Amphibian diversity in urban and peri-urban landscapes of Benin City, a Southern Nigerian City in the rainforest biotope

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Abstract

Benin City, the capital of Edo State of Nigeria has undergone tremendous changes in recent times, especially with the aggressive rate of urbanisation in the last two decades. This has invariably resulted in habitat loss and fragmentation for the amphibian community of the city and its environs. In order to determine the effect of urbanization on the amphibian diversity of the area, a survey was undertaken between July 2009 and July 2010 using Visual and Acoustic Encounter Survey method. Higher species diversity and richness was observed from the peri-urban compared to the urban areas. However, the abundance of amphibian in the urban zone was significantly higher than that of the peri-urban zone ($p<0.05$). *Hyperolius concolor* phases A and C, *H. sylvaticus*, *Afrixalus nigeriensis* and *A. vittiger* were restricted to the peri-urban area while *Ptychadena pumilio* and *Sclerophrys maculata* occurred more in the urban areas. The most dominant species was *S. maculata* (26.6%) while the least dominant species was *A. vittiger* (0.22%). Peri-urban areas contributed 53% while the urban zone contributed 47% to total abundance. More tree frogs were collected from the peri-urban than the urban sites, which could be due to the reduced vegetation cover in the latter. However, the paucity of tree frogs in the urban zone did not have any significant impact on the taxa differences between the two zones. The abundance of *P. pumilio* and *P. mascareniensis*, which are typical savanna frogs is an indication of the degraded nature of the study area. The low records of *A. poecilonotus*, *A. vittiger* and *H. concolor* phase A and the complete absence of forest-dependent species could be due to their inability to tolerate human influence on the environment. There is need for balance in the use of land resources for urbanization and amphibian conservation.

Keywords: Amphibians; urbanization; diversity; cryptic colouration.

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Introduction

In the last 30 years since the first international conference on declining amphibians, the issue of amphibian population decline has engaged the attention of several researchers from different countries (Green *et al* 2020). This phenomenon has been attributed to a number of causes, including climate change, introduction of invasive species, amphibian disease, especially chytridiomycosis (Zimkus *et al* 2020), introduction of exotic species, environmental pollution, agricultural land use and urbanization (Halliday 2005; Hamer and McDonnell 2008; Rohr *et al* 2008; Hamer and Parris 2011; Kruger *et al* 2015). Currently, habitat alteration resulting from agriculture (especially monoculture plantations) and urbanization are two forces that are rapidly changing the rainforest landscape in Africa. While the expansion of monoculture plantations is driven primarily by the need to increase crop acreage and profit, urbanisation is driven by the ever-increasing need to provide housing and other social infrastructure for the rural population drifting to urban centres for a better life. Both process impact negatively on the aquatic and terrestrial ecosystems, both of which are important to amphibians for the completion of their life cycles. Due to their sensitivity to environmental changes, amphibians tend to react quickly to changes in their habitats and are thus good indicators of environmental health (Blaustein and Wake 1995; Sparling *et al* 2001; Welsh and Droege 2001). Several investigators have identified urbanization as one of the major threats to amphibian populations worldwide (Marzluf 2001; Stuart *et al* 2004; Beebee and Griffiths 2005; Cushman 2006; Hamer and McDonnel, 2008; Measy and Tolley 2011; Mokhtla *et al* 2012; Kruger *et al* 2015).

