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Endangered Goliath Frog *Conraua goliath* (Boulenger, 1906): Threats, feeding habit and changes in habitat around the Douala-Edea National Park in Cameroon

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Abstract

Conraua goliath is the largest living frog on earth only found in restricted areas in Cameroon and Equatorial Guinea; ranked by IUCN as endangered and fully protected (class A) by Cameroon's forestry law. Knowledge on the species is still poorly documented. Using the Douala Edea National park, some ecological data at a finer scale are provided; such as: morphometric measurements taken on captured frogs, physico-chemicals parameters of rivers known as goliath frog habitat, threat identified by the survey of hunting and state of habitat, and inventory of macro invertebrate composing their diet. Length and weight were 31.13 ± 4.95cm and 225 ± 114.56 g (n=22) indicating that most captured specimen were juvenile. Giant frog preferred basic waters (8.5≤ pH ≤ 9.96) with temperatures ranging from 25.9 to 28.7°C, and rocky area with waterfall favoring high concentration of dissolved oxygen (5.3 to 8.3mg/L). Major threats were hunting and deforestation. Feeding habit is composed by 23 species of invertebrates dominated by *Desmoscaris sp*. There is a need to extend the geographical range of the study, to compile a strong data base needed by decision maker to develop a sustainable conservation policy and management plan for giant frog across its range.

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Introduction

Central and West Africa have the most important amphibian biodiversity in Africa, with an estimated potential of 437 species according to the IUCN Red List (Hansen *et al.*, 2009; Penner *et al.*, 2011). Of these species, 16 are Critically Endangered, 46 are Endangered, 32 are Vulnerable, 29 Threatened, 216 are of Least Concern, and 98 species have unknown status (Stuart *et al.* 2008).

A total of 89% of threatened amphibian species in Central and West Africa are endemic to the region and 53% are present in the Cameroonian highlands, thus highlighting the importance of conserving the diversity of amphibians. Among these species is the giant frog Conraua goliath (Boulenger, 1906), it belongs to the family of Conrauidae and are classified as "Endangered" by the International Union of the Conservation of Nature (IUCN) and animals of class "A", prohibited to hunting and collection without authorization by Cameroonian fauna law. It is known to be the largest frog on the planet. Its distribution area in the world is restricted. This species is endemic to Cameroon and Equatorial Guinea, and its presence is uncertain in Gabon (Wilson, 2002; Neveu, 2004). In Cameroon, the giant frog is found below 1000 m altitude, in the south-western part of the country and its distribution remains poorly known.

Few studies carried address the taxonomy of the species (Lamotte and Perret 1968), tadpoles (Lamotte *et al.,* 1959), parasites (Nguiffo *et al.*, 2015), locomotion (Hermann and Edwards 2006), breeding in captivity (Gewalt 1977, 1996) and spawning (Schäfer *et al.,* 2019). However, very little is known on his habitat, ecology, feeding habit, and threat. This species is exposed to various forms of pressure such as poaching for consumption and the marketing of its meat which generates animal proteins and income for local communities (Gonwouo and Rödel, 2008; Nguessu C., 2014), degradation of its habitat by agriculture practiced in lowlands and deforestation of wetlands. It is also used in the practice of certain rites (Ngueguim and Taboue, Unpublished data). Amiet (2004) indicated that this species is also subject to illegal export trade to zoos or as a pet. Due to these treats including pollution, climate change and emerging infectious diseases, amphibian populations have been declining at an alarming rate in many regions of the world (Blaustein and Wake, 1995; Wake and Vredenburg, 2008).

In general, the frog has been integrated into gastronomy from the 16th century. Thus, in several countries of the world, it is raised, marketed and consumed as animal protein. In 1992, Europe imported from Asia (China, Indonesia and Bangladesh) around 10,000 tonnes of frog legs, which represents 25 million euros (Jori, 1998; Hardouin, 2000). According to the UNDP (2011), the majority of countries in sub-Saharan Africa suffer from a dietary insufficiency in animal protein. These are met by products from conventional breeding and more by animals collected from the natural environment, particularly in rural areas (Evaliste *et al.*, 2016). This is the case of giant frogs, the consumed individuals are mainly collected from the natural environment using nets or dogs; these capture methods are not selective and constitute a serious threat to the population of this species (Collins & Storfer 2003). Frogs provide a white flesh, considered a luxury meat and easily accessible in rural areas compared to conventional animal proteins. In rural areas that are difficult to access, giant frog is sold at around 1,000 FCFA /kg against 2,000 FCFA /kg of fish and 2,500 FCFA /kg of chicken (Nkouateu, 2013).

