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Medium and large mammals' diversity, relative abundance and anthropogenic pressures around natural ponds in the central zone of Comoe National Park (Côte d'Ivoire)

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Abstract

Water points in protected areas are critical hubs for wildlife, providing drinking and gathering sites. This study investigates the diversity of medium and large mammals and the impact of human activities around ponds in the central zone of Comoe National Park, Côte d'Ivoire. Using a combination of reconnaissance walks and camera traps, we surveyed seven ponds at the end of the dry season to assess mammalian diversity and human pressures. Twenty mammal species were recorded, indicating an important diversity within the study area. Small and medium ponds showed the highest diversity and evenness indices, whereas larges ponds had the lowest diversity and was dominated by African buffalo (*Syncerus caffer*). This pattern may reflect habitat preferences, forage quality, and competition dynamics. Artiodactyls were the most frequently observed group, while carnivores and threatened species like elephants and leopards were rare, suggesting anthropogenic pressures or detection limitations. Evidence of illegal human activity—such as bushfires, spent cartridges, and food remnants—was observed at multiple ponds. These findings highlight ponds as both biodiversity hotspots and human attractive zones. Strengthening monitoring around such critical habitats is essential. The combined use of camera traps and reconnaissance surveys should be expanded for long-term monitoring to improved conservation strategies.

Keywords: Anthropogenic disturbance; Mammal diversity; Protected area; Water point, Comoe

Introduction

Tropical ecosystems host remarkable mammalian biodiversity, but they are increasingly threatened by human activities, particularly agriculture, logging, gold mining, and urban expansion (Fa *et al.*, 2002; Krause & Nielsen, 2019; Taylor & Dunstone, 1996).These anthropogenic disturbances contribute to the rapid erosion of biodiversity, fueling concerns about a sixth mass extinction (Ceballos *et al.*, 2017). To counter this decline, conservation efforts are being implemented, notably through the establishment of protected areas, which play a crucial role in safeguarding threatened species (Watson *et al.*, 2014). However, even within these supposed wildlife refuges (Geldmann *et al.*, 2013), illegal human intrusions—such as hunting, fishing, or farming—undermine their effectiveness (Bruner *et al.*, 2001; Craigie *et al.*, 2010; De Alban *et al.*, 2021) .

These pressures, particularly poaching, severely affect medium- and large-sized mammals (Dufour *et al.*, 2015; Ripple *et al.*, 2016). These species are especially targeted due to their commercial value and the high local demand for bushmeat (Macdonald *et al.*, 2011; Ripple *et al.*, 2014, 2015). As a result, several protected areas, though intended as sanctuaries, have become sources of illegal bushmeat supply. This is notably the case of Comoe National Park (CNP), a UNESCO World Heritage Site located in the savanna zone of northeastern Côte d'Ivoire. CNP is the largest protected area in West Africa, harboring rich and diverse biodiversity (Scholte *et al.*, 2025). Once renowned for its abundance of large mammals, the park experienced a drastic decline in its wildlife populations between 1978 and 1998 (Fischer & Linsenmair, 2001). The situation worsened during the political unrest from 2002 to 2011. However, since the country's stabilization in 2012, the park's management has significantly improved. In 2017, CNP was removed from the list of World Heritage Sites in Danger (IUCN, 2017). Nevertheless, significant human intrusions still occur within the park, continuing to threaten mammal populations (Atta *et al.*, 2020; Gohoré *et al.*, 2025).

In protected areas, certain zones such as salt licks or water points play a key role as essential drinking and gathering sites for wildlife (Gagbe *et al.*, 2024; Ndaimani *et al.*, 2016). During the dry season, ponds become critical survival zones for animals, concentrating both their activity and the risks posed by human disturbances (Ogutu *et al.*, 2014) These areas can thus become prime targets for poachers. Several studies conducted within CNP have highlighted the strong anthropogenic pressure on the park's mammal populations without focusing on key attraction zones such as ponds.

Therefore, to better understand the importance of these zones in terms of wildlife presence and anthropogenic threats, the objective of this study is to assess the diversity and the relative

abundance of mammals around the ponds in the central zone of CNP, and to identify the signs of human pressures in these areas. A combination of foot-survey (reconnaissance walk) and camera trapping method was applied, and this research findings support the proposal of appropriate conservation measures to better protect these vulnerable species.