Others have remarked that depending on the degree of urbanization, some sensitive species stand the risk of elimination (Davidson *et al* 2001, 2002; Riley *et al* 2005). Alterations in trophic dynamics have also been recorded, resulting in rapid changes in species composition, with food webs, which differ from the original habitats

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(Faeth *et al* 2005). Thus, an integrated approach to studying and understanding urban ecological systems has been employed using both social and ecological approaches, concepts and theories (Grimm *et al* 2000). Urban development and traffic have been observed to impact negatively on the population of some tree frogs, even at great distances from their breeding sites (Carr and Fahrig 2001; Pellet *et al* 2004; Onadeko and Ogoanah 2017). In other studies, amphibians have been observed to form an urbanization gradient (with lower amphibian larval richness in urban wetlands compared with rural wetlands), to avoidance of certain ponds close to areas of high human activities as against high species richness in wetlands located in urban fringes (Knutson 1999; Gagne and Fahrig 2007; Hamer and Parris 2011; Kruger *et al* 2015; Onadeko 2016). According to Gagne and Fahrig (2010), an understanding of the progressive effects of urbanization on amphibians over time could be used as a model for predicting further effects of environmental degradation.

From available literature, there is no report of any study that has investigated the effects of urbanization on amphibian diversity in Nigeria. There are a few studies that have made anecdotal reference to anuran diversity in relation with parasitological investigations (Aisien *et al* 2009; Aisien *et al* 2017). These studies have shown that amphibian diversity in sub-urban communities around Benin City is low as a result of the continuing growth of human settlements (Edo-Taiwo *et al* 2020). Elsewhere, studies by Akani *et al* (2004) have described the effect of oil industry development on amphibian populations while Onadeko and Roedel (2009) attributed the low diversity recorded in the anuran surveys in south-western Nigeria to degradation and conversion of natural forests in that region. The present study was therefore undertaken to determine the diversity of amphibian in urban and peri-urban habitats in Benin City with the aim of drawing the attention of urban planners to the need to designate forest refugia for amphibians in urban areas.

Materials and methods

Study area

The study was carried out in Benin City (6°23′N and 6°28′N and 5°13′E and 6°38′E), and some sub-urban communities around the city (Figure 1). The locations are within the tropical rainforest where the wet season lasts from April to October and the dry from November to March, with a short and mild harmattan spell between December and January. The urban locations are in the heavily built up areas of the city with long history as residential, governmental and business districts. In this area, there are fewer undeveloped plots in which the vegetation consisted of shrub bush and ornamental trees.

A total of nine (9) sites, (approximately 12.6km^2) were sampled within the urban area (Table 1). The ten peri-urban locations sampled (approximately 22.45km^2) are in the fast developing areas, populated mainly with residential buildings and few business premises (Table 1). The buildings are interspersed between large patches of secondary forest, tall grasses and farm bush with the aquatic resources for the frogs limited to temporary ponds formed during the rainy season.

Amphibian specimens were collected from July, 2009 to July, 2010 from urban and peri-urban locations, covering both the wet and the dry seasons. Collections were made early in the mornings between 0500hr and 0700hr and in the evenings between 1900hr and 2100hr by two collectors, using the Visual and Acoustic Encounter approach (Heyer *et al* 1994). Amphibians collected were identified according to the field guides of Roedel (2000).

Table 1: Sampling localities and coordinates

Sampling sites	Sampling sites	Coordinates
Urban	Ekewan Road	6°19´N; 5°35´E
	Ikpoba Hill	6°21´N; 5°39´E
	Murtala Mohammed Way	6°20´N; 5°38´E
	Sapele Road	6´18´N; 5°37´E
	Sokponba Road	6°19´N; 5°38´E
	Uselu	6°43´N; 5°36´E
	Uwasota	6°23´N; 5°36´E
	BDPA Housing Estate	6°23´N; 5°36´E
	Evbuomore	6°24´N; 5°36´E
Peri-Urban	Aduwawa	6°21´N; 5°40´E
	Benin Techical College Road	6°24´N; 5°36´E
	Ekosodin	6°24´N; 5°37´E
	Isihor	6°24´N; 5°36´E
	NNPC Depot (Agbor Road)	6°20´N; 5°41´E
	Egor Quarters	6°21´N;5°36´E
	Osasogie	6°43´N; 5°36´E
	Ugbighokho	6°15´N; 5°33´E
	Ugbowo	6°23´N;5°36´E
	Uwelu	6°22´N;5°34´E