A participatory diagnosis carried out in 5 villages and with 67 fishermen from the lower Sanaga and around Lake Ossa indicates that this species has completely disappeared from the list of animals regularly caught (Ngueguim, 2018). It is in such a context and with regard to the conservation status of the giant frog, that this study was conducted on the outskirts of the Douala- Edéa National Park in order to improve knowledge on the distribution, habitat, the diet, threats and biology of the species. This information is useful and could inform decision-makers in the development of a national strategy for the conservation of giant frogs in Cameroon.

Material and methods

Site description

The Douala Edea National Park is ranked by WWF among the 200 sites of high biodiversity regarding its diversity of habitats and species which include elephants, gorilla, more than 70 species of migratory birds, 135 species of fishes, sea turtles, marine mammals as well as a large diversity of amphibians (CWCS, 2006). A great number of these species found in the park and the surrounding areas are listed among the 1600 species included in the IUCN red list of threatened species such as giant frog. More precisely, the study was conducted in six villages surrounding Douala - Edea National Park including many rivers surveyed such as Nyong, Lokoundje, Mang and Sanaga (Table 1, Fig. 1). Altitude of the studied area varies from 150 to 40 meters. The area has equatorial climate with two main seasons, the rainy season (from March to November) and the dry season (October to February). Rainfall varies from 2500 to 4000mm per year and the temperature range between 22°C to 29°C.

Table 1. Localities and rivers surveyed during the study.

Region / Division	Locality	Rivers	Geographic position
South / Ocean	Donenda	Nyong	03°23,047'N ; 010°03,296' E
	Bonguen	Nyong	03°33,337'N ; 010°06,805' E
	Dihane	Nyong	03°29,197'N ; 010°04,195' E
	Singla	Lokoundje	03°10,698'N ; 10°01,656' E
Centre / Sanaga Maritime	Sackbayeme	Sanaga	04°02,216'N ; 010°34,418'E
	Song - Mbengue	Sanaga	04°03,887'N ; 010°33,929'E

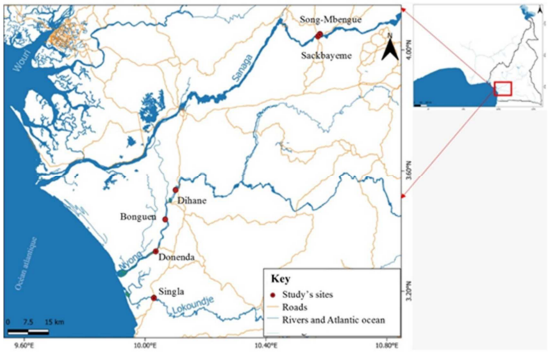

Fig. 1. Map of the study zone.

Biology and ecology of Giant frog

Taxonomy

Table 2 below presents the taxonomy of giant frog. They bilong to amphibian class, order Anura, the family of Conrauidae, genus *Conraua* and specie *Conraua goliath*.

Biology

Giant frog is the largest known frog in the world; an adult can weigh up to 3.5kg with the body length estimated at 32cm. Their eyes can be nearly 2.5cm in diameter and their life span up to 15 years in captivity and 20 years in the wild (Amiet, 2004). The metamorphosis from tadpole to adult frog can take up to 100 days. These animals are nocturnal and only come out at night to look for food (Amiet, 2004).

Some amphibians extract are use in pharmaceutical industry to cure painkillers and in the treatment of traumas like burns and heart attacks. A stable and predictable water and temperature regime can play a vital role in amphibian including: determination of phenological patterns of reproductive activity; determination of the spatial distribution of community assemblages in the provision of suitable breeding sites.

