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The amphibian's fauna of a West African forest relict near a hydroelectric Dam (Southwest of Côte d'Ivoire)

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Abstract

This study reports the amphibian's fauna sampled from the Biodiversity Conservation Area of the hydroelectric dam of Soubré city (southwestern Côte d'Ivoire). This study aims to provide a better understanding of the diversity of amphibians in this relict forest of 200 ha, in order to assess the ecological health of this ecosystem for conservation and sustainable management perspectives. During dry season (from 26 February to 4 March 2018) and rainy season (from 17 to 23 June 2018), we recorded 14 species of anurans grouped into eight genera and six families. The study sites comprise an amphibian fauna consisting mainly of savannah specialists and degraded forest (64.28% of total species richness). Based on the IUCN Red List, all species recorded are of least concern. Also, these species are well distributed in the different regions of Côte d'Ivoire and Africa. Thus, it is necessary to monitor the ecology of the species and to protect subsequently the different habitats of this area.

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Introduction

Tropical forests cover about 6% of the world's land area (Myers, 1989). From West Africa to Central Africa, there are two blocks (Upper Guinea and Lower Guinea) containing some of the greatest biological diversity in the world (Myers *et al.*, 2000). Since the beginning of the 19th century, these tropical forests have been experiencing a gradual decrease in their area. This dynamic is, in general, linked to the combined impacts of climate variability, the growth of African populations and changes in social habits (Pain-Orcet *et al.*, 1999).

However, several authors have demonstrated a close relationship between the composition of faunal communities and habitat diversity (Lips *et al.*, 2003). Others have also shown that forest fragmentation could cause local extinction of plant species (Hill and Curran 2003). Similar observations have been made for animal communities, including birds, mammals (Beier *et al.*, 2002), reptiles and amphibians (Hillers *et al.,* 2008).

Urbanization, logging, agriculture, and the energy sector (construction of high-voltage power lines and hydroelectric dams) are leading to reductions or fragmentation of certain habitat types and concomitant changes in biodiversity (Kirk, 2003). The rate of species extinction is rampant, leading the scientific community to believe that a sixth mass extinction is setting in, given the loss of species over the past centuries and millennia (Bellard *et al.,* 2012). The dependence of many amphibian species on both aquatic and terrestrial habitats places them in a state of permanent threat as deterioration in the quality of both terrestrial and aquatic environments could disrupt their life cycles and affect their populations (Dunson *et al.,* 1992). Therefore, they provide more information on environmental disturbances affecting different ecosystems (Blaustein *et al.,* 2003). Thus, amphibians are excellent biological indicators of tropical ecosystems (Channing, 2001).

In Côte d'Ivoire, the creation of hydroelectric dams dates back to the 1950s (Assemian *et al.* 2006). On the one hand, it was a response to the country's search for energy independence in favor of hydroelectricity and, on the other, to a political will to reduce interregional disparities (Tia & Touré, 2016). It is in this context that, in order to mitigate the deficit in energy coverage, the Ivorian State decided to build a hydroelectric dam on the Sassandra River, located in the Soubré city. This infrastructure contributes to general development and human advancement (Skinner *et al.,* 2009). However, the construction of this structure is a source of many problems, including massive and forced displacement of populations (Pottinger, 2012) and the destruction of the natural environment with all its components. Aware of the consequences on the natural environment, the Ivorian state in an effort to reconcile environment and development, has included in its development program, the realization of an environmental and social impact assessment (ESIA) prior to the implementation of any project likely to have an impact on the environment (Kadjo *et al.*, 2017).

The policy of erecting an area for biodiversity conservation within the operating space of an industrial or mining company is recent. There is the example of Agbaou which dates from 2017. For the hydroelectric dam development of the Soubré, the ESIA allowed the development of an Environmental and Social Management Plan (ESMP)

In order to compensate for habitat losses, the ESMP proposed a restoration and rehabilitation zone immediately downstream of the dam called the Biodiversity Conservation Area (BCA). The BCA would be a sanctuary or refuge area for terrestrial wildlife in general and amphibians in particular.

