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Influence of water quality on the distribution of pygmy hippopotamus (*Choeropsis liberiensis,* Morton 1849) in Taï National Park in Côte d'Ivoire

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Abstract

The pygmy hippopotamus (*Choeropsis liberiensis*) is a rare and cryptic mammal that has been classified as endangered by the International Union for Conservation of Nature since 2011. The main threats to its survival are poaching, habitat damage caused by cash crop farming, forest fragmentation and gold mining. Of these threats, habitat destruction appears to be the most significant for this emblematic species, whose Taï National Park (TNP) is home to the world's largest wild population. Being a semi-aquatic species, the quality of the habitat of this species is certainly linked to the quality of the forest cover and the soil substrate, but above all to the water quality in which the pygmy hippopotamus spends more than half a day of its life. The aim of this study is therefore to show the quality of the water frequented by hippopotamuses and the influence of water quality on their distribution (HP) in the TNP. To achieve these objectives, a qualitative analysis of the main watercourses in the TNP was carried out, using automatically triggered cameras deployed along the banks of these watercourses. Physical and chemical parameters were measured at each site between March 2022 and February 2023. The results of this study show a variation in the physico-chemical characteristics of the watercourses visited by the pygmy hippopotamuses and that dissolved oxygen and pH significantly influence the distribution of the pygmy hippopotamus in the TNP. This study suggests that water quality should be incorporated into the ecological monitoring tools used in the TNP.

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Introduction

Classified as endangered by the International Union for Conservation of Nature IUCN (Ransom *et al.,* 2015; Ola and Benjamin, 2019), The pygmy hippopotamus (*Choeropsis liberiensis*) faces multiple threats, notably habitat destruction due to cash crop agriculture, forest fragmentation, poaching, and illegal gold mining operations. (Conway, 2013; Bogui *et al.,* 2016; Ouattara *et al.,* 2018; Erazo-Mera *et al.,* 2024). The pygmy hippopotamus (PH) is endemic to four West African countries: Guinea, Liberia, Sierra Leone, and Côte d'Ivoire. Most wild individuals are found in Côte d'Ivoire, particularly in Taï National Park (Roth *et al.,* 2004 ; Mallon *et al.,* 2011 ; Bogui *et al.,* 2016 ; Ouattara *et al.,* 2018). The wild population appears to be significantly reduced due to socio-political instabilities that have occurred in the four West African countries that naturally harbor this species (Conway, 2013). In addition, human activities in and around the park, in particular illegal gold panning and the discharge of products (fertilisers) used in agriculture, support the hypothesis of a reduction in the population of pygmy hippopotamus in the TNP. Human activities lead to pollution of watercourses, the preferred habitat of pygmy hippopotamus in the TNP. Studies by Gooré Bi (2009) carried out in the aquatic systems of Côte d'Ivoire's coastal zone revealed three main sources of pollution. These are agricultural activities, gold panning and industrial wastewater discharges. This situation could lead to a dysfunction in the ecological balance, particularly in the distribution of aquatic and semi-aquatic species in general, including the HP (Koné *et al.,* 2003; Bogui *et al.,* 2016; N'Guessan *et al.,* 2021; Allouko *et al.,* 2022). Pygmy hippos are known to be semi-aquatic animals with a strong preference for rivers, streams and marshy areas, their distribution being closely linked to the availability of water for bathing, body temperature regulation and habitat (Roth *et al.,* 2004; Mallon *et al.,* 2011; Garteh, 2014; Bogui *et al.,* 2016). Given the importance of aquatic environments for the survival of this species, it is essential to assess the water quality of streams within TNP (Taï National Park) which shelters the pygmy hippopotamus. Recent studies on the pygmy hippopotamus have provided relevant information primarily regarding the species' potential role in seed dispersal (Van Heukelum *et al.,* 2010), the environmental factors that influence its distribution (Bogui *et al.,* 2016), use of the habitat (Ouattara *et al.,* 2018), the rate of degradation of these droppings as a key factor in assessing abundance (Digbeu, 2020) and determining its diet (Hendier *et al.,* 2021). The aim of this study is to demonstrate the influence of water quality on the distribution of pygmy hippopotamuses in Taï National Park. More specifically, the aim is to (i) determine the physicochemical parameters in the main watercourses and (ii) relate the distribution of hippopotamuses to the quality of the water in the TNP.

