasy frog, *Mantella cowani*, and its phylogeographic relationships to the widespread *M. baroni. Conservation Genetics* **6**:1041-1047.

Chiari, Y., Orozco-terWengel, P., Vences, M., Vieites, D.R., Sarovy, A., Randrianirina, J.E., Meyer, A. and Louis, E., Jr. 2006. Genetic identification of units for conservation in tomato frogs, genus *Dyscophus. Conservation Genetics* **7**:473-482.

Clark, V.C., Raxworthy, C.J., Rakotomalala, V., Sierwald, P. and Fisher, B.L. 2005. Convergent evolution of chemical defense in poison frogs and arthropod prey between Madagascar and the Neotropics. *Proceedings of the National Academy of Sciences of the USA* **102**:11617-11622.

Glaw, F. and Vences, M. 1994. *A fieldguide to the amphibians and reptiles of Madagascar*. 2nd edition. Vences & Glaw Verlag, Köln, Germany.

Glaw, F. and Vences, M. 2006. Phylogeny and genus-level classification of mantellid frogs. – *Organisms Diversity and Evolution* **6**:236-253.

Harper, G.J., Steininger, M.K., Tucker, C.J., Juhn, D. and Hawkins, F. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation* **34**:325-333.

Mattioli, F., Gili, C. and Andreone, F. 2006. Economics of captive breeding applied to the conservation of some selected amphibian and reptile species from Madagascar. *Natura* **95**:67-80.

Mercurio, V. and Andreone, F. 2005. The tadpoles of *Scaphiophryne gottlebei* (Microhylidae, Scaphiophryninae) and *Mantella expectata* (Mantellidae, Mantellinae) from Isalo Massif, central-southern Madagascar. *Alytes* **23**:81-95.

Raxworthy, C.J. and Nussbaum, R.A. 2001. Extinction and extinction vulnerability of amphibians and reptiles in Madagascar. *Amphibian and Reptile Conservation* **2**:15-23.

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. 2005. Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences USA* **102**:18497-18501.

Vences, M., Vieites, D.R., Glaw, F., Brinkmann, H., Kosuch, J., Veith, M. and Meyer, A. 2003. Multiple overseas dispersal in amphibians. *Proceedings of the Royal Society B* **270**:2435-2442.

Vences, M., Kosuch, J., Rödel, M.-O., Lötters, S., Channing, A., Glaw, F. and Böhme, W. 2004. Phylogeography of Ptychadena mascareniensis suggests transoceanic dispersal in a widespread African-Malagasy frog lineage. *Journal of Biogeography* **31**:593-601. ■

1 Although only some 226 species are currently classified through the Global Amphibian Assessment, several new species were recently described, including *Paradoxaphyla tiarano* from Masoalo Forest in north-eastern Madagascar (Andreone *et al.* 2006a).

2 The Ranidae were disaggregated into several families by Frost *et al.* (2006). In Madagascar, *Pthychadena* is ascribed to Ptychadenidae and *Hoplobatrachus* to Dicroglossidae. Thus, the number of families becomes five.

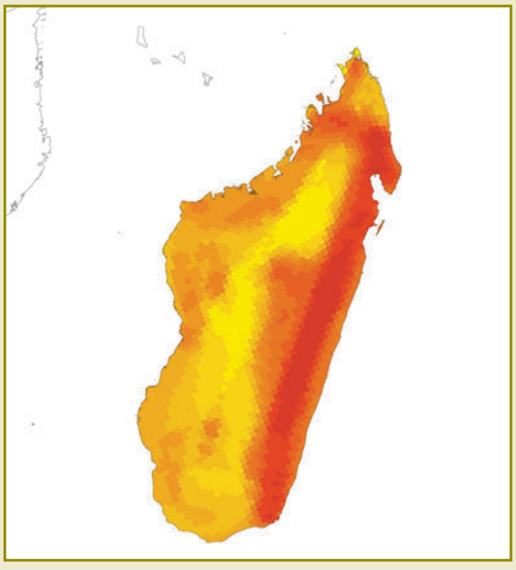

Figure 1. *Richness map of amphibian species in Madagascar, with dark red colours corresponding to areas of higher richness. Colour scale based on 10 quantile classes. Maximum richness equals 91 species.*

Figure 2. *Forest cover map for Madagascar, and existing protected areas in black. Red corresponds to forest clearance between 1990 and 2000, brown to clearance between 1975 and 1990, and green to forest cover in 2000.*

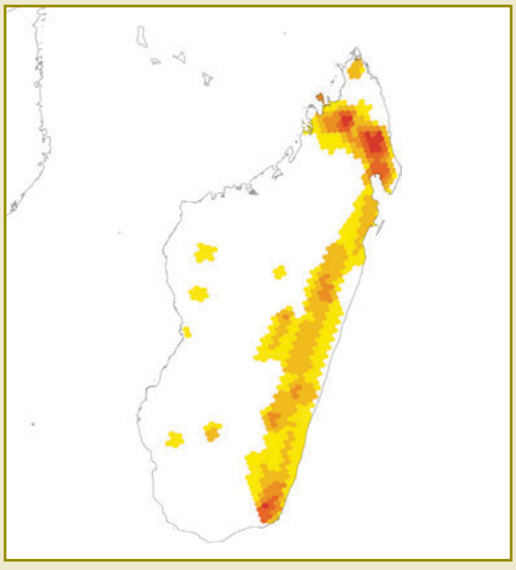

Figure 3. *Richness map of threatened amphibian species in Madagascar, with dark red colours corresponding to areas of higher richness. Colour scale based on five quantile classes. Maximum richness equals nine species.*

ESSAY 5.3. FROG BIODIVERSITY IN CAMEROON

Around 200 species of frogs occur in Cameroon (Amiet 1989), including several unnamed taxa, but the final total could be as high as 210 due to limited knowledge of the extreme north and south-east of the country. Comparisons with the less well prospected neighbouring countries in central Africa are difficult, but the frog fauna of Cameroon is almost certainly the second most diverse in continental Africa, after the Democratic Republic of the Congo.

Components of Cameroon's frog fauna

Cameroon's frog fauna largely consists of four ecological components. The *savannah component* (*c.* 35 species) is associated with grassy and herbaceous habitats over a broad latitudinal extent, from the small savannahs near Yaoundé, north to the steppes around Lake Chad. Very few species occupy this entire area, most being distributed in latitudinal bands reflecting their different tolerances of drought. All have wide distributions outside Cameroon, and their tadpoles develop in still water.