Thematic studies started in June 2017, these have allowed to make an inventory of the vertebrate fauna of this area. It is in this perspective a study on the spatial distribution of the amphibian's population in this area has been conducted.

Several research works on amphibians have been carried out in different protected area of Côte d'Ivoire, namely those of Rödel & Branch (2002),

Rödel & Ernst (2004) in Taï National Park (the West region), those of Assemian *et al.* (2015), Kouamé *et al.* (2018) in Banco National Park (the Southeast region) and Kpan *et al.*(2014) in Tanoé-Ehy Swamp Forests. This study aims to provide a better understanding and for documenting the amphibian's diversity of an unprotected forest in order to diagnose the health of this ecosystem for conservation and sustainable management perspectives.

Material and methods

Study area

The city of Soubré is located in southwestern Côte d'Ivoire at 5°47' N and 6°37' W, at an altitude of 134 meters and about 130km from the Gulf of Guinea (Gronner, 1982). The Biodiversity Conservation Area (BCA) is located immediately downstream of the Soubré hydroelectric dam. In this formerly sparsely inhabited region, an abundance of wildlife still inhabits the surrounding forests. It constitutes an ecological continuum of 200 ha distributed on the left and right banks of the Sassandra River (Fig. 1).

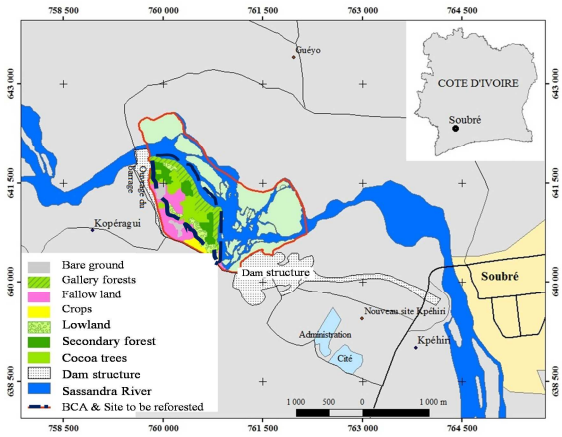

Fig. 1. Map of the Soubré Hydroelectric dam Biodiversity Conservation Area (BCA) and its location in Côte d'Ivoire.

The climate of Soubré corresponds to the equatorial regime of attenuated transition according to Girard *et al.* (1971) with two seasons, a long rainy season from March to October and a dry season from November to February. The average annual temperature is relatively low, hovering around 25.8°C (Skoroby *et al.*, 2013).

In terms of vegetation, the Soubré region is located in the territory of the pelohygrophilous and subhygrophilous forests with Sassandrian facies. These forests will later be called the ombrophilous sector of the dense humid evergreen forests (Guillaumet and Adjanohoun, 1971).

The Department of Soubré highlights three areas in terms of relief. These are the Valleys, the Low Plateaux and the High Plateaux.

The fauna of this region was typical of dense forest areas (cephalopods, buffaloes, elephants, monkeys, etc.), to which we must add species that are found in both forest and savannah areas such as the harnessed guib. Unfortunately, logging and farming, and especially poaching, have decimated the large mammals. Nevertheless, some harnessed guib, antelope, deer or gazelle and rodents such as grass cutter (*Thryomys swinderianus*), squirrels and others can still be found (Anonymous 1, 2016).

Survey sites

We surveyed amphibian species in four distinct habitat types (Fig. 2) with different amphibian assemblages: Fallow land (FL), Forest' relict (FR), Swampy area (SA) and Nursery (Nu). The geographic positions of all study sites were recorded with a hand-hold Garmin 60 CSx. In Table1, we provide a list of all sites including a brief description of each habitat type.