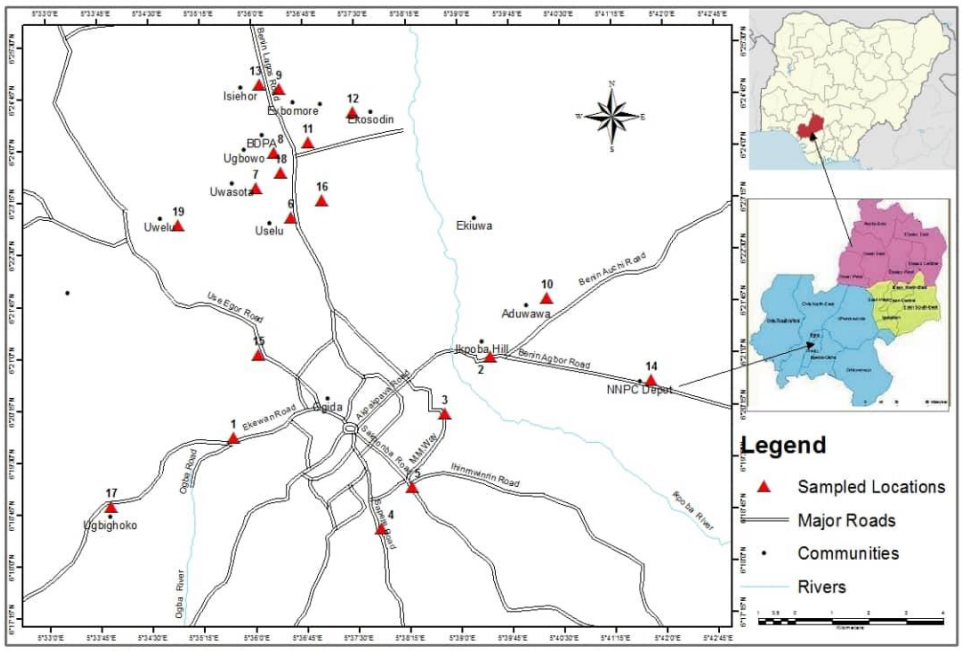

Figure 1. Map of Urban and Peri-Urban Benin City showing sampled locations

Statistical analysis and diversity measures were determined using Paleontological Statistics (PAST) version 2 (Hammer *et al* 2001).

Results

A total of 929 individuals belonging to five families, seven genera and fourteen species were encountered during the study period. Of these, 497 individuals from five families, seven genera and nine species (*Arthroleptis poecilonotus*, *Leptopelis spiritusnoctis*, *Sclerophrys maculata*, *Hoplobatrachus occipitalis*, *Afrixalus dorsalis*, *Ptychadena bibroni*, *P. mascareniensis*, *P. oxyrhynchus* and *P. pumilio*) were collected from the urban locations (Table 2) while 432 individuals from five families, seven genera and fourteen species were recorded in the peri-urban locations (Table 2). Species recorded exclusively in the peri-urban locations included *Hyperolius concolor* (phases A and C), *H. sylvaticus*, *Afrixalus nigeriensis* and *A. vittiger*

The species abundance of the anurans encountered in this study is as shown in Table 2. The dominant species in the peri-urban and urban locations were *Sclerophrys maculata*, *Ptychadena pumilio* and *Afrixalus dorsalis*. In the peri-urban locations, it was in the order *Ptychadena pumilio* > *Sclerophrys maculata* > *Afrixalus dorsalis* while for the urban zone it was in the order *Sclerophrys maculata* > *Ptychadena pumilio* > *Afrixalus dorsalis.*