The *montane component*, represented by about 50 species, many endemic, is restricted not only to mountains but also to high plateaus in western Cameroon. The boundary between this component and lowland faunas is between 800 and 1,200m. These species prefer forests or are indifferent to vegetation type, and for many the tadpoles develop in streams.

The *forest component* includes some 80 species that are generally confined to closed-canopy forest. These species depend mainly on ecological conditions created by a closed canopy, rather than on the exploitation history of the forest (primary or secondary), or on floristic composition. Amiet's (1989) study of the Yaoundé forest frog fauna showed that it consisted overwhelmingly of species living in leaf-litter (43%), or on vegetation (39%), with half of the water-dependent species associated with streams. This component includes many species and some genera that are, more or less, restricted to Cameroon, especially in the west.

The *"parasylvicolous" component* includes some 30 species confined to the forest zone and gallery forests in the savannah zone. These species do not live in intact forest, but in habitats that have been disturbed, either as a result of natural processes, or because of degradation by humans (Amiet 1989). Most of these species occur widely outside Cameroon, their tadpoles developing in still or slow-flowing waters.

There is also a small component of about six species that occur widely in the savannahs, and in degraded habitats in the forest zone, often in villages and large urban areas.

These components are not homogeneous, and can be subdivided into elevational zones (montane component) or latitudinal zones (savannah component). However, the limits of these zones are less clear than those that separate the components themselves.

Causes of the diversity of Cameroon's frog fauna

Several factors contribute to the high level of frog diversity in Cameroon. The first is the wide variety of natural conditions in the country. An old tourist advertisement boasts that Cameroon is "the whole of Africa in just one country", which is not an exaggeration. Diversity is boosted by interplay between climatic and geomorphological factors. The country covers over 12° of latitude, including most of the climatic gradient of western and central Africa north of the equator, from a very rainy equatorial to tropical climate (with rainfall decreasing as one goes northwards).

This pattern is modified by two major axes of relief. The first is the Cameroon mountain ridge, a series of massifs, often of volcanic origin with peaks over 2,000m, the highest being Mount Cameroon (4,095m). The ridge runs SSW-NNE, with numerous southern and western slopes exposed to the monsoon rains. The second is the Adamawa Plateau, which, at an altitude of 1,000-1,200m, crosses the entire country between 6° and 8°N, and has a relatively cool and humid climate. Thus, there is a complex patchwork of rainfall patterns in Cameroon, analysed in depth by Suchel (1972, 1988). In addition to affecting the overall climate, these high plateaus and mountain massifs also display vertical climatic zoning, resulting in the diversification of ecological conditions over very short distances.

While the diversity of current climatic conditions undoubtedly contributes to the diversity of Cameroon's frog fauna, climatic changes during the Quaternary are the main cause. These changes (see Maley 1996, 2001) resulted in repeated modifications to the distribution of bioclimatic zones, and have been a major cause of frog speciation, affecting in particular lowland forest and montane species. Lowland tropical and montane forests both experienced phases of expansion and regression. When habitats became fragmented, allopatric speciation took place in isolated areas, causing remarkable diversification in genera such as *Cardioglossa*, *Astylosternus* or *Leptodactylodon*, which include pairs and trios of closely related species. Some of these close relatives have remained allopatric, while others have become sympatric or even syntopic (Amiet 1980, 1987). However, Quaternary climatic changes are too recent to explain the presence of 15 genera, endemic, or largely endemic, to Cameroon (Amiet 1989). Most of these have tadpoles that develop in well-oxygenated, running water, a habitat that is plentiful in the hilly highlands of the west and south-west. These genera presumably evolved *in situ* during the formation of the Cameroon mountain ridge.

More recently, human impact on the environment has had favourable consequences on savannah and "parasylvicolous" species. Maintenance of savannahs by fire since the last episode of forest regression has aided the expansion of savannah species (for example, in the northern part of the southern Cameroon Plateau, which under current climatic conditions should be forest, but which is in fact dominated by savannah). In the forest zone, agricultural clearings have provided habitats favourable to "parasylvicolous" species, especially with the increasing destruction of forests since the start of the colonial period. Some "parasylvicolous" species of western origin, now quite common, were not found by the first collectors, and some of these might have reached Cameroon in the last 150 years, and continue to expand towards the east or south-east. Judging by the speed at which certain "parasylvicolous" species settle in newly opened forest sites, this hypothesis does not seem outlandish.

Geographic patterns of diversity

Figure 1 shows how the frog fauna is distributed in relation to the main bioclimatic units of the country. In regions Ic, II, Va and Vb, the numbers of species have probably been underestimated, but regions Ia, Ib and III will remain the centres of Cameroon's frog diversity. The high diversity in regions Ia and III is due to the large number of endemic and near-endemic species. Region III includes virtually all of Cameroon's montane species, none of which occur in other mountainous regions in Africa. Regions Ia and Ib include several "parasylvicolous" species (those in Ia and Ib being of "western" and "Congolese" origin, respectively). However, the higher diversity in Ia is due to the presence of several endemic species on the coastal plain, especially between the lower Sanaga and the Mungo rivers, and also south of the lower Nyong River (both probably being forest refugia during past climatic fluctuations).

Threats to Cameroon's frog fauna

The ecological conditions and the overall diversity and endemism of frogs vary across the regions of Cameroon, and this affects the threats facing the frog fauna. Moreover, future environmental changes in the context of the country's socio-economical and political situation need to be considered.

The frog faunas in regions IV, Va and Vb are not at great risk, despite these regions being greatly affected by human activity, as most of the species are adaptable. Conversely, in region II, the savannah species are, in theory at least, doomed to eventual extinction, as the forest should be expanding rapidly under current climatic conditions. However, the species in question also occur in regions IV and V, and forest species would presumably spread in region II.

The situation is much worse for the forest species in regions Ia, Ib and Ic, with the increasingly serious loss of forest, which seems inevitable due to lack of political commitment to conservation. However, frogs are less seriously affected than large mammals because, thanks to their small size, they are often able to survive in what little forest remains. They can also survive in areas of shifting cultivation where rotations allow for rapid recovery of the forest cover. Logging has limited impact as there is very little clear-cutting in Cameroon, but commercial tree plantations (such as oil palm) do have a very negative impact on forest frogs, and are especially prevalent in region Ia.

