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Spatial and seasonal dynamics of amphibians from shallows and forests in urban and Peri-urban areas of Daloa (Ivory Coast, West Africa)

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Abstract

The disappearance of forests and biodiversity in Côte d'Ivoire is also due to the expansion of urban areas. This expansion was carried out without any concern for the preservation or restoration of the natural resources. The Daloa area, in addition to the forest relics, contains shallows, important for agriculture. These shallows were mostly landing sites for drainage water from various horizons. To assess the conservation status of these environments, amphibians, due to their high sensitivity to changes in environmental conditions, were used to assess the biotic integrity of the ecosystems. Thus, daytime and night-time sampling were carried out in urban, peri-urban shallows and peri-urban forests. These acoustic, visual and capture samplings lasted 12 months and revealed the presence of 20 amphibian species. Nineteen species were found in urban shallows, peri-urban forests and 17 species in peri-urban shallows respectively. There was no significant difference between the species richness of the different habitats (Kruskal-Wallis test, $p > 0.05$). Furthermore, in the rainy season, amphibian diversity was higher in peri-urban forests than in shallows. In addition, over the whole study area, Amphibian abundance was higher in the rainy season than in the dry season. Also, the most frequent species in this area was *Ptychadena mascareniensis*. Finally, in the rainy season, the distribution of Amphibians in peri-urban forests was more equitable than that of dry season and in other sites.

Keywords: Amphibians diversity; Shallows; Peri-urban forests; Urban; Seasons

1. Introduction

Biodiversity is being drastically lost in Africa and around the world: for example, of the 6260 species of amphibians listed worldwide, 2030 are classified as threatened with extinction [1]. The major cause of the reduction in biodiversity is the degradation of forest ecosystems [2]. In Côte d'Ivoire, following independence, the choice of development based on agriculture resulted in the loss of most of its forest resources. The disappearance of forests and biodiversity in this country is also due to the expansion of urban areas. This expansion is taking place without any concern for the preservation or restoration of the natural heritage [3]. Disappearance of forests does not spare the Daloa area. In this area, urban and peri-urban environments, in addition to the forest relics, contain important shallows for agriculture [4]. These shallows are mostly landing sites for drainage water from various horizons [5].

However, for sustainable management of the ecosystems, regular assessments of their ecological health are needed. Various biological communities are used as indicators of the state of conservation or degradation of an environment. Amphibians, due to their high sensitivity to environmental disturbances, are excellent indicators of the biotic integrity of ecosystems [6]. For these reasons, a better understanding of the diversity of Amphibians in the area is required. Very few studies on Amphibians has been carried out in the Daloa area. The only information we have concern the

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adaptability of anurans in the urban area of Daloa [7]; the study of the diet [8] and endoparasite [9] of *Phrynobatrachus latifrons* and *Ptychadena mascareniensis*. The aim of the present study is to determine spatial and seasonal variations of amphibian population in the shallows and forests of urban and peri-urban areas of Daloa.

2. Material and methods

2.1. Study area

This study has been carried out in the West-central of Ivory Coast; precisely in shallows and forests of urban and peri-urban areas of Daloa. The study area is located between 6°30 and 8° North latitude and between 5° and 8° West longitude [10]. Fourteen sampling sites were prospected. These are shallows that are used for market gardening and rice cultivation. The forests were secondary forests. These sites have been grouped into three types of ecosystems: urban shallows; peri-urban shallows and peri-urban forests (Figure1).