The highest diversity was recorded from the peri-urban zone, which had diversity between 1.04–1.95 while in the urban zone the recorded diversity was between 0.69 and 1.7. The highest number of eleven (11) species was collected from NNPC Depot, a peri-urban location with a diversity of 1.95, the highest recorded from both zones, while two locations Murtala Mohammed Way (MM Way) and Sokponba Road within the urban zone had the least number of species of two (2) and diversity of 0.5 and 0.6, respectively. Although Ikpoba Hill is located in the urban area with only eight species, this location had the highest number of individuals (212; 22.8%). The absence of tree frogs from the urban zone which resulted in the lower number of taxa did not have any significant difference in the number of taxa between the two zones ($p>0.05$). Percentage contribution of the two zones to the total abundance of amphibians in the study showed that the peri-urban area contributed 53% while the urban zone contributed 47%. The abundance (number) of amphibians in the urban zone was significantly higher than the peri-urban zone ($p<0.05$).

Discussion

It has been established that urbanization is one of the drivers of amphibian decline (Czeck *et al* 2000; Marzluff 2001; Stuart *et al* 2004; Beebee and Griffiths 2005; Cushman 2006; Hamer and McDonnell 2008; Measy and Tolley 2011; Mokhtla *et al* 2012; Kruger *et al* 2015). Results from this study further buttresses this fact, in view of the low species number (14) recorded from Benin City and its peri-urban communities. The urban areas which had lost most of its green space (forest cover) harboured only nine species while the peri-urban characterized mainly by habitat fragmentation had 14 species. The species absent from the urban locations were mainly the tree frogs due to the absence of necessary forest cover and habitat disturbances (McKinney 2002). The low species

Table 2: Amphibian diversity in urban and peri-urban locations in Benin City, Nigeria

	Species	*S. maculata*	*P. bibroni*	*P. oxyrhynchus*	*P. mascareniensis*	*P. pumilio*	*H. occipitalis*	*A. poecilonotus*	*H. concolor* (A)	*H. concolor* (B)	*H. sylvaticus*	*A. dorsalis*	*A. vittiger*	*A. nigeriensis*	*L. spirtusnoctis*	No of species	No of individuals
Peri-Urban	Aduwawa	4	5	-	19	52	17	-	-	-	-	3	-	-	1	7	101
	Isihor	23	2	-	1	6	6	-	-	-	-	-	-	-	-	5	38
	Ugbiyokho	1	-	-	3	2	10	-	-	-	-	-	-	-	-	4	16
	Egor	5	3	-	5	2	-	-	-	-	-	-	-	-	-	4	15
	NNPC Depot	12	1	-	2	9	11	2	16	6	-	40	2	-	27	11	128
	Ugbowo	15	-	-	5	6	6	-	-	-	-	15	-	-	-	5	47
	Uwelu	3	-	-	-	4	3	-	-	-	-	-	-	-	-	3	10
	Benin Technical College Rd	4	-	-	2	8	2	-	-	-	-	4	-	-	1	6	21
	Osasogie	5	-	-	-	2	2	-	-	-	3	9	-	-	2	6	23
	Ekosodin	15	2	1	5	3	2	-	-	-	2	-	-	2	1	9	33
Urban	Evbuomore	50	-	14	-	15	1	-	-	-	-	-	-	-	-	4	80
	Ekewan Rd	5	-	-	-	-	-	-	-	-	-	9	-	-	3	3	17
	Ikpoba Hill	56	9	6	19	71	8	-	-	-	-	30	-	-	13	8	212
	MM Way	-	-	-	3	11	-	-	-	-	-	-	-	-	-	2	14
	Sapele Rd	-	-	-	5	11	-	1	-	-	-	2	-	-	-	4	19
	Sokponba Rd	-	-	-	2	-	-	-	-	-	-	-	-	-	2	2	4
	Uselu	6	-	-	8	9	4	-	-	-	-	4	-	-	-	5	31
	Uwasota	31	-	-	6	19	9	1	-	-	-	27	-	-	1	7	94
	BDPA	12	-	-	1	9	1	-	-	-	-	3	-	-	-	5	26
	Total	247	22	21	86	239	82	4	16	6	5	146	2	2	51	14	929
	% Abundance	26.6	2.4	2.3	9.3	26	8.8	0.4	1.7	0.7	1	16	0.2	0.2	5.5		101

number recorded is consistent with records obtained from an urbanized (Aisien *et al* 2017) and an urbanizing (Edo-Taiwo *et al* 2020) rainforest biotopes in southern Nigeria, where few species were similarly recorded.