Materials and methods

Study area

The study was carried out in the Taï National Park (TNP), located in the south-west of Côte d'Ivoire between latitudes 5°15'and 6°7' north and longitudes 7°25'and 7°54' west (Fig. 1). This Park covers an area of 536,016 hectares (OIPR, 2014). Relative humidity varies from 85% to 99%, with an annual rainfall of 1800 mm and an average temperature of 24°C (Brou, 2009). The exceptional quality of its fauna and the high level of endemism of certain species have earned it the status of a global biodiversity hotspot (Myers *et al.,* 2000). Two main vegetation types cover the TNP: dense evergreen forest with *Eremospatha macrocarpa* and *Diospyros mannii* in the northern half and dense evergreen forest with *Diospyros spp.* and *Mapania* (Kolongo *et al.,* 2006). The TNP is drained by numerous permanent watercourses which are divided between two large catchment areas and two basins of small coastal rivers. These are the Sassandra river basin for Lake Buyo in the north-east, and the Cavally River basin in the north-south-west, covering 80% of the TNP's surface area. It is made up of the Moumo, Hana, Meno, N'sè, Nipla and Audrenisou rivers, which flow from north to south and west of the forest massif. The basins of the small coastal rivers, namely the San Pédro with its tributary in the south-east and the Néro at the southern tip of the massif (OIPR, 2014).

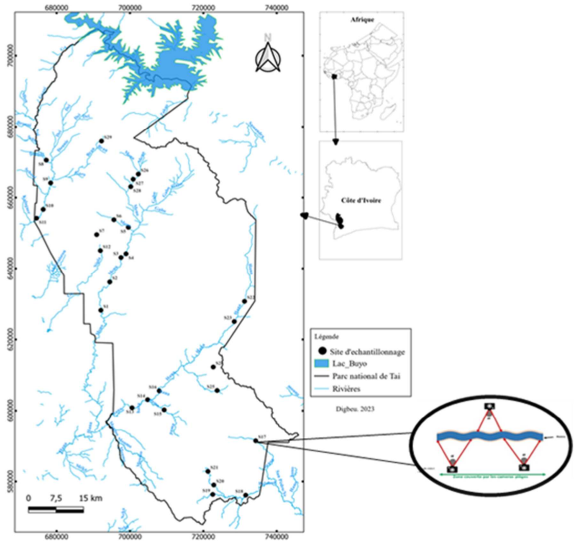

Fig. 1. Map showing the location of the TNP and presentation of the sampling system

Data collection

Data were collected during the period March 2022 to February 2023 at 29 sampling sites on the Meno (S1, S2, S3, S4, S5, S6, S26, S27 and S28), N'se (S8, S9, S10, and S11), Nipla (S7 and S12), Hana (S13, S14, S16, S22 and S23, S24, S25), Pama (S15) Palabod (S18, S19, S20 and S21) San pedro (S17) and Bran (S29). The sampling sites were chosen on the basis of recent studies of the distribution of pygmy hippopotamuses in the TNP, based on signs of presence (fresh droppings, footprints, habitats, etc.), direct observations and video captures using automatic cameras (Bogui *et al.,* 2016; Ouattara *et al.,* 2018; WCF, 2020; Houa *et al.,* 2022; Tiedoue *et al.,* 2023).

