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Habitat use in wild pygmy hippopotamus (*Choeropsis liberiensis)* in Taï National Park, Côte d'Ivoire

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ABSTRACT

The Pygmy Hippopotamus (PH) *Choeropsis liberiensis* (Morton, 1849) is a rare and cryptic mammal. Considered as an endangered species by International Union for Conservation of Nature in 2017, the main threats to PH are the fragmentation of its habitat, the forest, and hunting. Its population has greatly diminished during the last two decades from nearly 15,000 individuals to an estimated number of approximately 3,000 individuals today. Studies of this species' ecology in the wild are rare. This study focuses on habitat use and locomotion pattern in the Taï National Park (TNP) in Côte d'Ivoire, the last stronghold of the PH in the world. Camera-traps pictures and direct observations of hippo signs and individuals were used for this study in a preselected area where observation had shown that this is the habitat of the species. The study describes the features of the micro-habitat of the PH and shows how this habitat is used daily as well as the movement pattern in the wild. These results add to the ecological knowledge of this endemic species and contribute in building a knowledge-based conservation strategy.

Keywords: Pygmy hippopotamus, home range, habitat requirements, West Africa.

INTRODUCTION

The Upper Guinean Forest is considered as part of the "global biodiversity hotspots" characterized by their high level of endemic species and rapid loss of habitat (Myers et al., 2000). Among the 45 endemic mammals in this area, the Pygmy Hippopotamus (PH) *Choeropsis liberiensis* (Morton, 1849) is listed as one of the most endangered species with a natural distribution in only four countries: Liberia, Sierra Leona, Guinea, and Côte d'Ivoire (IUCN, 2007; Mallon, 2011). Its forest habitat is extremely fragmented and under increasing pressure

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from logging and farming. At the last count in 1994, fewer than 3,000 individuals remained (UICN, 2007; Ransom et al., 2015), with an estimated decline rate of 20% in the coming decades (Roth et al., 2004). The large majority of wild living individuals occur in Côte d'Ivoire, especially in Taï National Park (TNP). Thus, given these pressures, and the socio-political and military crisis that this country experienced in 2002-2011, the number of wild individuals is likely to be far lower. Such low abundance of remaining individuals in the wild represents a crucial challenge which needs adapted strategy for long-term conservation.

However, to date, little is known about the biology and behavior of the PH in the wild (Lewison & Oliver, 2008; Conway, 2013) and existing threats at local levels. Most documented threats are habitat loss, fragmentation and poaching (Mallon et al., 2011). Fortunately, this specie seems not to be really involved in human-wildlife conflict (Kouao et al., 2018). Observing the PH in the wild is a challenge because of its cryptic behaviour. Hence, innovative technologies, particularly camera trapping that was used successfully in studying other African mammals (Nguelet et al., 2016) appear as a good opportunity (Trolle et al., 2008; Vine et al., 2009; Conway, 2013; Garteh, 2014). Recent studies provided relevant information on the species in TNP, mainly on the potential role of this species in seed dispersal (Van Heukelum, 2010) and on the drivers of its distribution (Bogui, 2018). This study focusses on the description of micro-habitats and habitat use by the wild population of the PH in TNP.

MATERIALS AND METHODS

Study site

Taï National Park (5 °50 N, 7 °21 W), Côte d'Ivoire, is the largest protected block of rainforest in West Africa. Camera traps data were collected from March to December 2012. The selected study area covered about 30 km^2 within the Park and 80% of the area was crossed by four rivers: Audrénisrou, Nipla, N'sè and Méno.

Data Collection

Twelve infrared, digital cameras Bushnell Trophy Cam, Bushnell Corp., Overland Park, KS, USA were used. All cameras were set to operate 24 hours and take pictures upon detection of an animal or any other environmental variable moving such as other animal, branches etc. Time and date were automatically recorded on the pictures.

At each index location, the Universal Transverse Mercator (UTM) coordinates were recorded with a Global Positioning System (GPS). In addition, general habitat type, vegetation and soil features were also described from locations where the presence of PH was recorded.