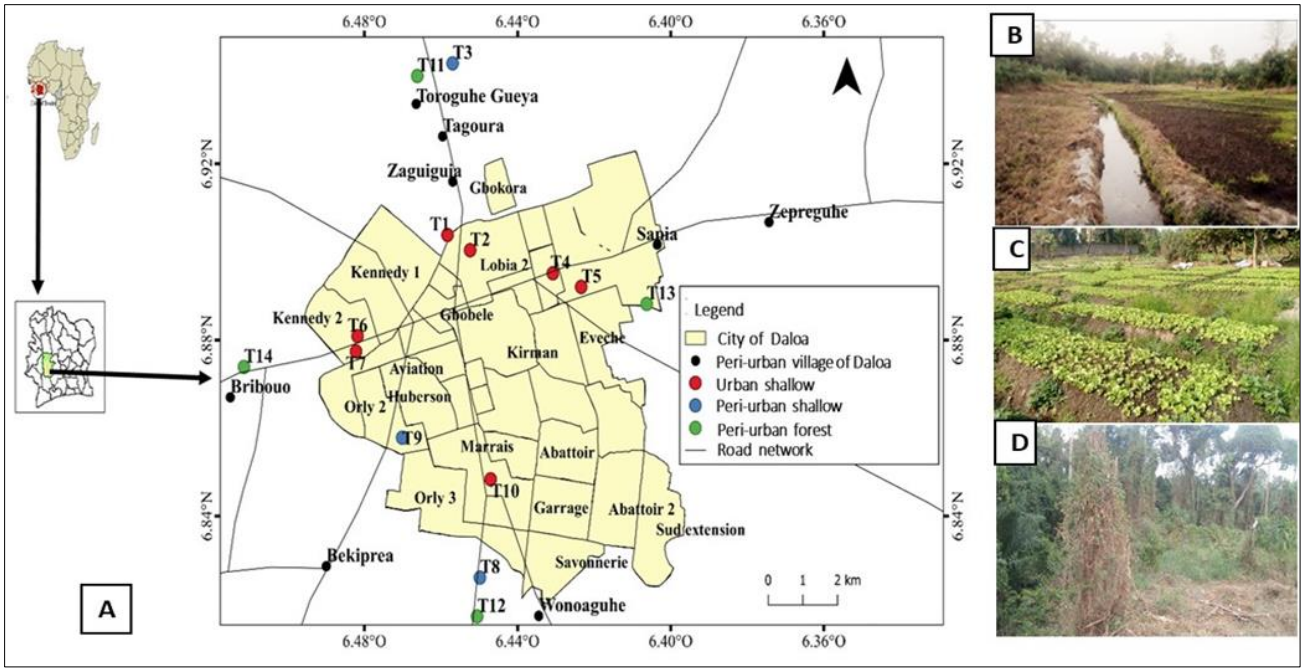

Figure 1 Study area location (A) and Overview sampling sites: peri-urban shallow of Toroguhe (B) urban shallow of Issia road (C) and peri-urban forest of Sapia (D)

2.2. Amphibians sampling

Aquatic species were captured using a dip net or a box. For nocturnal sampling, a head torch was used: the light of the torch dazzling the frog, the capture was done manually. Afterwards, the carrying of the captured live specimens was done with portable plastic aquariums. Furthermore, upon arrival at the sample processing site, the captured individuals were identified using the determination keys [11] and [12].

2.3. Data analysis

Data on the Amphibians sampled were used to compare different Amphibian populations from the sites. These were : species richness (number of species encountered), species abundance (number of individuals encountered), Shannon diversity index (H') : $H' = -\Sigma Pi \log2 Pi$, with $Pi = ni/N$; i : a species from study area ; Pi : Proportion of a species i in relation to the total number of species (S) in the study environment and ni : number of specimens for species i and N is the total number of specimens of all species in the environment. This index underlines overall diversity of Amphibians settlement. Concerning Equitability Index (E), it has made possible to study the regularity of species distribution and to compare the diversity of two settlement with different specific richness (Rs) ([13]; [14]); it varies between 0 and 1 and has the formula: $E = H'/ Hmax$ (with $Hmax = Log2(S)$ and S is the number of settlement species forming the stand). In addition, these data were also used to calculate the frequency of occurrence of each species. The formula is: $F (\%) = (Fi / Ft) \times 100$ (Fi: number of surveys including species i ; Ft : total number of surveys conducted). It allowed to distinguish: constant species ($F \geq 50\%$); accessory species ($25\% \leq F < 50\%$) and accidental species ($F < 25\%$). For statistical analysis,

the Kruskal-Wallis test was used to compare Amphibian populations in urban shallows, peri-urban shallows and peri-urban forests sites. This analysis was carried out using PAST software version 2.17C.

3. Results

3.1. Taxonomic composition of study area

During this study, 20 species of Anuran Amphibians were sampled in the forest and shallow sites of urban and peri-urban areas of Daloa. These species were divided into 9 families and 11 genera (Table 1).