Region III has lost much forest, especially on the Bamileke Plateau. However, on the humid southern and western mountain slopes cleared forest can be replaced quickly by dense secondary vegetation suitable for many montane frogs (few species are completely dependent on intact forest). However, the tendency of the Bamileke and Banso peoples to clear large areas of habitat is alarming. For frogs living at very high elevations in open habitats, the threat level is low.

The Goliath Frog *Conraua goliath* (EN) requires particular mention as the only directly threatened frog in Cameroon. In the past it was sold in large numbers to at least one American importer for the ridiculous practice of jumping competitions. Now, these frogs, which used to be eaten only occasionally, have become prized game actively sought after, at least in the area of Nkongsamba (G. Renson, pers. comm.). Special traps have even been invented for catching this species, a victim of the current fad for bushmeat. With lack of law enforcement and endemic corruption, conservation measures are ineffective, and the future of the Goliath Frog depends on a change in food habits among local people.

The most effective measure of conservation for forest and montane frogs in Cameroon would be total preservation or restoration of a 30m-wide band of forest on both sides of water courses, whatever their size and location (including in commercial plantations). This solution, based on this author's 29 years of field research in Cameroon, would safeguard a huge portion of biodiversity in all taxonomic groups, and would contribute to quantitative and qualitative improvements in water reserves. Such a measure, if it were adopted, would require the means, and above all the political will, to implement in a resolute manner.

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References

Amiet, J.-L. 1980. Révision du genre *Leptodactylodon* (Amphibia Anura, Astylosterninae). *Annales de la Faculté des Sciences de Yaoundé* **27**:69-224.

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

Amiet, J.-L. 1989. Quelques aspects de la biologie des Amphibiens Anoures du Cameroun. *Année biologique* **28**:73-136.

Maley, J. 1996. The African rain forest - main characteristics of changes in vegetation and climate from the upper Cretaceous to the Quaternary. *Proceedings of the Royal Society of Edinburgh* **104B**:31-73.

Maley, J. 2001. The impact of arid phases on the African rain forest through geological history. In: W. Weber, L.J.T. White, A. Vedder and L. Naughton-Treves (eds.), *African Rain Forest Ecology and Conservation*, pp. 68-87. Yale University Press, New Haven, Connecticut, USA.

Schiøtz, A. 1999. *Treefrogs of Africa*. Chimaira, Frankfurt am Main, Germany.

Suchel, J.-B. 1972. *La répartition des pluies et les régimes pluviométriques au Cameroun*. Travaux et documents de géographie tropicale, 5. Université fédérale du Cameroun et C.N.R.S.

Suchel, J.-B. 1988. "Les climats du Cameroun". Thèse de Doctorat d'Etat, Université de Saint-Etienne, France. t. I-III: 1188 pp., et t. IV, atlas.

Astylosternus ranoides (Endangered) is known only from western Cameroon, where it has been recorded from the Bamboutos Mountains, Lake Oku, and Mount Neshele, at altitudes of 2,000-2,600m asl. © Jean-Louis Amiet

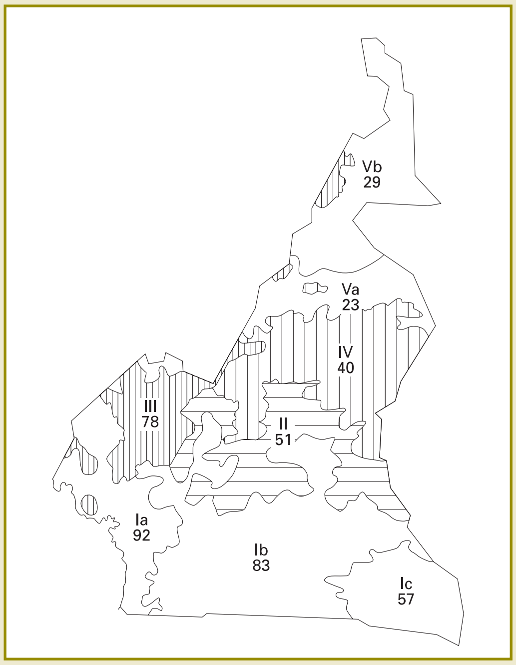

Figure 1. *Map of Cameroon showing the major bioclimatic regions, with the number of species recorded from each region. Key for bioclimatic regions: Ia: coastal plain tropical lowland forest (92 species); Ib: southern Cameroonian plateau tropical lowland forest (83); Ic: Congo basin tropical lowland forest (57); II: southern Cameroonian plateau gallery forests and Guinea savannah (51); III: Cameroon mountain ridge mountains and high plateaus (78); IV: Adamawa Plateau (40); Va: northern Cameroon Sudan savannah (23); and Vb: northern Cameroon Sudano-Sahelian savannah and Sahel (29). For methodology in defining these regions and estimating species totals, see (Amiet 1983).*

ESSAY 5.4. THREATENED ISLANDS OF AMPHIBIAN DIVERSITY IN WEST AFRICA

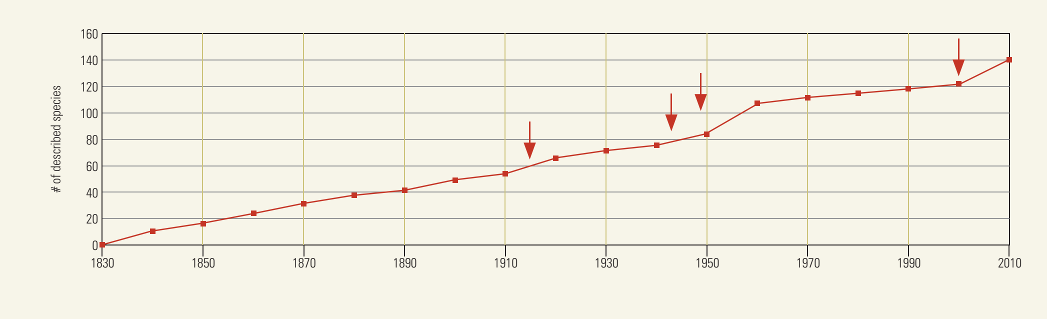

__Figure 1.__ Number of described West African amphibian species per decade (including known but not yet described new species for the last decade). Black arrows indicate the start of periods of more intensive survey and taxonomic work. These significant increases were mainly due to (arrows from left to right) P. Chabanaud; J. Guibé, M. Lamotte and co-workers; A. Schiøtz and J.-L. Perret and M.-O. Rödel and co-workers. With the exception of the 1960s (A. Schiøtz) new amphibian species have been described at a near constant rate of about 0.7 species per annum. Since 2000 the description rate increased to more than 1.8 species per annum and is not yet reaching any visible plateau, hence illustrating that the West African amphibian fauna still is far from being well known.