Reproduction

There is very little information on giant frog reproduction. Breeding is taking place mainly during the dry season. They haven't a vocal sac as other frog, therefore, to attract female, male usually open their mouth to make a long whistling noise. Courtship can be axillary if the male holds the female in the armpits and lumbar if he grasps it in the groin.

Females lay several hundred eggs forming large clutches in the vegetation or rock in or beside river or stream. The male waters these eggs with his sperm during the laying process. But because of predators (ants, reptiles, birds) and environmental factors just few eggs will hatched into tadpoles. Larval development takes 85-95 days to reach maturity (Boulenger, 1906). Fig. 2 shows the development phases of frogs.

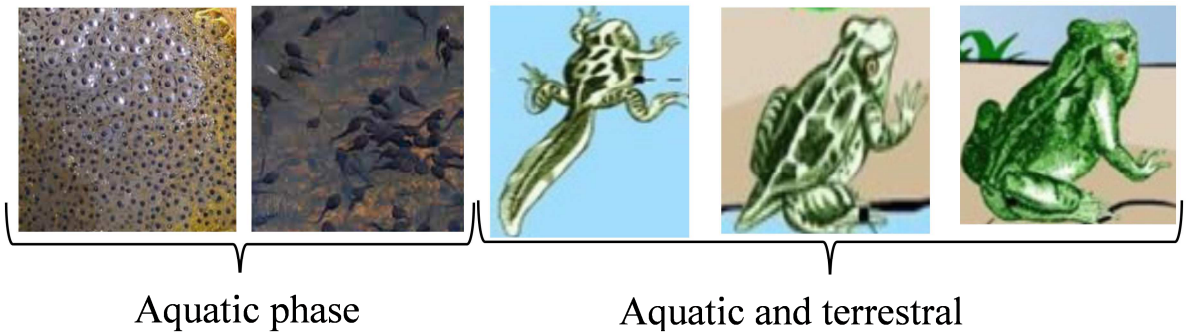

Fig. 2. Giant frog growth stages.

Geographical distribution and habitat

Giant frog is endemic of tropical rainforest of western Africa within the South Western part of Cameroon and North of Equatorial Guinea. They live in and around fast-flowing rivers and streams, rocky or sandy, near waterfalls and in humid or swamping area with high oxygen content (Sabater Pi, 1985). The characteristics of giant frog habitat and distribution in Cameroon are poorly documented.

However studies carried by various authors (Koumbo, 2015; Nguiffo *et al*., 2015; Tasse, not yet published) indicated that giant frog can be found in the rivers Mpoula, Ngounja, Mbo, Dibombe, Nkebe, Bantoum, Bipelhe, Gounja, Mbete, True-Water harbor, Nkam, Ham, Sole and Tingue in Mungo division of Cameroon. The presence of the specie is also mention in Campo ma'an national park, in some other rivers of Littoral and Centre regions. These information need to be verified.

Feeding habit

Anours have two feeding strategies. They are passive predators who stop to wait for their prey. In this approach they capture little prey, but large in size. They can also act as opportunistic predators that consume large amounts of small prey.

Adult individuals have a varied diet consisting of plant debris (dead leaves, plant roots) and macro invertebrates (crustaceans, molluscs, myriapods, insects, arachnids, snails, small frogs, small turtles, small rodents and snake) (Solé and Rödder, 2010; Nkouateu, 2014; Nguete *et al*., 2019).

At tadpole stage, *Conraua goliath* is herbivorous consuming mainly the green alga *Dicraea warmingii* which is an aquatic plant growing exclusively under the waterfall and the fast flow streams of tropical forest as well as other aquatic organisms (Boulenger, 1906). When growing, frog becomes carnivorous preferring mobile prey (Morin, 2008).