Table 1. Geographic coordinates of the survey sites, search effort (measured in person-hours: p-h) and short habitat characterization. FR = Forest relict, FL = Fallow land, SA = Swampy area, Nu = Nursery

Sites	Latitude (N)	Longitude (W)	Number of visits	p-h	Habitats
FR	05°47'50.7"	006°38'54.1"	4	40	Forest relict, closed canopy
FL	05°47'44.3"	006°38'47.1"	4	40	Abandoned cocoa/coffee plantation, clear canopy
SA	05°47'34.0"	006°39'03.5"	4	40	Grassland, permanent pond, open habitat
Nu	05°47'52.6"	06°38'56.6"	4	40	Nursery, open habitat

Fig. 2. Partial view of the different habitat types of the Biodiversity Conservation Area of Hydroelectric dam of Soubré; a = Fallow land (FL); b = Forest relicts (FR); c = Nursery (Nu); d = Swampy area (SA).

Sampling methods

The survey was carried out on two seasons: during seven days in dry season (from 26 February to 4 March 2018) and seven days in rainy season (from 17 to 23 June 2018). Amphibians were searched visually and acoustically in all different habitats by two people, during day and night from 7am to 10am and from 6pm to 8pm (GMT) following Heyer *et al.* (1994) and Rödel and Ernst (2004) methods. The sampling effort amounted to 10 person-hours per day and was kept constant throughout the study. We tried to include all different habitats, but in particular put emphasize on habitats where frogs were assumed to be encountered (swamps, rivers, streams, ponds, etc.).

Encountered individuals were determined to species level and the nomenclature used herein follows Frost (2021). After capture, frogs were identified to species level, measured, sexed, and if not kept as vouchers, released in their respective habitats. Snout-urostyle-length (SUL) was taken with a dial caliper (accuracy ± 0.5 mm). In addition, representatives of each species were collected, anesthetized in chlorobutanol solution and thereafter preserved in 70% ethanol. Voucher specimen were deposited in the collection of Hydrobiology Unit of the Laboratory of Biology and Tropical Ecology at Jean Lorougnon Guédé University (Côte d'Ivoire).

Data analysis

As species detection probability seemed to differ between species and number of calling males could not be reliably counted on the sites, we herein only use qualitative and no quantitative data. We calculated the estimated species richness, and thus the sampling efficiency, with the Jack-knife 1 (Heltshe and Forrester, 1983) and Chao 2 (Chao, 1987) estimators (software: EstimateS, Version 9.1.0; Colwell, 2013). These estimators are incidence based. We used the presence / absence data of the daily species lists (14 days of survey work) for all 14 species recorded (Table 2). To avoid order effects, we accomplished 500 random runs of the daily species lists. In order to test for the similarity or difference in amphibian species composition in each habitat type, the Jaccard's similarity index was calculated, using the software PAST (Version 2.17c; Hammer *et al.*, 2001).

Results

Species richness and community composition

Overall, we recorded 14 anuran species in six families and eight genera in BCA of Soubré. A total species list with sites records, known habitat preferences, distribution and IUCN Red List Category is given in Table 2. The Jack-knife 1 estimator calculated 17(sd: ± 3.39) species for the area, the Chao 2 estimator estimated 14 (sd: ± 0.1) species. We hence probably recorded about 82.35–100% of the local species pool.

The majority of the encountered species are closely associated with farmbush and savannas habitats (seven species; 50%). Two species (14.28%) predominantly occur in forest, but tolerate degraded habitats such as farmbush (secondary growth or degraded forest) or even savanna (Table 2). Two species (14.28%) *Leptopelis viridis* and *Phrynobatrachus francisci* particularly prefer savanna habitats. Also one specie (7.14%) *Ptychadena bibroni* only be located farmbush habitats and normally do not occur in pristine forests. And one specie (7.14%) *Hyperolius fusciventris lamtoensis* is closely associated with forest habitat. At most survey sites, the amphibian assemblages were dominated by farmbush and savannas species (Table 2).

Table 2. Anuran species recorded in the Biodiversity Conservation Area of Soubré, with habitats (see Table 1), general habitat preference and distribution range. FR= Forest relict, FL= Fallow land, SA= Swampy area, Nursery= Nu, S = savannah, FB = farmbush (degraded forest and farmland), F = forest, A = Africa (occur also outside West Africa), WA = West Africa (defined as the area west of the Cross River in Nigeria), ULG = Upper and Lower Guinea (forest zone west and east of the Dahomey Gap), * = taxon with complex of several species.