West Africa, here defined as the region from Senegal in the west to Nigeria in the east and extending north to the southern border of the Sahara Desert, covers almost all larger African biomes, ranging from rainforests along the Atlantic Ocean's coast, over various types of savannahs to semi-deserts. In the border region of Guinea, Côte d'Ivoire, and Liberia, as well as within Sierra Leone, there are also several higher mountain ranges representing rare examples, at least in the West African context, of montane grassland.

Amphibian research in West Africa dates back to the middle of the 19th century. In general, the diversity of amphibians in West Africa is high, with around 175 amphibian species having been recorded from this region, including four caecilians and 171 anurans. While some forests may support as many as 40 different amphibian species in an area as small as 2 ha, amphibian richness is also high in some savannah formations (sometimes surpassing 30 frog species in only a few square kilometres). However, while new species have been described on a continual basis, species description curves have never attained any sort of saturation (Figure 1) suggesting that many new species remain undiscovered.

Around one-fifth of the region's amphibian fauna is considered to be threatened (34 species), including 14 species that are listed as Vulnerable, 16 Endangered, and four Critically Endangered. A further 19 species are classified as Near Threatened. The four Critically Endangered species include two species, *Nimbaphrynoides occidentalis* and *N. liberiensis*, known only from a few square kilometres on Mount Nimba's grassland mountain ridge and a very limited area in Liberia's rainforest on Mount Nimba's southern slopes, respectively. A third species, *Bufo taiensis*, is only known from four specimens collected from the region of Taï National Park in Côte d'Ivoire, while the fourth species, *Conraua derooi* (currently considered Possibly Extinct on the IUCN Red list), was described from, and only very recently rediscovered, in the southern part of the Ghanaian-Togolese mountainous borderline.

Many West African forest amphibians have very small ranges, possibly due to fluctuations in the region's forest cover (Wieringa and Poorter 2004). These fluctuations presumably also served as a catalyst for amphibian speciation and are a reason for today's high diversity. In the Pleistocene and pre-Pleistocene, rainforests were either increasing towards the north in humid periods or were shrinking to comparatively small forest refugia during drier periods (Falk *et al.* 2003). The recent distributions of West Africa's endemic frogs matches well with the rough location of these postulated forest refugia, namely south-western Ghana (Rödel *et al.* 2005), south-western Côte d'Ivoire (Rödel and Branch 2002), and the Mount Nimba area (Rödel *et al.* 2004; Figure 2).

However, new evidence lends support for a much finer grained picture, adding a few more distinct Pleistocene or Pre-Pleistocene forest remnants to the Upper Guinea highlands (Rödel *et al.* unpubl.). The Upper Guinea highlands region stretches from Sierra Leone and Guinea through Liberia to western Côte d'Ivoire, and forms part of the Guinean Forests of West Africa biodiversity hotspot (Bakarr *et al.* 2004). In order to understand West Africa's forest history and to reveal potentially overlooked centres of endemism, an accurate knowledge of the location of historical forest refugia is needed. Current research aims to locate these former forest refugia by investigating the relationships between various leaf litter frog species and populations from West African forests. The recent distribution patterns of these amphibians and the genetic divergences of populations of these frogs will help us to reconstruct the history of West Africa's forest cover (Hillers *et al.* unpubl.).

On this regional scale we have also started to analyse landscape characteristics such as climate, vegetation, altitude, and topo-diversity with respect to their potential influence on amphibian species richness. Our analyses have revealed positive correlations of species richness with rainfall, forest cover, and habitat diversity. Based on these three parameters, we have been able to model areas believed to harbour a high richness of amphibian species. These areas coincide with the aforementioned areas of former forest refugia, which hence would be not only islands of high endemism but also of corresponding high amphibian diversity (Penner *et al.* unpubl.).

Unfortunately, these areas are also among the most threatened regions in West African. South-western Côte d'Ivoire, the area with the most extensive tracts of remaining forest in the country, lost about 80% of its forests within the last 30 years (Chatelain *et al.* 1996). Guinea has little more than about 5% of its former rainforests left (UICN 1996), and many of its remaining forested mountain ranges are threatened by open-cast mining operations. Given the distributional limitations of many forest amphibians and the vast tracts of forest areas that have already been lost, it is not unreasonable to expect that several species have already gone extinct without having been discovered and described scientifically.

But even selective logging might be a severe danger to the endemic West African forest frogs. We have shown that habitat degradation markedly alters the composition of forest frog communities, and many endemic and range-restricted forest frogs do not prevail in logged or fragmented forests (Ernst and Rödel 2005). Moreover, not only does forest degradation negatively affect particular species, but it severely and non-randomly reduces the functional diversity of forest species assemblages, i.e., specific life history traits disappear (Ernst *et al.* 2006). The latter is particularly important for ecosystem renewal and reorganization following change and it provides adaptive capacity in a world of complex systems, and human-dominated environments. The loss especially concerns species with tadpoles that are dependant on larger stagnant or slow-flowing waters. In conclusion, West Africa still supports an extraordinary rich amphibian fauna, albeit restricted to steadily declining islands of diversity.