Three combined design types were used:

- (i) during the first three months of the study, four cameras were set up systematically every 2 km along each of the four rivers (O'Brien et al., 2010) for seven days. A total of 25, 3 km was covered in the study area;

- (ii) in an area of 293.899 km², cameras were installed systematically, based on a quadrat pattern 3x3 km (Figure 1) so as to s increase the chance of observations in limited areas (Conway, 2013, Bogui, 2018); two quadrats were installed around each River for 30 days; the distance between two quadrats was 2 km based on the territory size of adult males (1.5 km^2);

- (iii) cameras were installed in a non-systematic design but on the basis of PH presence signs (footprint, feces etc.) in preferential living environments; two cameras were installed once PH signs were observed in a specific area; in total 27 areas were covered by camera traps with this design.

From these three designs, in total, 86 good quality pictures were analysed for this paper out of more than 5 000 photos in which other animal and/or environmental variables from the forest were found. In addition to camera trapping, pedestrian surveys were conducted in the study area to observe direct and indirect signs of PHs and describe the different types of habitats used by the species. Moreover, all anthropogenic threats were recorded in order to establish a relationship between habitat use and human activities.

Data analysis

GPS records allowed to map the home range of PHs in order to characterize habitat structure and use. Moreover, a Redundancy Analysis (RDA) with Canoco 4.5 software was used to establish correlation between individual presence and living pattern (McGarigal et al., 2000).

As for habitat description, biophysic indicators were determined following partially habitat description used by Adjin et al. (2011). Table 1 shows the categories distinguished by the biophysic indicators used.

To describe habitat use, a combined data from camera trapping and direct observations were conducted. An excel sheet was used to encode observed behaviors from pictures and from observed signs during pedestrian surveys (Table 2).

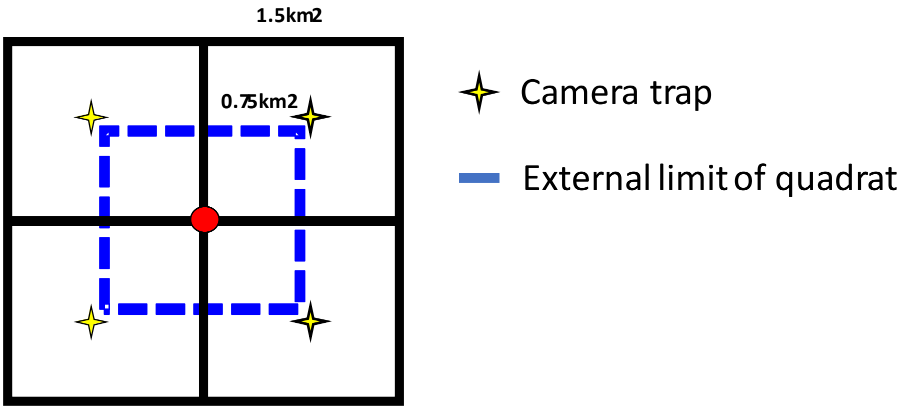

Figure 1: Quadrat pattern design for Camera trap.

Table 1: Biophysics indicators recorded.

Biophysic indicators	**Categories**
Topography	shoal
	flat
	Rough
For vertical structure	high tree
	shrub
Undergrowth	clear
	closed
Typology of canopy	open canopy
	closed canopy
Soil type	Wet (frequently wet)
	dry (the soil does not hold water on the surface even after the rain)

Table 2: Number of index obtained.

Observation	Index		Individual observed	Total
	Feces	**Footprints**		
Number	483	46	3	532

RESULTS

Micro-habitat description

In the TNP, PHs were most often found close to rivers, mainly near the shoreline. Indeed, the micro-habitat is globally marked by a shoal with a soil soaked, usually near the shoreline and where vegetation stratum is high. In general, the canopy is opened, and the undergrowth closed. In addition, the home range is shaded by the overlying vegetation composed by *Raphia sp*, *Tarrietia utilis*, etc, with a muddy or sandy soil (Table 3).