3.2. Occurrence of Amphibians in study area

The Table 2 presents constants of occurrence (C %) of Amphibian species in the study area. These occurrence values reveal that the species *Ptychadena mascareniensis* (Figure 2A) was constant on each transect of the study area. It was followed by *Sclerophrys regularis* (Figure 2B) and *Phrynobatrachus latifrons* (Figure 2C) which were mostly constant in shallows transects. Accidental species were the most represented in the study area (their proportions vary from 40 to 84.62 %).

Table 1 Distribution of Amphibians taxa inventoried in shallows and forests transects of urban and peri-urban environments

Taxa	Urban shallows							Peri-urban shallows			Peri-urban forests			
	T1	T2	T4	T5	T6	T7	T10	T3	T8	T9	T11	T12	T13	T14
Phrynobatrachidae														
Phrynobatrachus latifrons	x	x	x	x	x	x	x	x	x	x	x	x	X	
Phrynobatrachus sp	x												X	
Phrynobatrachus tokba	x												X	x
Bufonidae														
Sclerophrys regularis	x	x	x	x	x	x	x	x	x	x	x	x	X	x
Sclerophrys Maculata	x	x	x	x	x	x	x	x		x	x	x	X	x
Ptychadenidae														
Ptychadena bibroni			x					x	x	x	x	x		
Ptychadena Longirostris		x	x					x	x		x	x	X	x
Ptychadena mascareniensis	x	x	x	x	x	x	x	x	x	x	x	x	X	x
Ptychadena oxyrhynchus		x	x		x	x			x	x	x		X	x
Arthroleptidae														
Arthroleptis poecilonotus			x		x			x		x	x	x	X	x
Leptopelis viridis	x	x						x	x		x	x	X	x
Dicroglossidae														
Hoplobatrachus occipitalis	x	x	x	x	x	x	x	x	x	x	x	x	X	x
Hemisotidae														
Hemisus marmoratus		x	x					x	x	x		x	X	

Hyperoliidae														
Afrixalus dorsalis	x		x	x	x	x				x		x	X	x
Hyperolius concolor		x	x	x		x		x				x	X	x
Hyperolius fusciventris				x	x	x				x			X	
Hyperolius guttulatus		x		x					x		x		X	
Hyperolius nitidulus		x	x										x	x
Microhylidae														
Phrynomantis microps	x	x								x				
Ranidae														
Amnirana galamensis									x			x	X	x
Total	10	13	13	9	8	10	5	11	11	12	11	13	18	13

T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13 et T14 are transects

Table 2 Occurrence of Amphibian species from forests and shallows in urban and peri-urban areas of Daloa

	Urban shallows							**Peri-urban shallows**			**Peri-urban forests**			
	T1	**T2**	**T4**	**T5**	**T6**	**T7**	**T10**	**T3**	**T8**	**T9**	**T11**	**T12**	**T13**	**T14**
Phrynobatrachidae														
Phrynobatrachus latifrons	***	**	***	***	**	**	***	***	**	***	**	*	* *	-
Phrynobatrachus sp	*	-	-	-	-	-	-	-	-	-	-	-	*	-
Phrynobatrachus tokba	*	-	-	-	-	-	-	-	-	-	-	-	*	*
Bufonidae														
Sclerophrys regularis	***	***	**	*	**	**	***	**	***	***	*	***	**	**
Sclerophrys Maculata	*	**	*	*	*	*	*	*	-	*	*	*	-	*
Ptychadenidae														
Ptychadena bibroni	-	-	**	-	-	-	-	*	**	*	*	*	*	-
Ptychadena Longirostris	-	*	*	-	-	-	-	*	**	-	*	*	**	*
Ptychadena mascareniensis	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Ptychadena oxyrhynchus	-	*	*	-	*	*	-	-	*	*	*	-	*	*
Arthroleptidae														
Arthroleptis poecilonotus	-	-	*	-	-	*	-	*	-	*	*	*	*	**
Leptopelis viridis	*	*	-	-	-	-	-	*	*	-	*	*	*	**
Dicroglossidae														
Hoplobatrachus occipitalis	**	***	**	**	*	**	*	***	**	*	*	*	*	*
Hemisotidae														
Hemisus marmoratus	-	*	*	-	-	-	-	*	*	*	-	*	*	-
Hyperoliidae														