Threats

In general, amphibian populations declined at an alarming rate in many area of the world due to habitat loss and fragmentation, pollution, climate change and diseases (Blaustein and Wake, 1995; Sala *et al*., 2000; Wake and Vredenburg, 2008). Amphibian populations decreased by more than half during the last decade mainly due to deforestation and poaching and by other incompletely understood factors in areas that are perceived to be intact from human disturbance (Alford and Richards, 1999; Amiet, 2004; Carey *et al*., 2001). Information indicating that amphibians are suffering of decline even in protected areas was first highlight during the First World Herpetology Conference held in England at Canterbury in 1989. To face the problem it was establish a Declining Amphibian Populations Task Force (DAPTF) in collaboration with the Species Survival Commission of IUCN. Amongst the threats one can list:

*i) Physical habitat modification or fragmentation***.** It can significantly affect species distribution and species extinction. It is known that, the probability of local population extinction increases with the distance between populations (Scribner *et al*., 2001).

ii) Climatic change. It has effect on habitat deterioration. Amphibians are particularly sensitive to changes in their milieu, due to their double lifestyle which is aquatic at larvae stage and terrestrial when adult. They lives in humid area and can't support higher level temperature which affects their highly permeable and fragile skin, and has negative impact on embryo and larval development.

iii) Predation. The presence of predators in amphibian habitat has been listed as factor responsible for population declines, including the collapse of whole communities mostly due to the fact that amphibian species are philopatric (Fisher & Schaffer, 1996). Interaction between population species can conduct to regulate their abundance and distribution.

iv) Diseases. Amphibians can carry several hematophagous vectors in their aquatic and terrestrial habitats which infect them with a wide variety of cellular blood parasites, including rickettsiae, viruses, protozoa, microfilariae, and yeast (McKenzie and Starks, 2008). Among these haemoparasites, Filarioidea nematodes are typically found in the blood and the lymphatic system. The spread of microfilariae out of the lymphatic system causes lethargy, and certain filarial species such as *Foleyella* sp. and *Waltonella* sp. cause mortality in frogs. There are also worms affecting the digestive track and the mostly deadly disease of amphibians is the chytrid fungus (Klaphake, 2009; Nguiffo *et al*., 2019).

v) Ecological importance of amphibian. The decreasing of amphibian population can have negative effect on ecosystems and people. Amphibians are components of various ecosystems and constitute sometime the highest fraction of vertebrate biomass. They play a key role in trophic channel and are either predator or prey and indicators of global environmental health and resilience. They are exposed to aquatic and terrestrial pollution due to their sensitive and permeable skin and living habitats which are both aquatic and terrestrial. Also, amphibians interact during their lifetime with a large range of other species. They play an important ecological role in food web by regulating the population of certain animals and insects species; as well as being food for others.

Data collection

Physicochemical parameters of rivers and streams

The study took four months field trip. During the first field trip, living area of giant frog was localized along rivers and streams using a GPS. The physicochemical parameters of these milieux were monitored daily at 6 a.m. on fixed points with a Horiba multipara meter. The collected data were temperature, pH, dissolved oxygen, conductivity and turbidity.

Analysis of changes in the vegetation on giant frogs' habitats

Changes occurring in the vegetation was studied through the comparative analysis of the satellite images of the area over decade from 2009 – 2019. The different types of land use were assessed.

Frog inventory

Inventories were made through daily and nightly patrols on 400 m transect along the stream as described in Schäfer *et al.* (2019). A number of 8 patrols were done, four daily and four nightly patrols on each of the four surveyed rivers for a total number of 48 patrols. Data collected were composed by direct observation of frogs and nest and indirect index made of whistling noise.

Morphometric parameters

The sample was composed of death or alive animals captured by fishermen and hunters. All alive animals were released in their natural milieu according to the gentle agreement signed with fishermen. The parameters measured using a tape were Total Length, Standard Length, Leg Length, Arm Length, Trunk Width and weight using a scale (Fig. 3).

Feeding habit

In rivers, substrate samples were collected, then spread out on a white cloth to collect benthic macro-invertebrates using forceps. These macro-invertebrates were then treated with 10% alcohol, and

rinsed with mineral water before being stored in glass jars containing 10% formalin (Neuveu, 1978). Identification is carried out in the laboratory using a binocular magnifying glass (OPTIKA) and the identification guide for the main benthic macro-invertebrates of Quebec freshwater (Moisan, 2008).