	Habitat				Distribution			Habitats preferences			
Family/Species	FR	FL	SA	Nu	A	WA	ULG	F	FB	S	IUCN
Arthroleptidae											
Arthroleptis cf. *poecilonotus** (Peters, 1863)	x	x	x	x	x			x	x	x	LC
Leptopelis viridis (Günther, 1869)			x		x					x	LC
Bufonidae											
Sclerophrys maculata (Hallowell, 1854)		x	x	x	x				x	x	LC
Dicroglossidae											
Hoplobatrachus occipitalis (Günther, 1858)		x	x		x				x	x	LC
Hyperoliidae											
Afrixalus dorsalis (Peters, 1875)			x		x				x	x	LC
Hyperolius concolor (Hallowell, 1844)	x	x	x			x			x	x	LC
Hyperolius fusciventris lamtoensis (Schiøtz, 1967)	x						x	x			LC
Hyperolius guttulatus (Günther, 1858)	x		x			x		x	x		LC
Phrynobatrachidae											
Phrynobatrachus latifrons (Ahl, 1924)		x	x	x	x				x	x	LC
Phrynobatrachus francisci (Boulenger, 1912)	x			x		x				x	LC
Ptychadenidae											
Ptychadena bibroni (Hallowell, 1845)	x	x	x	x	x				x		LC
Ptychadena longirostris (Peters, 1870)		x				x		x	x		LC
Ptychadena mascareniensis (Duméril & Bibron, 1841)	x	x	x	x	x				x	x	LC
Ptychadena pumilio (Boulenger, 1920)			x		x				x	x	LC
Total	7	8	11	6	9	4	1	4	11	10	

Four species (28.57%) do not occur outside West Africa (defined as the area west of the Cross River in Nigeria), and are often restricted to smaller parts of West Africa. One of all recorded species *Hyperolius fusciventris lamtoensis* occur only in the Upper and Lower Guinea forest zone (from west to east of the Dahomey Gap). According to the IUCN Red List, all recorded species are Least Concern.

Concerning the habitat specific species richness in hydroelectric dam BCA of Soubré, we recorded the highest species numbers in Swampy Area (11 species), followed by Fallow land (eight species) and Forest relict (seven species). Species richness was lowest at Nursery (six species). Three species (*Arthroleptis* cf. *poecilonotus, Ptychadena bibroni* and *Ptychadena mascareniensis)* were common to all four surveyed habitats. The results of the Sørensen's similarity for pairwise comparisons in the four surveyed sites are presented in Table 3. At least more than 50% of the recorded species were similar between habitats.

Table 3. Sørensen's similarity values for pairwise comparisons of the anuran community between the four surveyed habitats. FR= Forest relict, FL= Fallow land, SA= Swampy area, Nursery= Nu.

Habitat	FL	SA	Nu
FR	53,33	55,55	61,53
FL		73,68	71,42
SA			58,82

Species accounts

We hear comment on four species of particular interest.

Arthroleptis cf. poecilonotus Peters, 1863

Arthroleptis cf. *poecilonotus* (Fig. 3a) comprises a complex of species, which currently cannot be assigned with certainty to a valid name (compare Rödel and Bangoura, 2004; Blackburn, 2010; Blackburn *et al.*, 2010; Channing and Rödel, 2019). In BCA two species occur in syntopy. These two species are indistinguishable based on morphology and habitat preferences, but discernible by calls (Ernst and Rödel, 2005). Herein we treat them as one taxon.

This taxon is remarkable as we could find them in all habitats, thus being present in all terrestrial ecosystems of the BCA. These terrestrially breeding frogs with direct development (Lamotte and Perret, 1963; Barbault and Trefaut Rodrigues, 1979) were abundant in the leaf litter.