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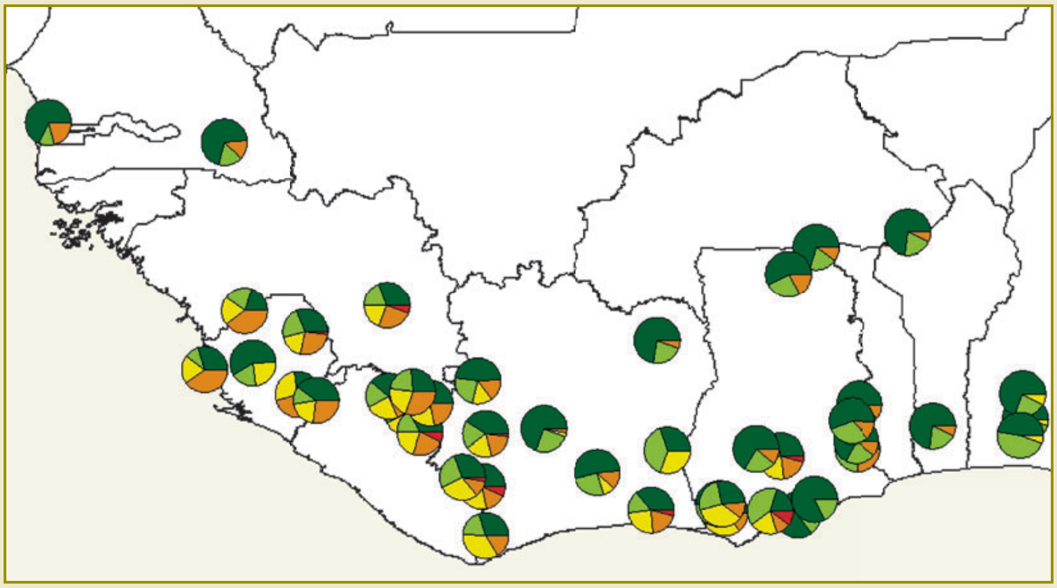
References

Bakarr, M., Oates, J., Fahr, J., Parren, M., Rödel, M-O. and Demey, R. 2004. Guinean Forests of West Africa. In: R.A. Mittermeier, P. Robles-Gil, M. Hoffmann, J.D. Pilgrim, T.M. Brooks, C.G. Mittermeier, J.L. Lamoreux and G. Fonseca (eds.), *Hotspots: Revisited*, pp. 123-130. CEMEX, Mexico City, Mexico.

Chatelain, C., Gautier, L. and Spichiger, R. 1996. A recent history of forest fragmentation in southwestern Ivory Coast. *Biodiversity and Conservation* **5**:783-791.

Ernst, R. and Rödel, M.-O. 2005. Anthropogenically induced changes of predictability in

__Figure 2.__ Endemism of West African amphibian species. Shown are 42 well-known amphibian communities and the respective proportion of endemic species. The level of endemism ranges from local (red, e.g. Nimbaphrynoides occidentalis, *estimated range: 111km²) and regional (orange, e.g.* Kassina lamottei, *13,002km²) endemics, to species that occur in the Upper Guinea forest zone (yellow), West Africa (clear green), Central and West Africa (green, e.g.* Phlyctimantis boulengeri, *294,445km²) to species with an almost sub-Saharan distribution (dark green, e.g.* Kassina senegalensis, *12,263,903km²).*



tropical anuran assemblages. *Ecology* **86**:3111-3118.
Ernst, R., Linsenmair, K.E., and Rödel, M.-O. 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.
Falk, T.M., Teugels, G.G., Abban, E.K., Villwock, W. and Renwartz, L. 2003. Phylogeographic patterns in populations of the blackchinned *Tilapia* complex (Teleostei, Cichlidae) from coastal areas in West Africa: support for the refuge zone theory. *Molecular Phylogenetics and Evolution* **27**:81-92.
Rödel, M.-O., Bangoura, M.A. and Böhme, W. 2004. The amphibians of south-eastern Republic of Guinea (Amphibia: Gymnophiona, Anura). *Herpetozoa* **17**:99-118.
Rödel, M.-O. and Branch, W.R. 2002. Herpetological survey of the Haute Dodo and Cavally forests, western Ivory Coast, Part I: Amphibians. *Salamandra* **38**:245-268
Rödel, M.-O., Gil, M., Agyei, A.C., Leaché, A.D., Diaz, R.E., Fujita, M.K. and Ernst, R. 2005. The amphibians of the forested parts of south-western Ghana. *Salamandra* **41**:107-127.
UICN 1996. *L'atlas pour la conservation des forêts tropicales d'Afrique*. Editions Jean-Pierre de Monza, Paris, France.
Wieringa, J.J. and Poorter, L. 2004. Biodiversity hotspots in West Africa; patterns and causes. In: L.F. Poorter, F. Bongers, F. Kouamé and W.D. Hawthorne (eds.), *Biodiversity of West African forests. An ecological atlas of woody plant species*, pp. 61-72. CABI Publishing, Cambridge, Massachusetts, USA. ■

ESSAY 5.5. THE AMPHIBIAN FAUNA OF THE EASTERN ARC MOUNTAINS OF KENYA AND TANZANIA

In 1983 three botanists – Jon Lovett, Roger Polhill and John Hall – were sitting together at the foot of the Uluguru Mountains discussing recent discoveries of rare plants in the Udzungwa Mountains, previously thought to be endemic to the Usambaras and Ulugurus (Lovett 1998). From the analysis they were making, it was clear that these rare forest plants were found only on the crystalline peaks of a series of isolated mountain ranges in south-eastern Kenya and Tanzania. These mountains were showing remarkable similarities in terms of species richness and composition and since they are set in a half-moon 'arc' shape, they decided to name them collectively as the Eastern Arc Mountains (Lovett 1998). The name first appeared in an article written by Jon Lovett for the Kenyan magazine *Swara*, in 1985.

The Taita Hills of Kenya and the Pare, Usambara, Nguru, Nguu, Ukaguru, Uluguru, Rubeho, Udzungwa, Malundwe and Mahenge Mountains in Tanzania comprise the Eastern Arcs. They lie within the intertropical montane region and were formed by heavily metamorphosed Pre-Cambrian basement rocks, rising to 2,635 m in elevation (Kimhandu peak in the Ulugurus). They are part of one of the Earth's richest biodiversity hotpots and amongst the most important regions in Africa for concentrations of endemic animals and plants, with at least 93 species of endemic vertebrate (Burgess *et al.* 2007).

The Danish batrachologist Arne Schiøtz published a short paper highlighting the importance of the basement hills of Tanzania (the name Eastern Arc was still to be coined) as a regional centre of amphibian endemism (Schiøtz 1981). The Eastern Arcs are home to about 94 named amphibian species, of which 57 are endemic or near-endemic. A further 17 species have been recently discovered and are awaiting formal description (all of which are probably endemic). A rough estimate, therefore, of the total number of amphibians (described and undescribed) in the Eastern Arc Mountains is 121 species, of which 74 occur are endemic or nearly so. The remarkable species richness and the high level of endemism is due to the great age of the Eastern Arc Mountains (they uplifted at least 30 million years ago), to their archipelago-like arrangement, and to the climatic influence of the Indian Ocean that kept the mountains relatively wetter and warmer than the surrounding areas during past climatic fluctuations. The high number of endemic species in small areas, the co-occurrence of recent and old lineages, and the consequent biogeographical implications make these mountains of extreme biological and conservation interest.