Methods

Study aera

The study was conducted in CNP, north-eastern part of Côte d'Ivoire between 8°30' and 9°36' N and 3°6' and 4°25' W. The park covers 1,148,756 hectares, and its Western section is crossed by the Comoe River (**Error! Reference source not found.**). The landscape is predominantly savannah, with gallery forests present along the rivers (Koné & Konan, 2022; OIPR, 2015). The park has a tropical sub-humid climate characterised by a long dry season (October to May, with temperatures reaching 37°C in March) and a shorter rainy season (June to September). Annual rainfall ranges from 900 to 1,200 mm (averaging 1,084 mm), and average temperatures range from 26 to 27°C (OIPR, 2015). Over 80% of the landscape consists of wooded and shrubby savannahs, but the park also contains gallery forests and forest patches. This creates a variety of microclimates and habitats, which are characteristic of this protected area (Kouassi *et al.*, 2014).

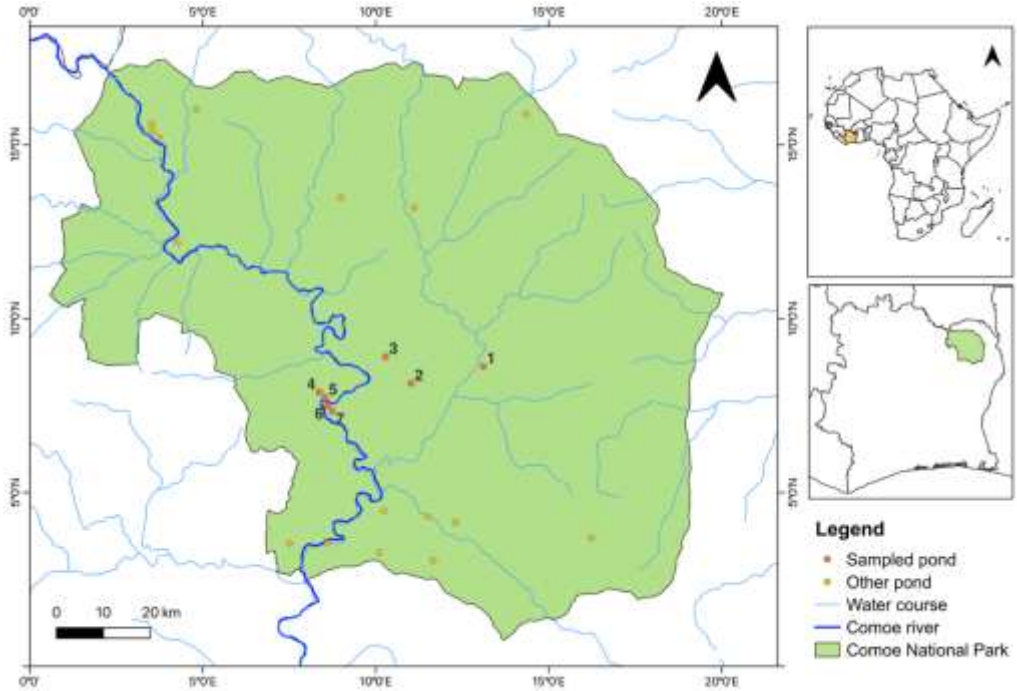

Fig. 1. Localization of Comoe National Park

Data collection

We collected the data during the dry season, from April to May 2022, using two methods reconnaissance walks (recce) and camera trapping (CT). We collected data at seven permanent ponds located in the core zone of CNP, selected for their limited accessibility to human activities and their high potential to attractmammalian wildlife. These ponds were chosen based on regular wildlife sightings reported by staff of the Ivorian Office of Parks and Reserves. Each pond was located more than 10 km apart to minimize the risk of double counting. We installed eight cameras around the seven ponds, with one camera per pond, except for Pond 2, where we placed two cameras due to its relatively larger size compared to the others. The camera installed at Pond 7 could not be recovered. On average, the seven sampled ponds each covered an area of approximately 600 m², with an average depth of around 63 cm..

During the reconnaissance walks, we followed predetermined transects, with possible deviations of up to 40° fromthe planned path, using the path of least resistance when necessary (White & Edwards, 2000). In this study, our goal was to search for animals, signs of their presence, as well as evidence of human activity, by walking 500 meters in the direction of each pond. Our survey team stopped whenever an observation was made to record the following information: the geographic coordinates of the observation, the type of sign detected (droppings, footprints, trails, vocalizations, etc.), the number of signs, the distance traveled, and the species name. Some animal signs were photographed using a digital camera. We used field guides to identify the wildlife recorded by camera traps and observed during the recce walks (Kingdon, 2015).