Afrixalus dorsalis	*	-	*	*	*	*	-	-	-	*	-	*	*	*
Hyperolius concolor	-	*	*	*	-	*	-	*	-	-	-	*	*	*
Hyperolius fusciventris	-	-	-	*	*	*	-	-	-	*	-	-	*	-
Hyperolius guttulatus	-	*	-	*	-	-	-	-	*	-	*	-	*	-
Hyperolius nitidulus	-	*	*	-	-	-	-	-	-	-	-	-	*	*
Microhylidae														
Phrynomantis microps	*	*	-	-	-	-	-	-	-	*	-	-	-	-
Ranidae														
Amnirana galamensis	-	-	-	-	-	-	-	-	*	-	-	*	*	*

*** = constant species (C > 50 %), ** = accessory species (25 % ≤ C ≤ 50 %), * = accidental species (C < 25 %);

(T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13 et T14 are transects).

Figure 2 Spécimens of *Ptychadena mascareniensis* (A); *Sclerophrys regularis* (B) and *Phrynobatrachus latifrons* (C)

3.2.1. Variations of Amphibians populations

Spatial variations of Amphibian diversity

Table 3 shows that Shannon index (H') is a bit higher in peri-urban forests (H'= 1.86) than in shallows: H' (urban shallows) = 1.65; H' (peri-urban shallows) = 1.68. As for Equitability Index (E), it is 0.64 in the forest sites, while in the urban and peri-urban shallows sites it is 0.57 and 0.62 respectively.

Finally, species richness (Rs) is 19 species in peri-urban forests and urban shallows and 17 in the peri-urban shallows. There is no significant difference between species richness of the different habitats (Kruskal-Wallis test, $p > 0.05$). Amphibians are more abundant in the shallows than in the peri-urban forests.

Table 3 Amphibian settlement diversity index for urban shallow, peri-urban shallow and peri-urban forest sites

	Species richness (Rs)	**Abundance (%)**	**Shannon index (H')**	**Equitability Index (E)**
Urban shallows	19	46.13	1.65	0.57
Peri-urban shallows	17	32.19	1.68	0.62
Peri-urban forests	19	21.68	1.86	0.64

Seasonal variations of Amphibian diversity

Table 4 reveals that during dry season, the Shannon index is lower in peri-urban forests (H'= 0.98) than in urban and peri-urban shallows with respective Shannon indices of 1.44 and 1.43. However, in rain season, Shannon index is higher in peri-urban forests (H'= 2.01) than in urban and peri-urban shallows (with respective Shannon indices of 1.7 and 1.78). As for Equitability index, it is subtantially the same ($E \approx 0.6$) in shallow sites and even during the different seasons. Moreover, in peri-urban forests, Equitability index is lower in dry season (E = 0.5) than in rainy season (E = 0.71). There was no significant difference between the specific richness of the different habitats during the dry and rainy seasons

(Kruskal-Wallis test, $p > 0.05$). Throughout the study area, Amphibians were more abundant in the wet season than in the dry season.

Table 4 Amphibian population diversity index of urban shallow, peri-urban shallow and peri-urban forest sites during dry (DS) and rainy (RS) seasons

Sites	**Urban shallows**		**Peri-urban shallows**		**Peri-urban forests**	
Seasons	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**
Species richness (Rs)	10	18	11	17	8	18
Abundance (%)	17.56	28.57	13.53	18.65	7.61	14.08
Shannon index (H')	1.44	1.7	1.43	1.78	0.98	2.01
Equitability Index (E)	0.65	0.6	0.62	0.64	0.5	0.71

DS: dry season; RS: rainy season

4. Discussion

Species richness obtained during this study is 20 Amphibian species divided into 9 families. This taxonomic richness is lower than that recorded by Kouamé *et al.* [7]. During their work carried out in urban and peri-urban environments in the district of Daloa, in the Centre-West of Côte d'Ivoire.