The main characteristics of habitats are the following ones:

- Shelters where PHs spend most of their time mainly during the day are composed by great roots stilts, buttresses, the big trunks of the big trees erected on the banks or fallen; the big trunks lying on the banks seem to create a shade and offer shelters that hide or dissimilate the movement of PHs; the roots form shelters with windows-like appearances from which the PHs may observe its environment easily without being noticed (Figure 2).
- Banks where PH individuals were observed, present variable slopes. It was observed that shelters (n= 7) are more often characterized by low slop banks which allow PHs to easily reach the mainland from the water for their daily activities and come back to the shelters easily; PH were observed (n = 4) walking in rivers' beds (Nipla and Audrenisrou) with a steep bank; these banks could provide a protection to PHs from potential predators and other dangers like falling trees.
- Closed undergrowths provide a cool shade for PHs and offer walkways formed by branches and creepers to allow PHs to enter or quietly exit its habitat.
- The footpaths developed either by other mammals like monkeys or human within the Park are sometime used by PHs. Several presence indicators were observed on these paths including footprints (n= 27) and feces (n= 210).

There is a link between PH distribution and some biophysics features of the microhabitat. Indeed, Redundancy Analysis (RDA), illustrated with Figure 3, explains that footprints and PH individuals encountered were mostly observed in marshy areas (presence of water and moist soil) located in shallows with open canopy and closed undergrowth. That applies mostly to Meno and N'sê river areas, in contrast to the Audrenisou and Nipla rivers. That is revealed by the analysis of axes 1 and 2 of RDA explaining 72.20% and 22.40% of the inertia, respectively for a total of 94.6% of the total inertia.

Habitat use

All direct observations of PHs made during the day (n=4), were in shoal with a high wet soil. Within the rivers beds used by PHs, some burrows environment for Pygmy Hippo were observed under some strong tree roots or trunks of dead trees (Figure 4, from 4a to 4 c)).

Most pictures of PHs were recorded at night, with 71 observations (82.5%) compared with day pictures (n=86). The daytime observation of a PH was made early in the morning between 6.30 and 8.00. am. Observed adults were solitary as e two adults have never been photographed together during the study period.

Based on collected tracks and photos from camera traps, it can be concluded that PHs move along some specific paths (n= 12). Indeed, a relative high number of PH footprints were observed along three specific trails. These trails were used both at night and daytime. Figure 5 emphasized the use of specific trails to go out and come back to the burrow. The movement pattern from the burrow were mainly observed between the early evening (after 6.00 pm) and the morning (between 5.00 and 8.00 am) (see Table 4). Only once, was an individual observed leaving the burrow at noon.

From the 483 feces recorded during the study period, droppings were mainly dispersed scattered in grasses, small plants and shrub trunk (85%) and directly on the ground (15%). Dropping produced in water are excluded from our analysis.

Most droppings were dispersed on herbaceous with 75% and young trees which are under 0.5 meter (17%) and shrub trunk (8%). An analysis of plant species used for droppings revealed no link with some specific plants that could be used by PHs.

Figure 2: Typical shelters of Pygmy Hippopotamus.