The camera traps were installed to capture both diurnal and nocturnal animals, with the purpose of observing rare and cryptic species (Rovero *et al.*, 2010; Trolliet *et al.*, 2014). We placed each camera trap approximately 50 cm above the ground on a supporting tree, at locations where we had observed signs of animal presence around the ponds. We selected a longer video recording duration (60 seconds) and a short interval between two successive detections (3 seconds) to ensure that all relevant information on moving wildlife within the camera's field of view was captured. Once the settings were configured, we mounted the camera trap on the trunk of a tree near the pond ensuring that the position allowed the lens to cover the main animal visitation points around the pond.

Data analysis

We calculated the Shannon diversity index (H') to quantify the diversity of mammals around the ponds in the central zone of the CNP (PNC), and Pielou's evenness index (E) to

assess the dominance level among species, using R software version 3.2.2. The Shannon diversity index, which ranges from 0 to 5, was calculated using the formula [1]:

$$H' = -\Sigma\, pi \times \log2\,(pi) \qquad [1]$$

Where pi represents the relative abundance of species i..

Pielou's evenness index, which approaches 0 when one species strongly dominates the community and equals 1 when all species are equally abundant, was calculated using the formula [2]:

$$E = H' / \log(S) \qquad [2]$$

Where H' is the Shannon index and S is species richness.

We evaluated the relative abundance (RA) of species by relating the number of individuals of a given species to the total number of individuals recorded at all sites (Dajoz, 1982), using the formula [3]:

$$RA = (ni / N) \times 100 \qquad [3]$$

Where ni is the number of individuals of species i, and N the total number of individuals recorded. The relative abundance of a taxonomic Order was obtained by summing the relative abundances of its constituent species.

We identified the species captured by camera trapping and confirmed the identification of the observed species using an illustrated Guide to the Mammals of Africa (Kingdon, 2015). The videos and images from the camera traps were collected and organized, excluding negative captures, which were those that did not show any animal species, or displayed species that were difficult to identify, or showed species other than mammals. A capture was considered positive when the captured animal species was clearly identifiable as a mammal.

Results and discussion

Diversity of medium and large-sized mammals

The survey of ponds in the central zone of CNP recorded 20 species of medium (8 species)- and large-sized mammals (12 species) by combining reconnaissance walks and camera trapping conducted from April to May 2022 (Figure 1, Table I). During the reconnaissance walks, 44 signs of mammal presence were observed around the seven sampled ponds. These signs included feces, footprints, feeding remains, and burrows. Based on these indicators, six species were clearly identified: the aardvark (*Orycteropus afer*), the African

savanna elephant (*Loxodonta africana*), the African buffalo (*Syncerus caffer*), the olive baboon (*Papio anubis*), the hartebeest (*Alcelaphus buselaphus major*), and the patas monkey (*Erythrocebus patas*). Other observed signs of animal presence could not be identified to the species level but may correspond to species such as duikers or large bovids.

Common genet, *Genetta genetta*

Patas monkey, *Erythrocebus patas*

Medium sized mammals

Panthère, *Panthera pardus*

Bubales, *Alcelaphus buselaphus*

Common warthog, *Phacochoerus africanus*

African buffalo, *Syncerus caffer*

Oribi, *Ourebia oureb*

Roan antelope, *Hippotragus equinus*

Large-sized mammals

Figure 1: Camera trap pictures of two medium sized and six large-sized mammals identified around the pounds of the CNP

Table I: Species richness and relative abundance of medium -and large-sized mammals observed from April until May 2022 by combining recce walks and camera trapping in the central zone of CNP, northeastern Côte d'Ivoire