These authors carried out 62 surveys with an equal duration of 4 hours of sampling in the mornings and nights. They inventoried 30 species of Amphibians grouped into 10 families. This difference in number of species would be due to the sampling frequency. Indeed, the work of these authors was carried out over a period of 36 months, unlike our study, which was carried out over 20 months. This low taxonomic richness would also be due to the narrowness of the sampling area, which is 0.16 ha per transect, contrary to that of Kouamé *et al* whose areas varied from 45 to 190 ha [7]. Our observations are consistent with those of Vallan who state that Amphibian species richness increases with habitat size [15]. This species richness is also considered low due to the high anthropisation that has degraded habitats favourable to Amphibians. Our point of view is corroborated by Hillers *et al*. For these authors, Amphibians are characterised by their great sensitivity to changes in environmental conditions [6]. However, the highest species richness was found in the forest transects (11 to 18 species) at the expense of the urban (5 to 13 species) and peri-urban (11 to 12 species) shallows transects.

This unequal distribution of Amphibians could be explained by the fact that in the more anthropised environments (shallows), human activities have considerably destroyed habitats, thus modifying their ecology [16]. In search of refuge, feeding and breeding sites, Amphibians could be found in peri-urban forests where the litter and canopy are favourable. Our observation is supported by Fauth *et al* and Menin *et al* who state that undergrowth litter is conducive to increased prey availability for Amphibians [17; 18]. Thus, these observations are in agreement with those of Werner and Glennemeir who argue that canopy cover influences the choice of breeding site for amphibians and thus conditions their movements [19]. This justifies their increased presence in forest environments. Finally, other authors have also supported our point of view through the results of their work. These have shown that species composition and assemblages reflect the degree of habitat disturbance or alteration [20; 21; 22]. Furthermore, considering species richness of each site, it appears that peri-urban forests and urban shallows supported the same number of amphibian species (species richness = 19). As for the peri-urban shallows, they were home to 17 species of amphibians. This observation can be explained by the fact that shallow in urban areas with permanent water points are the only habitats suitable for amphibians [23]. This unequal distribution of amphibians would be due to the lack of watering holes in forest areas.

Our conclusions are further supported by several authors who affirm that the permanent presence of water points in an environment is essential for the reproduction of amphibians and conditions their spatial distribution [24; 25; 26]. In addition, during dry and rainy seasons, diversity of amphibian settlement had less variation in shallow sites than in forest sites. Indeed, in both dry and wet seasons, urban and peri-urban shallows showed identical settlement stand diversities values ($H' \approx 1.4$ in the dry season and $H' \approx 1.7$ in the wet season). However, in forest area, stand diversity was higher in wet season ($H' = 2.01$) than in dry season ($H' = 0.98$). In addition, distribution of Amphibians was uneven in shallow environments in both dry and rainy seasons ($E \approx 0.6$). In peri-urban forests, distribution of Amphibians was found to be more equitable in rainy season ($E \approx 0.71$) than in dry season ($E \approx 0.5$). These observations are the result of

presence or absence of water in habitats. In shallows, diversity of amphibians settlement and their distribution remained stable despite seasonal variations because of habitats which were constantly wet. Shallows of our study area were all crossed by streams. In peri-urban forests, the lack of water reduced amphibians diversity, where as in the rainy season this diversity increased. In forests, distribution of species was more even in rainy season than in dry season. In shallows, it was less regular in both seasons. This last analysis is not in line with results of the work of [24], [25], [24], [26]. Furthermore, this finding is explained by the fact that ecological conditions would be more favourable in rainy season in peri-urban forests than in urban areas. Our finding is in agreement with Soro. According to this author, during the rainy season, forests provide favourable ecological conditions (presence of water, high humidity and adequate vegetation cover) for the regular distribution of amphibians [27].

5. Conclusion

Sampling in shallows and forests of urban and peri-urban areas of Daloa revealed the presence of 20 species divided into 11 genera and 9 families. Among these species, *Ptychadena mascareniensis* was found to be constant and the most abundant on the 14 transects of the sampling sites. In both dry and wet seasons, distribution of amphibians was irregular in shallows because these environments would have been constantly disturbed by human activities. However, in peri-urban forests, distribution of amphibians was only regular during rainy season: peri-urban forests, although in a degraded state, offered more favourable conditions for amphibians than urban and peri-urban shallows.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors have contributed equally to this work., authors have no conflicts of interest to declare.

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