Measurement of physicochemical parameters

Five environmental variables were used to describe the physico-chemical state of the water at each sampling station. Conductivity, pH, water temperature and dissolved oxygen were determined directly at the same sampling station using a Lovibond Senso Direct 150 multiparameter, in accordance with the study by Rodier *et al.* (2016). All these variables were measured between 7 and 12 hours in the field before the automatic cameras were installed. The habitat variables included were current speed, wetted channel width, canopy cover, main substrate type and transparency. Current velocity (m/s) was measured five times in the middle of the channel by timing a floating object (polystyrene cube) over five metres in the river. It was determined as the average of the five trials. The transparency (cm) of the water was assessed using a Secchi disc. The width of the wetted channel (m) was measured to the nearest centimetre inside each station, using a decameter. Vegetation cover (%) and the type of main substrate (sand, sand-gravel mix, gravel, clay-silt) were estimated by visual observation at the sampling site (Arab *et al.,* 2004; Rios and Bailey, 2006).

Installation of automatic trigger cameras

A total of 87 cameras (3 cameras per site) of the brands Bushnell Trophy Cam HD Aggressor, Model 119877, Bushnell Trophycam HD trail camera; http://bushnell.com, were deployed at the 29 sampling sites over a period running from March 2022 to February 2023.

The sampling system was not systematic; trapping was therefore carried out at potential sites likely to be habitats for pygmy hippopotamuses, in particular along watercourses and tracks used by the animals on their way to watering holes for swimming or taking refuge (Bogui *et al.,* 2016; Ouattara *et al.,* 2018; WCF, 2020). The cameras are installed within a radius of less than 30 metres of the installation point pre-registered in a GPS (Global Positioning System) at a height of between 0.3 and 1 metre from the ground, to prevent the cameras from being totally submerged when the water rises during the rainy season (Zurkinden, 2017). The parameters defined for the cameras were video mode, high sensitivity to movement, 60 seconds (s) recording following triggering by movement, a minimum interval of 05 s between two recordings and automatic recording of the date, time and temperature when the video is recorded (Ouattara *et al.,* 2018; N'Goran *et al.,* 2020; Houa *et al.,* 2022). The cameras were aimed primarily at animal tracks to observe the animal entering or leaving the river (Ouattara *et al.,* 2018). The cameras operated day and night (24 hours). At each camera location, the UTM coordinates were recorded using a GPS. The distance between two camera sites (2 km minimum and 5 km maximum) varied according to the intensity of the signs of presence and on the basis of the size of the adult territory, which is 1.5 km² (Conway, 2013; Garteh, 2014; Mallon *et al.,* 2011) .

Data processing and statistical analysis

Physical and chemical parameters

The averages of the various quality characteristics of each watercourse were analysed. These data were then subjected to statistical tests, in particular the Kruskal-Wallis (KW) test, to assess the significance of variations in the physico-chemical parameters of the watercourses collected in the field. The correlation between the physico-chemical parameters, the watercourses and the distribution of pygmy hippopotamuses in the TNP was carried out using Principal Component Analysis (PCA) using the 'Factoextra, FactoMineR and dplyr' packages of the statistical software R version 3.6.3 (R Core Team, 2019). Focussed Principal Component Analysis (FPCA) was then used to evaluate the relationships between the presence of pygmy hippopotamuses and environmental variables using the 'psy' packages of the R statistical software. FPCA is a variant of traditional principal component analysis. It uses the same types of matrices as PCA but differs in that it is centred or focused on a variable xi. It provides a graphical representation of the correlations between this variable xi and the other variables (Falissard, 1999).

Automatic trigger cameras

The data analysis consisted of viewing the videos from the automatically triggered cameras at the 29 sampling sites. The videos viewed were recorded in databases in Excel format. One database for the information obtained during the installation of the cameras and another for the identification of the animal species. The videos were viewed on the computer using video player software (VLC media player 3.0.2 64-bit) and the animal species were identified using the African mammal recognition guide (Kingdon, 2020). The distribution map of the pygmy hippopotamus along the watercourses was produced using QGIS software version 3.22 using the *Inverse Distance Weighted* (IDW) spatial interpolation method used by (Philip and Watson, 1982).