Historically, the Eastern Arc Mountains were probably covered by a mosaic of rainforests. These rainforests were concentrated mostly on the eastern slopes and on the upland plateaux and were interspersed with open grassland areas and with dry, semi-deciduous forests on the western slopes. The majority of endemic species occur in the wet forest that covered parts of the eastern slopes of the mountains. Although the forest environment has been well-studied, the grasslands and ecotones could represent a further frontier of batrachological exploration. At the southern tip of the Udzungwas, the so called 'Makambako gap' has long been considered the southernmost limit. However, recent cross-taxon studies are revealing that the Southern Highlands, especially the forests of Mt Rungwe and Livingstone, also contain many species previously assumed to be endemic to the Eastern Arcs. For example, amphibian species such as *Nectophrynoides viviparus* (VU), *Nectophrynoides tornieri* (VU), and *Leptopelis barbouri* (VU) demonstrate Mt Rungwe's Eastern Arc affinities (Davenport *et al.* 2003).

Recently, molecular analysis has shown that a number of genera and species in the Eastern Arc Mountains are genetically ancient. For example, DNA sequence data of caecilians, including Eastern Arc species, suggest that the origin of the caecilian fauna of Africa may 'predate the break-up of Gondwana' (Wilkinson *et al.* 2003). Similar suggestions are made concerning the microhylids and brevicipitids fauna of Africa based on DNA sequence data, which have exposed the extremely ancient age of these lineages (Loader *et al.* 2004). The present pattern of distribution and the presence of recent and old lineages could be interpreted as a consequence of stable local conditions, and to some degree the pattern can be attributed to local speciation or to local low extinction rates – in other words, long species persistence (Lovett *et al.* 2004).

Among the taxa occurring in the Arc, forest bufonids are of particular interest with a number of endemic genera and species like the extraordinary *Churamiti maridadi* (CR), with its shining skin resembling wet lichen, or the bicoloured *Nectophrynoides viviparus*. Ongoing molecular studies on forest bufonids are revealing the presence of lineages of East African origin as well as others derived from Guineo-Congolian taxa and ancient African-Asian linkages. Forest bufonids in the Arc are revealing a much more abundant species radiation than expected with several new species and genera awaiting description.

Many of the endemic species are confined to high-elevation sites and their distribution pattern may be due to relictualization. Other endemic species demonstrate intriguing and highly restricted ranges, deserving of special conservation strategies. These species display a 'single site' distribution, since they are confined to a single valley or parts of it, at certain elevations, and yet are surrounded by apparently suitable habitat. In just the Uzungwa Scarp Forest Reserve there are three strictly endemic species showing such distribution patterns: two dwarf forest bufonids, *Nectophrynoides wendyae* (CR) and *N. poyntoni* (CR), and the treefrog *Hyperolius kihangensis* (EN)(Menegon and Salvidio 2005). Another 'single site' species is the Kihansi Spray Toad *Nectophrynoides asperginis* (CR) occurring only in the Kihansi gorge, and now possibly extinct in the wild. This species is adapted to the peculiar habitat influenced by the constant spray provided by waterfalls. In this case, the small distribution is explained by the extremely peculiar local conditions in the lower Kinhasi gorge. The other three species inhabit sites with no apparent special conditions; they have been sought unsuccessfully in other suitable sites within the same forest patch. Differences thus exist between assemblages at sites at similar altitudes in adjoining mountain fragments or within single fragments, indicating a fine-scale geographic turnover in the herpetofauna of these areas.

The distinct nature of the herpetofauna species assemblages at high altitude, and the high elevational turnover of species, clearly demonstrates the importance of conserving forest at all altitudes. Areas of forest or marginal habitats, at all elevations, might also be vital in generating high species diversity, and need to be considered in the development of a holistic conservation strategy for the area. This suggests that not only is it important to conserve the forest along an elevational gradient, but it is also important to conserve fragments in geographically complex terrains, where isolated populations and therefore potentially new species may still exist, and are awaiting discovery.

Michele Menegon and Tim Davenport

References

Burgess, N.D., Butynski, T.M., Cordeiro, N.J., Doggart, N., Fjeldså, J., Howell, K.M., Kilahama, F., Loader, S.P., Lovett, J.C., Menegon, M., Moyer, D.C., Nashanda, E., Perkin, A., Rovero, F., Stanley, W.T., Stuart, S.N. 2007. The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation* 134:209-231.
Davenport, T.R.B., Machaga, S.J., Mwamtobe, A., Mwaipungu, O. and Hayes, B. 2003. Some notes on the amphibians of Mt Rungwe. Unpublished Report. Southern Highlands Conservation Programme / Wildlife Conservation Society (SHCP/WCS). 4 pp.
Loader, S.P., Gower, D.J., Howell, K.M., Doggart, N., Rödel, M.-O., Clarke, B.T., De Sá, R.O., Cohen, B.L. and Wilkinson, M. 2004. Phylogenetic relationships of African microhylid frogs inferred from DNA sequences of mitochondrial 12S and 16S rRNA genes. *Organisms, Diversity and Evolution* **4**:227-235.
Lovett, J.C. 1985. Moist forests of Tanzania. *Swara* **8**:8-9.
Lovett, J.C. 1998. Naming the Arc. *The Arc Journal* **7**.
Lovett, J.C., Marchant, R., Taplin, J., Küper, W., 2004. The oldest rainforests in Africa: stability or resilience for survival and diversity? In: A. Purvis, J.L. Gittleman, and T.M. Brooks (eds.), *Phylogeny and Conservation*. Cambridge University Press, Cambridge, UK.
Menegon, M., Salvidio, S., 2005. Amphibian and Reptile diversity in the southern Uzungwa Scarp Forest Reserve, South-Eastern Tanzania. In: B.A. Huber, B.J. Sinclair and K.H. Lampe (eds.), *African Biodiversity: Molecules, Organisms, Ecosystems*, pp. 205-212. Proceedings of the 5th International Symposium on Tropical Biology, Museum Koenig, Bonn, Germany.
Moyer, D.C. 1993. Foraging ecology, habitat selection, and community structure of afromontane forest birds in Tanzania. M.Sc. thesis, Louisiana State University and Agricultural and Mechanical College, Department of Zoology and Physiology. Baton Rouge, Louisiana, USA.
Schiøtz, A. 1981. The Amphibia of the forested basement hills of Tanzania - a biological. indicator group. *African Journal of Ecology* **19**:205-208.
Wilkinson, M., Loader, S.P., Gower, D.G., Sheps, J.A. and Cohen, B.L., 2002. Phylogenetic Relationships of African Caecilians (Amphibia: Gymnophiona): Insights from Mitochondrial rRNA Gene Sequences. *African Journal of Herpetology* **52**:83-92. ■