Mollov *et al* (2009) associated the drastic reduction in suitable amphibian habitats with increased urbanization, which decreased species diversity, dispersal and reduction in genetic diversity (Reh and Seitz 1990; McKinney 2008). This situation sharply contrasts with results obtained by Imasuen (2012) at the Okomu National Park, Nigeria (a protected rainforest sanctuary) and those from forested regions in Ghana and Western Togo (Roedel *et al* 2005; Hillers *et al* 2009), in which higher species diversity of 40, 47 and 45 species were respectively reported.

The abundance of species such as *S. maculata*, *Ptychadena pumilio*, *P. mascareniensis* and *A. dorsalis*, which are urban-tolerant species attest to the altered nature of the study locations and the consequent increase in the number of individuals when compared with that of the peri-urban zone. *Ptychadena mascareniensis* and *P. pumilio* are savanna frogs, which are known to invade degraded rainforest habitats. Some species such as *A. poecilonotus* (Figure 2A), *P. pumilio* (Figure 2B) and *Hyperolius concolor* (phase C) (Figure 2C) assumed darker cryptic coloration meant to conceal their presence and make them less conspicuous to predators in their exposed habitats. Oldham (2000) had remarked that some frog species could select a background matching their colour and adjust to its brightness. Another concealment

adaptation observed was in *Afrixalus dorsalis* (Figure 2D) in which a leaf-like pattern was observed on the dorsum (Figure 2E), enabling them to blend with their surroundings.

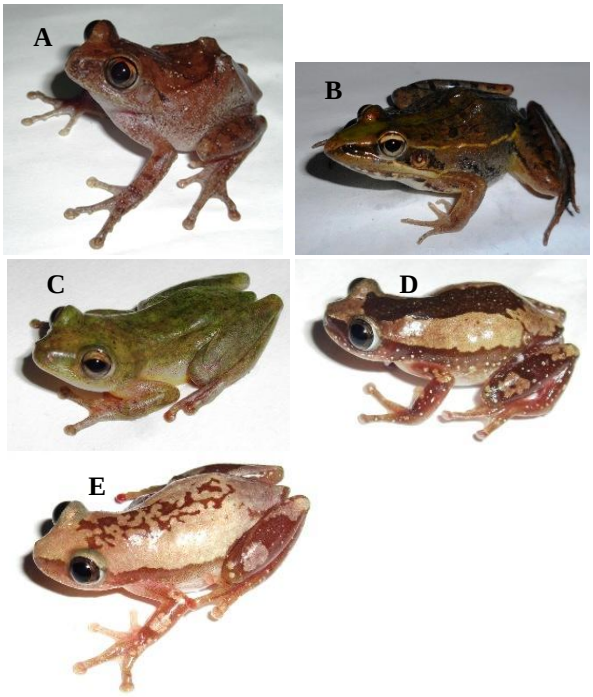

Figure 2A-E. A. Anuran species with concealment adaptations in urban and peri-urban environments of Benin City. A. *Arthroleptis poecilonotus*; B. *Ptychadena pumilio*; C. *Hyperolius concolor* (phase C); D. *Afrixalus dorsalis*; E. *Afrixalus dorsalis* with leaf-like pattern on the dorsum

The very low number of *Arthroleptis poecilonotus* could be due to the negative effects of human interference to its habitat in addition to the short life span of the frog (Roedel 2000). The damp leaf litter required for *Arthroleptis* spp. eggs to develop directly into froglets was also lacking in the study areas. In contrast, other workers including Ernst *et al* (2006) and Hillers *et al* (2008) have however remarked on the capacity of *Arthroleptis* spp. to survive in disturbed forests.