Fig. 3. Collection of field data on giant frog.

Results

Physico-chemical characteristics of living milieu

Surveyed rivers

The surveyed rivers presented the physico-chemical characteristics as shown in table 3. Temperature ranges from 25.9 ± 1.6 C at river Mang to 28.7 ± 1.1°C (Nyong) with a significant difference between the various rivers (F = 7.895, ddf = 3, p-value = 0.04). Giant frog preferred basic waters (8.5≤ pH ≤ 9.96); low electric conductivity range from 0.03 ± 0.02 to 0.08 ± 0.06 mS/cm and high concentration of dissolved oxygen (5.3 to 8,3mg/L) favor by fast water speed estimated between 1.2 and 1.1 m/s.

Table 2. Taxonomy of giant frog.

Kingdom	Phylum	Class	Order	Family	Genus	Species
Animalia	Chordata	Amphibia	Anura	Conrauidae	Conraua	*Conraua goliath*

Table 3. Physico-chemical characteristics of surveyed rivers.

Parameters	Rivers			
	Lokoundje	Mang	Nyong	Sanaga
T (°C)	28.1 ± 1.4ab	25.9 ± 1.6b	28.7 ± 1.1a	27.9 ± 1.6ab
pH	8.8 ± 2.8a	8.5 ± 1.9a	8.96 ± 2.7a	9.2 ± 2.2a
Electric conductivity (mS/cm)	0.08 ± 0.06	0.03 ± 0.02	0.08 ± 0.06	0.06 ± 0.04
TDS (mg/L)	40.40	30.09	50.26	34.6
ORP (mV)	108.5 ± 62a	227 ± 50a	109 ± 24a	134.7 ± 33a
Turbidity (NTU)	36.1 ± 3.3a	134.8 ± 104a	27.2 ± 1.2a	117.875 ± 22.7a
Dissolved Oxygen (mg/L)	8.3 ± 2.6a	7.1 ± 0.8a	6.68 ± 0.6a	5.3 ± 0.9a
Speed (m/s)	1.3 ± 1a	1.2 ± 0.5a	1.61 ± 0.09a	1.2 ± 0.03a

In a line, the value with the same alphabetic letters are not significantly different at 0.05 (p-value >0.05)

The surveyed rivers where giant frogs were found are rocky, with cascades and small waterfalls of 20 to 120cm height increasing water velocity

and turbidity, which could be followed by calm sandy areas of more than 50 m width and less than 10cm water depth; and stagnant and muddy sections less than 1.5 m deep (Fig. 4).

- Changing in vegetation on giant frog habitat 2009 to 2019

Analysis of satellite images of the studied area from 2009 to 2019 showed a change in vegetation due to various type of land use (Fig. 5). During the past decade, forest cover decreased from 17.8 km² to 10.82 km² meaning a loss of 69.8 ha/year around the studied site. This loss of forest cover was mainly for residence and fallow land destined for the agriculture.

Giant frog can survive in secondary habitats close to rivers and not in very heavily degraded areas (Farm bush).

Fig. 4. Habitat of giant frog along the studied rivers.

Feeding habit

A total of 23 species of macro-invertebrate were identified in the studied rivers and stomach contain of frogs. They could be grouped into 3 classes dominated in decreasing order by insects (68.75%), gastropods (21.88%) and Crustacean (9.38%). Rivers Mang and Sanaga are the most diversified as indicated by the Shannon diversity index (H') and species evenness (J) curve with respectively 15 and 11 species (a). The frequent species are *Desmoscaris sp, Ampullaria sp* and *Cleopatra sp* (b) (Fig. 6).

Population estimation and morphometric parameters of giant frog

During our daily and nightly patrols, we recorded 138 direct indices of presence and 40 indirect indices which in this case were the sounds. The most frequent observation has been done along the river Sanaga with 88 observations which represent 49.4% of the total observations.