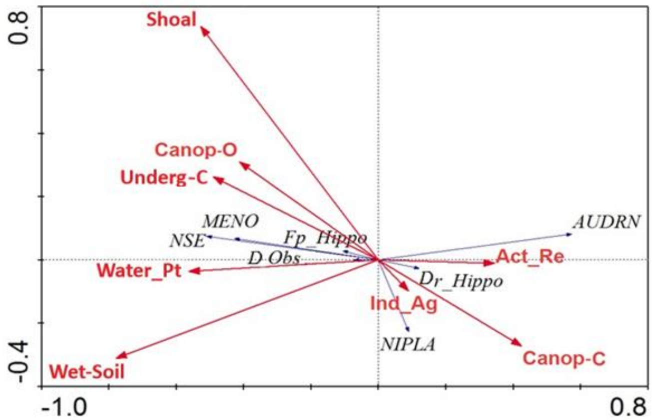

Figure 3: Link between Hippo presence and biophysics components based on redundancy analysis. Ind_Ag= Individual agression ; Act_Re=Research activities; Fp_Hippo=Footprints; Dr_Hippo=Dropping; Water_Pt=Water points; Canop-O= Open canopy; Canop-C= Closed canopy; Underg-C= Undergrowth Close; Underg-O= Undergrowth open ; Wet-soil ; dry-soil ; D Obs = direct observation ; AUDRN= audrénisrou sector ; NSE= N'sê sector; NIPLA= Nipla sector; MENO= Méno sector

Figure 4: Pygmy Hippo moving to a burrow in Taï National park (from picture a to c).

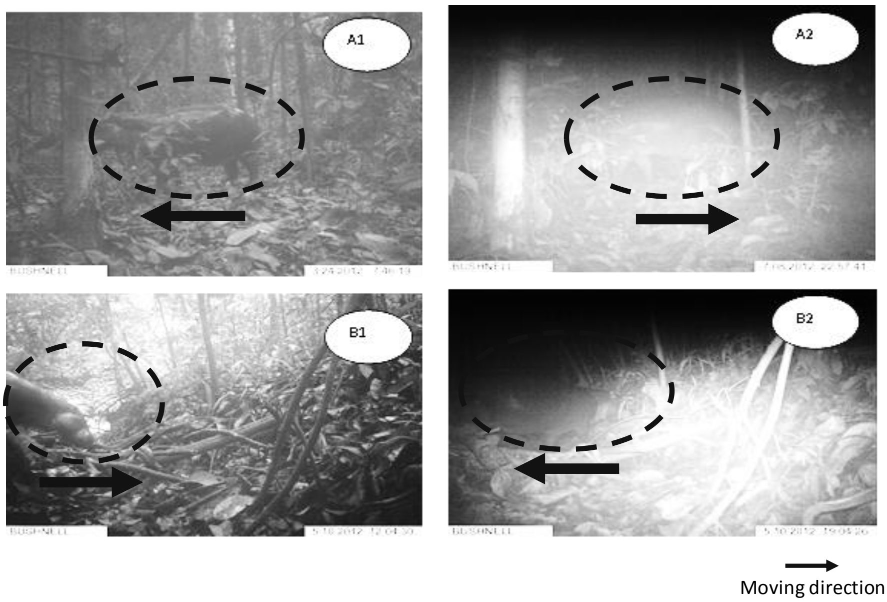

Figure 5: Itinerary A and B used by Pygmy Hippo during the day and night at different date. A1 and A2, for individual A moving in this area and B1 and B2 a second individual return moving the same day.

Table 3: Biophysical characteristic of PH habitat in the Taï National Park.

	Topography			**Vegetation structure**		**Canopy**		**Undergrowth**		**Soil humidity**		**Distance from rivers** (<100 m)	
	shoal	Flat	Rough	High	shrub	open	closed	clear	closed	wet	dry	yes	No
Number of pygmy hippo indexes	341	186	5	436	96	414	118	164	368	310	222	365	167
Direct observation of individuals	3	-	-	1	2	2	1	1	2	3	-	3	-

Table 4: Hourly distribution of animal activities.

Hours	**Month**							**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	
05h-06h			XX					**2**
06h-07h					XXX			**3**
07h-08h	XX		XX		X	X	XX	**8**
08h-09h				X				**1**
09h-10h								
10h-11h								
11h-12h								
12h-13h			X					**1**
13h-14h								
14h-15h								
15h-16h								
16h-17h								
17h-18h								
18h-19h				X		XX		**3**
19h-20h			XXXX					**4**
20h-21h		X			XX		XX	**5**
21h-22h							XX	**2**
22h-23h	X				X			**2**
Total	**3**	**1**	**9**	**2**	**7**	**3**	**6**	**31**