Categorie	Order	Familly	Species		Camera trap			Recce*		UICN red list (2025)
			Common name	Scientific Name	N Cpt	N indiv	Ar (%)	N indic	Ar (%)	
Medium-sized mammals	Artiodactyla	Bovidea	Black duiker	*Cephalophus niger*	1	1	0,84	0	0	LC
	Artiodactyla	Bovidea	Red-flanked duiker	*Cephalophus rufilatus*	6	6	5,04	1	2,27	LC
	Artiodactyla	Bovidea	Maxwell's duiker	*Philantomba maxwellii*	0	0	0	1	2,27	LC
	Carnivora	Viverridae	African civet	*Civettictis civetta*	4	4	3,36	0	0	LC
	Carnivora	Viverridae	Common genet	*Genetta genetta*	2	2	1,68	0	0	LC
	Primates	Cercopithecidae	Green monkey	*Chlorocebus sabaeus*	2	2	1,68	0	0	LC
	Primates	Cercopithecidae	Patas monkey	*Erythrocebus patas*	4	6	5,04	4#	9,09	LC
	Tubulidentata	Orycteropodidae	Aardvark	*Orycteropus afer*	1	1	0,84	12#	27,27	LC
	Artiodactyles	Bovidea	Waterbuck	*Kobus ellipsiprymnus*	3	4	3,36	1	2,27	LC
	Artiodactyla	Bovidea	Roan antelope	*Hippotragus equinus*	1	1	0,84	1	2,27	LC
	Artiodactyla	Bovidea	Hartebeest	*Alcelaphus buselaphus*	7	11	9,24	10#	22,72	LC
	Artiodactyla	Bovidea	Oribi	*Ourebia oureb*	7	8	6,72	0	0	LC
	Artiodactyla	Bovidea	Bushbuck	*Tragelaphus scriptus*	3	4	3,36	0	0	LC
Large mammals	Artiodactyla	Bovidea	African buffalo	*Syncerus caffer*	8	38	31,93	7#	15,90	NT
	Artiodactyla	Bovidea	Kob	*Kobus kob*	0	0	0	1	2,27	LC
	Artiodactyla	Suidae	Common warthog	*Phacochoerus africanus*	4	9	7,56	0	0	LC
	Carnivora	Hyaenidae	Spotted hyaena	*Crocuta crocuta*	2	4	3,36	0	0	LC
	Carnivora	Felidae	Leopard	*Panthera pardus*	3	3	2,52	0	0	VU
	Primates	Cercopithecidae	Olive baboon	*Papio anubis*	7	15	12,60	4#	9,09	LC
	Proboscidea	Elephantidae	African savanna elephant	*Loxodonta africana*	0	0	0	2#	4,54	EN

LC, least concern; NT, near threatened; VU, vulnerable.
*The identification of species presence indicators during recce remains subjective; precision is achieved at the family level.
#Clearly identified species.

From the camera traps, 17 mammal species including 7 medium and 10 large-sized were identified. Most of these species are listed as Least Concern according to the IUCN, with one species, the African savanna buffalo, classified as Near Threatened, and two species considered Endangered: the African savanna elephant and the leopard (*Panthera pardus*). Out of the 2546 videos recorded around the surveyed ponds, 509 (20%) contained mammal captures. The order Artiodactyla, represented by the Bovidae family, was the most dominant, accounting for 10 species (50% of all species observed at the site). It was followed by the order Carnivora, with two species from the Viverridae family, and one species each from the Felidae and Hyaenidae families. The order Primates, represented by the Cercopithecoidea family, included three species. Lastly, the orders Proboscidea and Tubulidentata were each represented by a single species.

The surveyed pounds show varying diversity indices (**Error! Not a valid bookmark self-reference.**). Pound 5, a small pond, has the highest (H = 2.236), while Pound 2, the only large pond, has the lowest diversity (H = 0.534). Regarding evenness, Pound 1 (E = 0.973) and 5 (E = 0.932) exhibit the most balanced species distributions, whereas Pound 2 shows a strong dominance of a single species, *Syncerus caffer*, with a very low evenness index (E = 0.385). Small and medium-sized ponds such as Pond 5 and Pond 3 recorded the highest diversity and evenness indices indicating not only high species richness but also a balanced distribution of species. In contrast, the only large pond (Pond 2), with an evenness index of 0.385, exhibited the lowest diversity and was heavily dominated by the African buffalo. In fact, numbers of African buffalo have also steadily recovered in this park (Scholte *et al.*, 2025).

Table II: Mammal diversity indexes at Ponds in the central zone of CNP

Pound	Shannon diversity index (H')	Pielou's evenness index

Pound 1	2.025	0.973
Pound 2	0.534	0.385
Pound 3	2.042	0.851
Pound 4	1.377	0.856
Pound 5	2.236	0.932
Pound 6	1.839	0.884

Relative abundance of medium and large-sized mammals

The number of observed mammals'species varied from one pond to another, ranging from 4 species at pond 2 to 11 species at ponds 3 and 4 (**Error! Reference source not found.**). At the large pond (P2), only large mammal species were recorded. The distribution of mammals by body size did not differ significantly between small and medium-sized ponds; in both cases, large mammals were the most frequently observed. The strong presence of buffalo at Pond 2 may be explained by their tendency to frequent large water bodies (Rumiano *et al.,* 2021), where they can access both water and high-quality forage (Ryan *et al.*, 2006 ; Kaszta *et al.*, 2016). Their frequency at Pond 2 suggests an environment with high-quality grass; however, a detailed study, of habitat quality around CNP ponds is needed to confirm this. The large size of Pond 2 likely provides better shelter and water availability, although this may come at the expense of habitat heterogeneity, which benefits more discreet or specialized species.