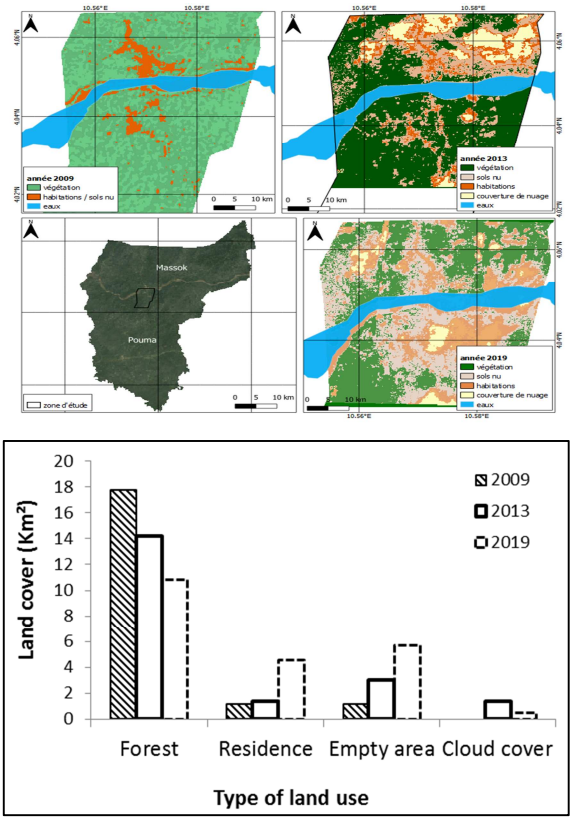

Fig. 5. Changing in vegetation during a decade (2009 - 2019) in giant frog habitat.

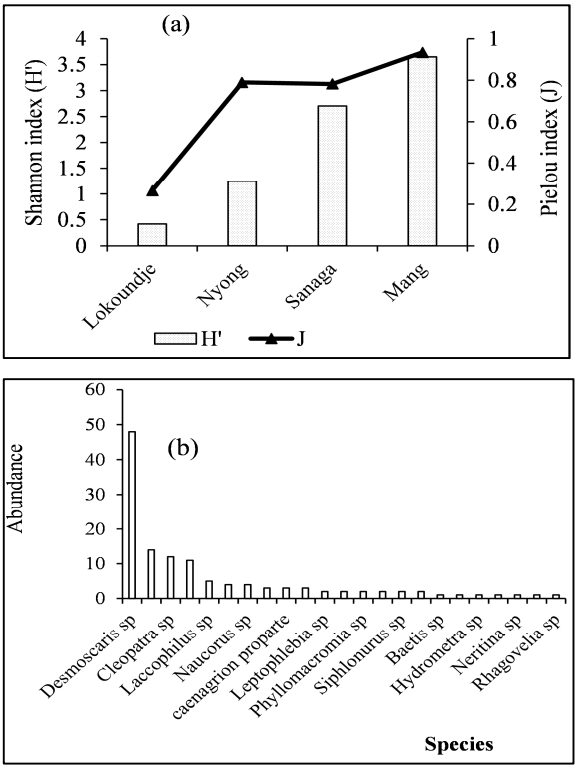

Fig. 6. Pielou index (J) (a) and frequency (b) of micro-invertebrates in rivers Mang, Sanaga, Lokoundje and Nyong.

The Chi square test shows that these rivers are not significantly different in term of observation index of giant frogs χ^2 = 1.767 with ddf = 3 and p-value = 0.622. A total number of 22 individuals were collected by 5 fishermen within the 4 months of hunting season. Table 4 shows that the sample is composed by juvenile with a high variability within their weigh estimated at 225±114.56g.

Table 4. Morphometric parameters of giant frog in rivers Mang, Sanaga, Lokoundje and Nyong.

Total length (cm)	Standard length (cm)	Legs length (cm)	Arm Length (cm)	Trunk Width (cm)	Total weight (g)
31.13±4.95	13.87±2.24	17.25±2.77	6.62±1.63	7.5±1.83	225±114.56

Fig. 7 shows the correlation between measured weight and total length of specimen. This can be represented by the allometric equation $W = 10.08TL^{0.8643}$ where W is the weight in gram and TL the total length with a coefficient of determination $R^2 = 0.77$.