Results

Physical and chemical parameters of TNP rivers

Table 1 shows the seasonal variations and the significant variations in the median values of the physico-chemical parameters of the river in the TNP. Minimum values of 2.5 mg/L and maximum values of 23.5 mg/L for dissolved oxygen content were observed respectively in the Palabod and Hana river during the rainy season. The median dissolved oxygen values differed significantly (Kruskal-Wallis test, $p < 0.05$) between the river. In addition, conductivity across all TNP rivers ranged from 28.86 µS/cm in Nipla to 159.9 µS/cm in the Meno River during the dry season. However, the observed values do not vary significantly (Kruskal-Wallis tests, $p > 0.05$) between the different rivers.

Median temperature values did not vary significantly (Kruskal-Wallis test, $p > 0.05$) across all rivers in the TNP. However, we recorded a minimum value of 23°C in the Meno River during the rainy season, and a maximum value of 26.3°C in the Hana River during the dry season. The minimum observed value of transparency is 10 cm in the Hana and Meno rivers in the rainy season and 125 cm in the Palabod river during the dry season. The median values of this parameter differ significantly (Kruskal-Wallis test, $p < 0.05$) from one river to anotherre. The pH of the rivers in the TNP varied between 3.65 (Hana River in the dry season) and 8.7 (Meno River in the rainy season) and the median pH values differed significantly (Kruskal-Wallis test, $p < 0.05$).

Table 1. Values of the various physicochemical variables in the rivers of the TNP as a function of the dry and wet seasons between March 2022 and February 2023