The most frequently observed species through direct sightings was the African buffalo (*Syncerus caffer*), accounting for 31.93% of individuals observed, followed by the olive baboon (*Papio anubis*) with 12.60%, and the hartebeest with 9.24%. Some species, such as the aardvark although rarely seen directly, were strongly represented through indirect signs (27.27%). Carnivores'

species were scarcely represented. The mammal community around the pound surveyed is largely dominated by herbivores. Artiodactyls were the dominant group, both in direct and indirect observations and in terms of relative abundance. This dominance aligns with findings from other savanna ecosystems, where herbivores are generally more numerous and more easily detected (Charles-Dominique *et al.*, 2016; Owen-Smith, 2013). Carnivores were underrepresented, which may reflect their naturally low densities or secretive behavior. The very low frequency of threatened species such as the African elephant and the leopard, despite their known presence in the park, may indicate ongoing anthropogenic pressure, high poaching risk, or limitations in detection capacity over a short sampling period.

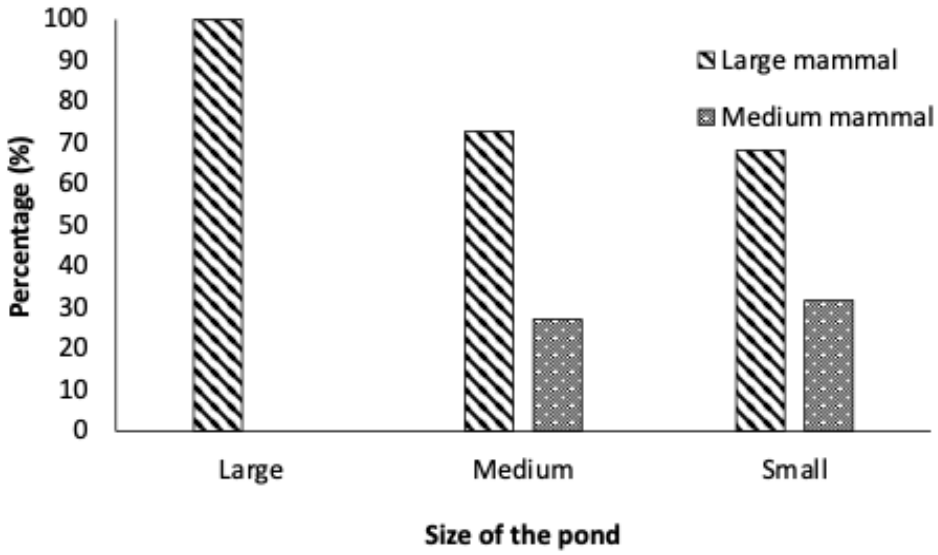

Figure 2. Species diversity of mammals according to the relative size of ponds in the central zone of CNP

Signs of human pressures

During the reconnaissance walks, various signs of human activities were documented in the vicinity of the water points. These signs included cooked food remnants, hearth traces for cooking, bushfire residues, and cartridge cases. Such evidence was observed near ponds 1, 4, and 6, as well as near pond 7, where the

camera that had been installed was not found. Indeed, clear signs of illegal human activity — bushfires, cartridge shells, and remnants of cooked food — were observed at several ponds (notably Ponds 1, 4, 6, and 7). These observations underscore the ongoing human intrusion into protected areas, even within core zones, a phenomenon well-documented in the literature (Bruner *et al.,* 2001; Craigie *et al.,* 2010; De Alban *et al.,* 2021), threatening wildlife and undermining conservation effectiveness. The disappearance of a camera at Pond 7 also suggests targeted theft or deliberate sabotage, potentially reflecting conflict or local hostility toward monitoring activities.

Conclusions

In conclusion, our results highlight the ecological importance of ponds as hotspots of mammal diversity and activity in the central zone of the Comoe National Park, particularly during the dry season. The combined use of camera traps and reconnaissance walks proved effective in detecting a wide range of species in a short time and should be expanded for broader and longer-term monitoring. A total of 20 medium- and large-sized mammal species were recorded over a relatively short period, illustrating the persistence of relatively rich biodiversity within this protected area. Small and medium ponds showed the highest diversity and evenness indices, whereas the large had the lowest diversity and was dominated by African buffalo (Syncerus caffer). Artiodactyls were the most frequently observed group, while carnivores and threatened species like elephants and leopards were rare, suggesting anthropogenic pressures. Evidence of illegal human activity—such as bushfires, spent cartridges, and food remnants—was observed at multiple ponds, with a camera trap stolen from Pond 7. Overall, these findings confirm that, although the CNP still supports a diverse mammal community, especially around water points, these critical habitats remain vulnerable to human pressures. This calls for enhanced patrolling and

monitoring of strategic zones such as ponds, as well as targeted actions to reduce poaching and other disturbances.

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