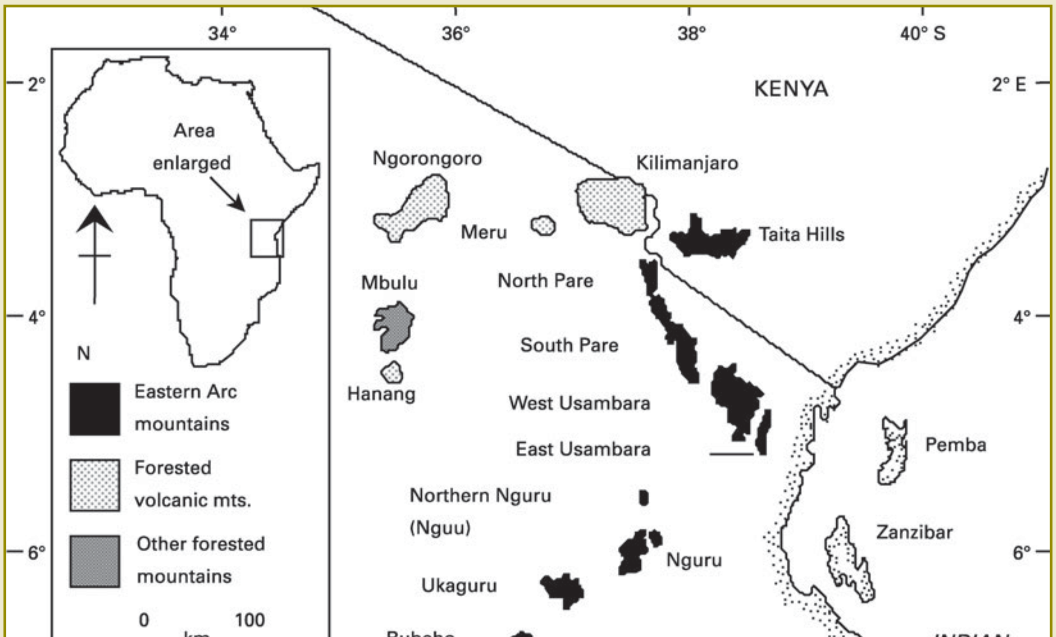


Figure 1. *Map showing the 13 blocks of the Eastern Arc Mountains of Tanzania and Kenya (reproduced, with permission, from Moyer 1993).*

ESSAY 5.6. THREATENED AMPHIBIANS OF SOUTHERN AFRICA

Although many species of amphibians have been described from Africa in recent years, amphibians as a group remain poorly known relative to other vertebrate taxa. An exception is South Africa, which has perhaps the best-studied fauna in the region, culminating in the *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland* (Minter *et al.* 2004). The larger southern African region, including Botswana, Namibia, Mozambique, Malawi and Zimbabwe, is home to 185 species of amphibians, of which 32 species (17%) have been assigned a status of conservation concern, including five as Critically Endangered, 16 as Endangered, and 11 as Vulnerable.

These threatened species have several things in common: they mostly occupy small areas, either on coastal plains, or in highland or montane grasslands or forests. The coastal areas are preferred localities for housing developments, and for farming wheat and other crops. The highlands and mountains are areas with high rainfall, and are selected for planting huge tracts of pine plantations. These threatened species evolved on highlands where there was sufficient moisture, often separated from other highlands by dry plains. The moist conditions that promoted speciation, thereby assisting the formation of a rich diversity of amphibians (see, for example, Channing *et al.* 2002, 2005; Clarke & Poynton 2005) are the same environmental conditions that are suitable for growing trees and other crops. Agriculture leads to severe habitat modification and fragmentation. All the well-known areas planted with exotic pines, such as the Amatola Mountains, the Elandsberg Mountains, and even Table Mountain in Cape Town, are home to endemic species of amphibians that are now threatened with extinction due to habitat loss and conversion. Furthermore, many of these species may be at risk of infection with the fast-spreading chytrid fungus, which is responsible for the extinction of amphibian species in many parts of the world (Daszak *et al.* 1999; Mendelson *et al.* 2006).

One-quarter of threatened species do not have normal life-cycles with free-swimming tadpoles. Instead, their tadpoles remain within the egg, and develop directly into small frogs. This negates the need for nearby pools of water, enabling these species to survive in areas where there is little chance of pools forming, such as in very sandy areas, forests and mountain tops. However, the species with tadpoles display some very unusual breeding strategies: some deposit eggs out of water, and the tadpoles must either move to water, or wait until the nest is flooded. The tadpoles of these species also display a range of adaptations. Most develop in streams or quiet pools, but the tadpoles of Broadley's Ridged Frog *Ptychadena broadleyi* (EN) live on wet rocks in forests, and both species of ghost frogs *Heleophryne* sp. have tadpoles that develop in fast-flowing rocky streams. The tadpoles hang onto rocks in these turbulent habitats by using a large sucker-like mouth. The Chirinda Toad *Stephopaedes anotis* (EN) breeds in small pockets of water trapped in tree-holes.

Protected areas have proved to be the most important conservation tactic in southern Africa, provided that the conservation area is large enough to include a viable population size of the threatened species. Protected areas that provide a haven for globally threatened amphibians include: Inyanga National Park, Chimanimani National Park and Chirinda Forest on the eastern highlands of Zimbabwe (*Afrana inyangae*, EN; *Bufo inyangae*, EN; *Arthroleptis troglodytes*, CR; *Probreviceps rhodesianus*, EN; *Stephopaedes anotis*, EN; *Strongylopus rhodesianus*, VU); Mt Mulanje Forest Reserve in Malawi (*Afrana johnstoni*, EN; *Nothophryne broadleyi*, EN; *Arthroleptis francei*, EN; *Ptychadena broadleyi*); Nyika National Park in Malawi (*Bufo nyikae*, VU), and Table Mountain National Park (*Capensibufo rosei*, VU; *Heleophryne rosei*, CR) on the Cape Peninsula of South Africa. Smaller reserves occur along the south and east coasts of South Africa, though these may not be adequate to sustain viable populations of threatened species in the region, such as Knysna Spiny Reed Frog *Afrixalus knysnae* (EN), Natal Spiny Reed Frog *Afrixalus spinifrons* (VU), and Pickersgill's Reed Frog *Hyperolius pickersgilli* (EN).