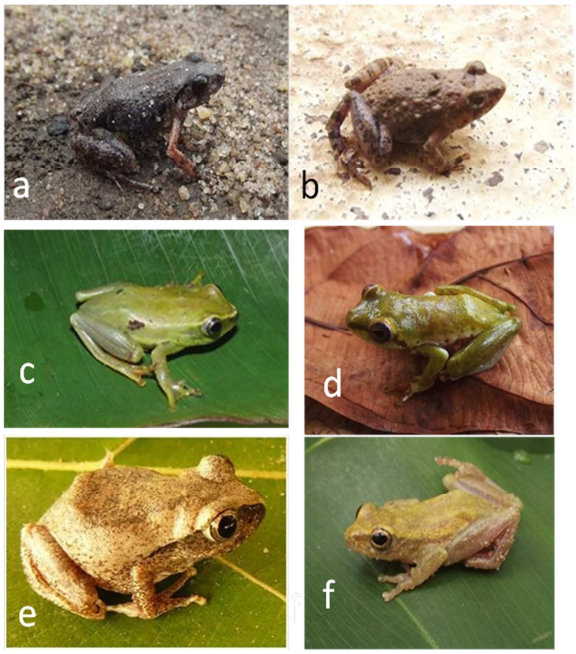

Fig. 3. Selected amphibian species from Bidiversity Conservation area of hydroelectric dam of Soubré. **(a)** *Arthroleptis* cf. *poecilonotus* female (SUL=23mm) ; **(b)** *Phrynobatrachus francisci* female (SUL=20mm) ; **(c)** *Hyperolius guttulatus* male (SUL=22mm) ; **(d)** *Hyperolius fusciventris lamtoensis* female (SUL=21mm) ; **(e)** *Leptopelis viridis* female (SUL=35mm) ; **(f)** *Hyperolius concolor* male (SUL= 22mm).

Hyperolius fusciventris lamtoensis Schiøtz, 1967

This species was common on all larger stagnant water bodies in open forest or farmbush situations. Most specimens well fitted Schiøtz's (1967) original description. This subspecies of *Hyperolius fusciventris* lives in primary forest in Taï National Park and Banco National Park, whereas the other subspecies like *Hyperolius fusciventris fusciventris* (Fig. 3d) are more associated with secondary forest and farm bush. The species breeds in small, temporary pools and marshes. We collected a female at a close canopy part of forest relict.

Leptopelis viridis (Günther, 1869)

This species mainly colonizes savanna habitats, both Guinea Sudan savanna (Perret, 1967; Rödel, 2000). Rarely, these frogs are founding in gallery forest and on river bank, too. At night, they always climb to elevated positions in the vegetation. *L. viridis* (Fig. 3e) is one of the most characteristics species inhabiting the West African savanna and the degraded areas of the former rainforest belt. At BCA, we found this specie in the Swampy area and in areas next to Nursery. The majority of the recorded males were observed at night calling exposed on the ground between short grasses, which is in contrast to the calling sites in natural habitats. There the species calls, often from high perch sites, in bushes and trees (Rödel, 2000).