DISCUSSION

Our results show that the home range characteristics of PH is strongly correlated with water courses. These areas are characterized by a specific topography, vegetation structure, undergrowth and humidity which create favorable conditions to the daily activities of PH. As described by Conway (2013), PHs prefer riparian habitats and swamps. In this study, we emphasized on the identification of the specific shelter zones which are characterized by a shoal with a soil soaked, usually near the shorelines. This structure of habitat facilitates entry and exit of the animal safely. The roots of the trees that litter the shores are from large trees and serve as hiding elements for individuals. Hence the destruction of such trees and the modification of such environments would pose dire threats to PH in view of their importance for the species. The characteristics of these shelter areas are not only favorable to the physical protection of the animal but also tothe physical protection of its skin that is sensitive to solar rays (Bogui, 2018).

The closing or opening of the canopy is not a determining factor for the presence of PHs. Indeed, in open canopy areas, the vegetation increases and creates the same shade as when the canopy is closed in the absence of any significant undergrowth vegetation. In both cases, the solar rays and /or the moonlight do not influence the level of brightness of the space exploited by the PH. This is supported by Conway, 2013 who showed that moonlight may have little effect when the canopy is dense and therefore little light penetrates into the forest.

In addition, this study shows that PHs mostly used specific itineraries for terrestrial locomotion. But each solitary individual, could have more than one burrow or use different ways to go back to the shelter. The collected movement patterns show more activities early in the morning and in the early evening as mentioned by Collen et al. (2011) in Sapo forest, Liberia and Conway (2013) in Sierra Leona. Concerning the trails used by PHs, we hypothesized three possibilities: (i) an adult PH may spend up to two days in the burrow; (ii) individuals who do not return to the burrow within 24 hours, probably have more than one burrow or (iii) have another entry to the shelter. All adult PHs were photographed alone and other signs, such as footprints, did not indicate pairing.

The characterization of this micro habitat emphasized the crucial role of the stabilization of the environment around the rivers for the survival of this emblematic species. This is where IUCN experts indeed argue that the greatest threat to this species comes from the destruction of its habitat. Thus, some efforts must be conducted to tackle this major challenge, coupled to the strategy against poaching that can create good conditions to preserve wildlife in general as observed in Burkina Faso (Dibloni et al., 2011).

Analysis of the droppings' dispersal in the habitat revealed that plants are mainly used as a substrate to scatter droppings. This behavior selected to mark territories has been observed in several other territorial mammals (Barja and List., 2005; Manfredi et al., 2006). Indeed, Scent-marking including droppings is a signalling in mammals and both territorial males in resource-defense mating systems and dominant males in dominance mating systems scent-mark. A large part of evidence suggests a links between scent-marking by mammals and intrasexual competition (Gosling and

Robert, 2001). We do observe that no specific choice on plants was developed by individual for fecal scattering. Thus, PHs may deposit feces both on trees without any specific choice and on the ground.

Conclusion

The PH adapts its daily behavior to the structure of its habitat. The main elements of this habitat that play an important role are topography, under-wood, canopy and soil type. A specific combined condition of these characteristics creates the appropriate conditions not only for the safety of the PH against predators but probably, also for the accomplishment of other daily activities. In addition to the basic requirements listed above, vegetation is used as a rejection for droppings. This could ensure a sustainability of territory's marking index. We can conclude that the daily life of PH is strongly related on certain characteristics states of its habitat. Thus, a disturbance of these environmental characteristics could constitute a real threat to this emblematic species. It therefore resorts the necessity to regularly assess the dynamics of this habitat in order to prevent possible risks to the survival of this species in wild.

COMPETING INTERESTS

The authors declare that they have no competing interests

AUTHORS' CONTRIBUTIONS

KO, IK and MP designed the protocol of the project as Co-principal investigators of the Pygmy Hippopotamus project. This team recruited CGB who collected data in the field. IK and KO supervised the field work with physical presence of KO in the field to supervise data collection. Analysis was done by CGB and KO. Finally, KO wrote the article and received relevant observations from CGB, IK and MP.

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