Several threatened species occur almost entirely within strictly managed, albeit different, areas. For example, the Cape Platanna *Xenopus gilli* (EN) occurs within the well-established Table Mountain National Park, with other populations in the newly proclaimed and still developing Agulhas National Park. However, even within these national parks, its security cannot be guaranteed, principally due to hybridization with the Common Platanna *Xenopus laevis* (LC) (Kobel 1981; Picker *et al.* 1996) although the extent of this problem may be limited (Evans *et al.* 1997). The Desert Rain Frog *Breviceps macrops* (VU) occurs in a narrow coastal zone along the west coast of South Africa and southern Namibia. This is a diamond mining area where access is restricted, and no development is permitted. However, the diamonds are mined by removing all the old beach sand above the bedrock. This effectively destroys the habitat where this species is found. Of course, even within many protected areas, a lack of management means that natural forest is still being removed, and agricultural activities (both subsistence and large-scale) have been reported from within these. Most (81%) threatened species occur largely (72%) or entirely (9%) outside of any conservation area.

Active protection of threatened species does occur in some cases, as in the Western Cape province of South Africa, where CapeNature was able to both thwart construction plans for a road that would have had devastating impacts on the breeding habitat of the Critically Endangered Micro Frog *Microbatrachella capensis*, and establish a new breeding site. This species is also being actively monitored by CapeNature, although continual active intervention by local authorities is required to halt the damaging effects of alien invasive plants on the breeding sites. As far as can be determined, the only threatened species that are subject to official long-term monitoring activities are Rose's Ghost Frog *Heleophryne rosei* (CR), the Micro Frog, and Cape Platanna. Among local conservation authorities, only CapeNature seems to be paying sufficient attention to the problem of threatened amphibians. In many other protected areas, including those to the north of southern Africa, it is not unusual for staff of reserves to be unaware of the importance of their reserve as a haven for a population of a globally threatened species.

Conservationists are able to determine effectively which species are threatened. We are also able to determine which species require the most appropriate conservation response, be it the establishment of a protected area or controlling invasive species. However, it seems that we are unable to initiate long-term programmes involving active management. Will we sit on the sidelines and tick off the species as they become extinct? Where there was once a rallying call from African conservationists, 'Save the Rhino!", we now need to encourage a 'Save the Frog!" campaign.

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References

Channing, A., Moyer, D.C. and Howell, K.M. 2002. Description of a new torrent frog in the genus *Arthroleptides* from Tanzania (Amphibia, Anura, Ranidae). *Alytes* **20**:13-27.

Channing, A., Menegon, M., Salvidio, S. and Akker, S. 2005. A new forest toad from the Ukaguru Mountains, Tanzania (Bufonidae: *Nectophrynoides*). *African Journal of Herpetology* **54**:149-157.

Clarke, B.T. and Poynton, J.C. 2005. A new species of Stream Frog, genus *Strongylopus* (Anura:Ranidae) from Mount Kilimanjaro, Tanzania, with comments on a 'northern volcanic mountains group' within the genus. *African Journal of Herpetology* **54**:53-60.

Daszak P., Berger L., Cunningham, A.A., Hyatt, A.D., Green, D.E. and Speare, R. 1999. Emerging infectious diseases and amphibian population declines. *Emerging Infectectious Diseases* **5**:735-48.

Evans, B.J., Morales, J.C., Picker, M.D., Kelley, D.B. and Melnick, D.J. 1997. Comparative molecular phylogeography of two *Xenopus* species, *X. gilli* and *X. laevis*, in the south-western Cape Province, South Africa. *Molecular Ecology* **6**:333-343.

Kobel, H.R., du Pasquier, M. and Tinsley, R.C. 1981. Natural hybridization and gene introgression between *Xenopus gilli* and *Xenopus laevis laevis* (Anura:Pipidae). *Journal of Zoology* **194**:317-322.

Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J. and Kloepfer, D. (eds.). 2004. *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland*. Smithsonian Institution, Washington D.C., USA.

Mendelson, J.R., Lips, K.R., Gagliardo, R.W., Rabb, G.B., Collins, J.P., Diffendorfer, J.E., Daszak, P., Ibanez, R., Zippel, K.C., Lawson, D.P., Wright, K.M., Stuart, S.N., Gascon, C., da Silva, H.R., Burrowes, P.A., Joglar, R.L., La Marca, E., Lotters, S., du Preez, L.H., Weldon, C., Hyatt, A., Rodriguez-Mahecha, J.V., Hunt, S., Robertson, H., Lock, B., Raxworthy, C.J., Frost, D.R., Lacy, R.C., Alford, R.A., Campbell, J.A., Parra-Olea, G., Bolanos, F., Domingo, J.J., Halliday, T., Murphy, J.B., Wake, M.H., Coloma, L.A., Kuzmin, S.L., Price, M.S., Howell, K.M., Lau, M., Pethiyagoda, R., Boone, M., Lannoo, M.J., Blaustein, A.R., Dobson, A., Griffiths, R.A., Crump, M.L., Wake, D.B. and Broody, E.D. 2006. Confronting Amphibian Declines and Extinctions. *Science* **313(5783)**:48.

Picker, M.D., Harrison, J.A. and Wallace, D. 1996. Natural hybridisation between *Xenopus laevis laevis* and *X. gilli* in the south-western Cape Province, South Africa. In: R.C. Tinsley and H.R. Kobel (eds.), *The Biology of Xenopus*, pp. 61-71. Zoological Society of London, Oxford, UK.

Afrana johnstoni *(Endangered) is known only from montane grassland and forest habitats on Mount Mulanje in southern Malawi. © Alan Channing*

Table Mountain National Park on the Cape Peninsula of South Africa is home to the only known population of the eponymous Table Mountain Ghost Frog Heleophryne rosei *(Critically Endangered), a cryptic species found from 240-1,060m asl. © Richard Boycott*