The high abundance of *S. maculata* in this study is in agreement with Roedel (2000) who observed that this African toad inhabits all habitat types, ranging from degraded forests to moist savannas, only avoiding very dry savanna and primary rain forests. The absence of *Afrixalus vittiger* from the urban area is in line with its preference for savanna habitat (Hughes 1988) as the urban areas have little or no vegetation. *Hyperolius concolor* (phases A and C) were only recorded in cultivated plots in the peri-urban areas, a finding which agrees with Roedel (2000), who described them as farm bush species.

The fewer numbers of tree frogs observed in the urban locations could be a direct effect of urbanization as most of the forest cover have been removed to accommodate human habitation, roads and other social infrastructure. Other effects include pollution and/or noise disturbance. For example, urban environments and roads have been shown to have strong and adverse effect on tree frogs' presence (Pellet *et al* 2004). Carr and Fahrig 2001 observed highly vagile amphibians as *Rana pipiens* as being more at risk of mortality in urban landscapes with high vehicular movements than less vagile ones as *R. clamitans*.

This trend was also observed by Onadeko and Ogoanah (2017) who recorded higher road kills in fast moving amphibians as *Ptychadena pumilio* compared to *Hoplobatrachus occipitalis*, which are less mobile. The low number of *Hyperolius concolor* (phase A) and *Afrixalus vittiger* could be due to their high sensitivity to traffic. The greater abundance of tree frogs in the peri-urban areas was due to the presence of shrubs and tall grasses close to shallow ponds in these areas, where also there were comparatively lower human activities. It is not known for how long these favourable conditions in the peri-urban areas will persist with the current rapid pace of urbanization and loss of green space and cover around Benin City. This is particularly devastating for amphibians that are habitat specialists. The low numbers recorded for *H. sylvaticus* and *A. nigeriensis* is not unconnected with the altered state of the urban and peri-urban environments in Benin City. Even at Okomu National Park, a protected pristine habitat, Imasuen (2012) recorded low numbers (22 and 25, respectively) for these frogs in a study that spanned a period of 15 months. If they were that rare in a pristine environment devoid of anthropogenic disturbances, it is not surprising that they occurred in relatively fewer numbers in the present study area.

The low species number recorded in this study shows that the effect of urbanization such as roads and increase in commercial, industrial and residential areas have resulted in habitat changes that may have made the city unsuitable for amphibian habitation. Seth (2006) also attributed low species number to the invasion by non-native mammals that could compete with or prey upon native amphibians.

Sadoju (2003) collected *Silurana tropicalis* in some ponds at Uselu, a location, which then was listed as peri-urban. The absence of this clawed toad in the present study is most likely due to their inability to tolerate anthropogenic effects occasioned by urbanization over time. More importantly, the presence of savanna species in urban Benin City as far back as 2003 showed that there was already a negative feedback of deforestation bearing down on the environment.

Conclusion

The amphibian species composition of Benin City recorded in this study was lower than that for Nigeria by earlier workers (Schiotz 1963, 1966). The presence of typical farm bush and savanna species is a potent indicator that the area is degraded. Ongoing road constructions and development of residential and industrial layouts observed within the study area is a cause for concern as they further eliminate the remaining patches of amphibian habitats and refugia. The resultant effect is the low species richness and diversity observed in this study. Despite the long duration of the survey, only a few species were recorded in the urban settings. It is likely that with a more intensive survey in the peri-urban areas, more species (especially cryptic individuals) may be recorded in these disturbed microhabitats. In order to conserve urban amphibians, there is need to have a paradigm shift in the management of urban green spaces. Deliberate effort should be made by urban planners to create forest refugia for amphibian and other animal fauna in urban and peri-urban areas.

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