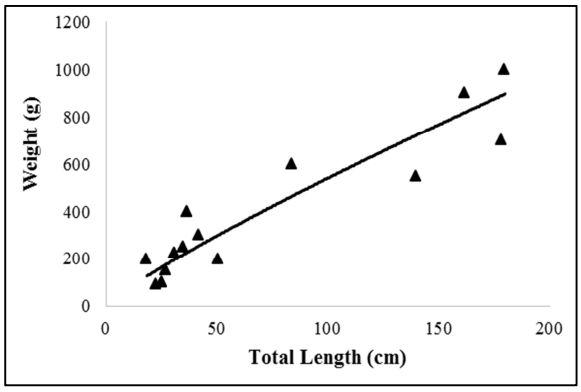

Fig. 7. Allometric equation presenting the correlation between the total length and the weight of giant frog in rivers Mang, Sanaga, Lokoundje and Nyong.

Discussion

Giant frogs were found in rivers Mang, Sanaga, Lokoundje and Nyong. Physicochemical parameters of these rivers such as temperature (25.9 to 28.7°C) and pH (8.5 - 9.2) are closer to those register by Schäfer *et al* (2019), in giant frog habitat in Mungo division (24.0 ± 1.5°C) and Koumbo (2015) in NKam division (pH = 8.0 ± 0.7). According to Morard & Zuberbühler (2006), acidic pH (pH = 4) causes limb deformation in Common frogs while pH between 7.8 and 8.3 is favorable to this specie; that of green tree frog (Pelophylax esculentus) is between 8 and 8.5; and dwarf frog (Conraua crassipes) around 6.4 (Donfack, 2015). In general, frogs live in transparent waters (Sabater-Pi, 1985). Oxygen dissolved in water (5.3-8.3mg/l) is a limiting factor in the metamorphosis process in frogs. During this phase the oxygen demand is high. A drop in oxygen level in water influences metamorphosis (Lamotte *et al*., 1959). Giant frog lives in waters rich in oxygen (Sabater-Pi, 1985); Donfack (2015) found 8mg/l oxygen in the streams frequented by this species.

The majors threat facing by this species are hunting pressure, degradation and deforestation which lead to the reduction of forest cover and expose habitat to ultrat violet UV and modification of microclimate.

The number of observation (138 direct indexes and 40 indirect indexes) after 48 patrols shows relative importance of giant frog population in the area. Despite the fact that our sample was composed by juvenile, no nest was found during our survey; while Schäfer *et al* (2019) found 22 nests after 12 patrols in Mungo making this area a probably hotspot for the goliath frog breeding.

It should be noted that our data are collected over a few months of the year and outside the breeding seasons in relatively disturbed areas which could justify the absence of nests in our sampling. The favorable moment to observe the goliath frogs is during the night in dry season when they get out from water for feeding or to lay their eggs.

The sample in this study is composed by juvenile frog with weight estimated at 225±114.56 g smaller than those expected from adult frog (3.5kg). The greatest threats to this frog include the fact that majority of the dense rainforest, habitat to the goliath frog has been degraded through logging for timber and opening the way for agriculture and human settlement. Giant frog is particularly vulnerable to habitat alteration due to its highly restricted range.

Conclusion

This study aimed at contributing to improve knowledge on the threats, diet and changes in habitat of giant frog around the Douala Edea national park. Goliath frogs were more abundant in the rivers Sanaga and Mang in the Sanaga Maritime division than Lokoundje and Nyong. Hunting for animal proteins and income, and deforestation are the main threats on the species. Morphometric parameters of captured specimen showed that the sample is composed by juvenile and there were no recorded nests. May be this can be explained by the fact that the surveyed was done out of the hunting season. Feeding habit is composed by 23 species of invertebrate amongst which *Desmoscaris* sp. is the more abundant. Giant frog prefers basic waters with high concentration of dissolved oxygen due to the presence of cascade and waterfall.

Based on these findings, it is necessary to extend the geographical scale of such effort to compile a strong data base needed by decision maker to develop a sustainable conservation policy and management plan for the giant frog in Cameroon.

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