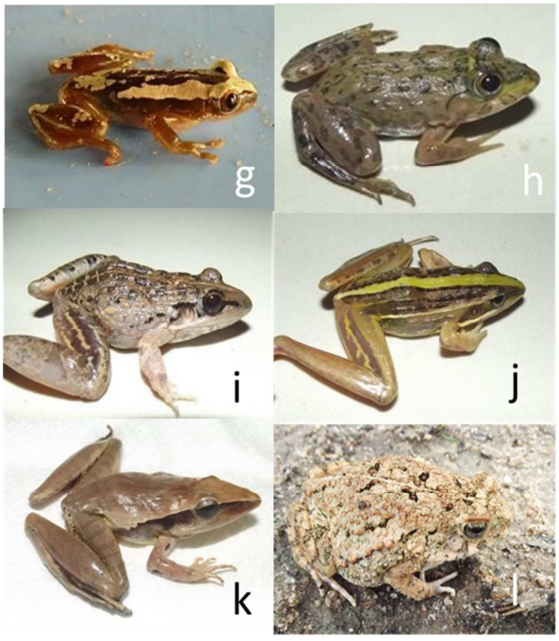

Fig. 3 (continued). Selected amphibian species from Biodiversity Conservation Area of hydroelectric dam of Soubré. **(g)** *Afrixalus dorsalis* male (SUL=21 mm) ; **(h)** *Hoplobatrachus occipitalis* female (SUL=41mm) ; **(i)** *Ptychadena bibroni* female (SUL=40mm) ; **(j)** *Ptychadena mascareniensis* male (SUL=36mm) ; **(k)** *Ptychadena longirostris* male (SUL=44mm) ; **(l)** *Sclerophrys maculata* female (SUL=34mm).

Hyperolius concolor (Hallowell, 1844)

Hyperolius concolor (Fig. 3f) is a typical West African farmbush species living in degraded forest of the forest zone and gallery forests in the savannah zone (Schiøtz, 1967; Rödel, 2000).

This specie was observed in the Forest's relic, Fallow land and Swampy area. It was particularly abundant among grasses near ponds.

Ptychadena mascareniensis (Dumeril & Bibron, 1841)
Ptychadena mascareniensis (Fig. 3j) inhabits humid savannas and forests (Rödel, 2000). According to Perret (1979), this frog prefers humid savannas and also invades degraded forest. We found *P macareniensis* in all surveyed habitats.

Discussion

The inventory of the amphibian's fauna in the Soubré Hydroelectric dam Biodiversity Conservation Area allowed to collect 14 species of anurans. The species richness of our study area is relatively low compared to those recorded in the eastern Côte d'Ivoire village forest of Yakassé-Mé (24 species) by Kouamé *et al.* (2014) and in the urban and peri-urban western area of Daloa (30 species) by Kouamé *et al.* (2015).

Indeed, the time allocated to this study was relatively short, unlike Kouamé *et al.* (2015) who sampled for three years. In addition, 56 species of amphibians have been recorded by Rödel and Ernst (2004) in Taï National Park. This park, located in the same region as the study area, represents the largest protected rainforest in West Africa.

Concerning the specific diversity of habitats, 11 species were inventoried in the Swampy area compared to eight (8 species) for the Forest relict, seven (7 species) for the Fallows land and six (6 species) for the Nursery.

This species richness observed in the swampy habitat is due to the permanent presence of water in the environment, creating favorable conditions (availability of food resources, lower rates of threats and predation) for the development of amphibians (Vallan, 2000; Assemian *et al.,* 2009). This swampy area also played an important role in providing refuge for several other species in particular during the heat of the day and the dry season.

The presence of species in swampy areas such as *Ptychadena mascareniensis, Ptychadena pumilio, Phrynobatrachus latifrons, Afrixalus dorsalis, Hyperolius concolor, Hyperolius guttulatus, Hoplobatrachus occipitalis, Leptopelis viridis and Sclerophrys maculata* could be explained by the favorable conditions offered by these habitat to the development of these taxa inflicted to degraded wetlands (Rödel and Glos 2019). Also, these species would be typical species of grassland formations and degraded open environments (Rödel, 2000). In addition, the presence of some typical forest species such as *Hyperolius fusciventris lamtoensis* in the forest relict was highlighted in this study. Our observations are similar to those of Adeba *et al.* (2010) in Lamto Reserve and Oussou *et al.* (2022) in Taï National Park who encountered this frog in forested areas.

Conclusions

Our study allowed the sampling of a total of 14 species of amphibians grouped in 8 genera and 6 families. The greatest species richness was observed in the Swampy area with 11 species.

The strong presence of savannah species and clearings in our study sites show that these environments are disturbed. The species inventoried are assigned to least concern and are well distributed in the different regions of Côte d'Ivoire and Africa.

The results obtained in this work are a contribution to the study of amphibian ecological interest. In addition, with a view to establishing this conservation area as a voluntary protected area with national status, ecological monitoring of the species and subsequent protection of the habitats in this area would be necessary. A development plan for the degraded habitats should be put in place.

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