Rivers	Site	Season	Veg	Can	DO	pH	CND	T	Tr	Cl_sil	san	gra	Ww	V
Meno	S1	Dry season	10	10	10	5,5	31,2	24,6	30	80	15	5	20	0,03
	S1	Rainy season	10	7	12,5	6,8	37,6	25,3	40	70	15	15	20	0,02
	S2	Dry season	5	10	12,5	5,9	38,84	24,8	30	90	10	0	25	0,04
	S2	Rainy season	5	9	14,6	6,7	37,75	23	25	80	15	1	35	0,05
	S3	Dry season	5	10	16,6	6,4	44,46	23,5	40	15	85	0	30	0,041
	S3	Rainy season	5	10	12,5	7	54,13	24,8	19	10	90	0	50	0,04
	S4	Dry season	5	10	12	7	31,36	24,7	35	5	90	5	20	0,03
	S4	Rainy season	5	10	14,6	6,7	37,75	25,4	25	5	95	0	35	0,05
	S5	Dry season	10	10	6,8	7,2	36,04	24,4	20	10	85	5	10	0,03
	S5	Rainy season	10	10	12	7,2	46,8	23,6	13	15	80	10	10	0,2
	S6	Dry season	10	10	5,7	5,2	39,62	25,5	18	10	90	0	12	0,04
	S6	Rainy season	5	10	14,7	7,5	38,84	25	25	5	95	0	15	0,041
	S26	Dry season	5	10	9	8,1	183,3	25,1	30	5	95	0	3,7	0,1
	S26	Rainy season	5	10	14,2	8,4	72,23	25,5	50	0	95	5	6	0,04
	S27	Dry season	20	10	12	8,1	183,3	24,4	30	0	100	0	23	0,02
	S27	Rainy season	15	10	16,6	6,4	44,46	24,2	40	0	95	5	30	0,04
	S28	Dry season	20	10	9	8	114,7	24,5	25	5	85	10	5	0,01
	S28	Rainy season	10	10	17,3	8,7	72,85	24,9	10	5	95	0	7	0,06
Nipla	S7	Dry season	15	5	3,2	6,4	36,82	26,3	20	5	95	0	5	0,04
	S7	Rainy season	5	5	5,2	6,5	44,3	24,4	18	10	90	0	10	0,03
	S12	Dry season	5	10	4,4	5,2	28,86	24,3	20	5	90	5	15	0,05
	S12	Rainy season	5	10	4,7	6,7	78,47	23,8	30	5	95	0	7	0,05
N'se	S8	Dry season	10	5	14,5	4,8	66,46	25,4	50	15	85	0	23	0,1
	S8	Rainy season	5	5	17	7	59,12	24,8	45	15	95	0	25	0,04
	S9	Dry season	5	20	14,9	5,2	56,16	25,3	80	0	90	10	12	0,11
	S9	Rainy season	13	15	16	7,1	53,51	24,5	60	5	90	5	10	0,05
	S11	Dry season	5	10	10,7	6,6	46,8	25,5	46	0	90	10	15	0,03
	S11	Rainy season	5	10	17,5	7,3	52,1	24,9	30	0	100	0	20	0,04
Hana	S13	Dry season	13	5	16,5	4,4	51,64	25,3	45	90	10	0	35	0,1
	S13	Rainy season	5	5	12	6,5	42,12	24,6	28	85	10	5	50	0,06
	S14	Dry season	14	5	21	4,9	52,26	24,8	20	5	90	5	30	0,1
	S14	Rainy season	5	5	16	7,1	36,35	23	20	5	95	0	45	0,08
	S15	Dry season	15	5	8	5,3	49,45	24,8	45	0	95	5	7	0,03
	S15	Rainy season	5	5	17	6,5	67,08	23,5	50	0	90	0	8	0,02
	S16	Dry season	16	10	10	6,1	50,08	25,4	30	100	0	0	25	0,02
	S16	Rainy season	5	10	13,5	5,9	38,38	24,7	35	95	5	0	30	0,05
	S22	Dry season	5	5	21	5	52,57	24,4	10	95	5	0	10	0,02
	S22	Rainy season	10	5	23,5	6,1	49,69	23,6	10	90	5	5	13	0,07
	S23	Dry season	10	5	19,6	5,2	53,04	25,5	10	100	0	0	11	0,04
	S23	Rainy season	5	10	15,6	6,8	46,33	25	24	90	5	5	23	0,09
	S25	Dry season	5	10	18,5	3,7	55,85	25,1	31	5	90	5	25	0,06
	S25	Rainy season	5	10	23,5	6,3	68,48	25,5	70	5	95	0	10	0,03
San pedro	S17	Dry season	10	5	17,2	6,7	39,47	24,4	20	0	95	5	12	0,05
	S17	Rainy season	5	5	13,1	7,4	31,51	24,2	12	0	90	10	12	0,04
Palabod	S18	Dry season	5	10	8	7,1	54,44	24,5	60	0	95	5	13	0,1
	S18	Rainy season	5	10	17	7,6	45,71	24,9	15	5	90	5	16	0,05
	S19	Dry season	5	15	2,5	6,9	55,54	26,3	125	0	0	100	10	0,01
	S19	Rainy season	5	15	5,7	6,1	47,58	24,4	60	0	0	100	23	0,01
	S20	Dry season	5	15	2,5	6,9	55,54	24,3	125	0	5	95	12	0,01
	S20	Rainy season	8	15	5,4	7,3	63,49	23,8	40	0	0	100	14	0,02
	S21	Dry season	10	20	14,8	7,2	41,03	25,4	125	0	10	90	8	0,02
	S21	Rainy season	3	15	3,5	6,9	55,54	24,8	42	0	5	95	10	0,01
Bran	S29	Dry season	15	5	8,5	8,1	159,9	25,3	57	0	95	5	3,2	0,04
	S29	Rainy season	5	5	18,2	7	132,6	24,5	30	0	80	10	6	0,08

Ww= wetted width, gra = gravel, CND = conductivity, san = sand, Veg = plant debris, T = temperature, Can = canopy, DO = dissolved oxygen, V= velocity, Tr = transparency, pH = Hydrogen potential, Cl_sil = (Clay-silt) complex

Regarding the presence of plant debris on the rivers, the minimum value of 3% was obtained on the Palabod river during the rainy season and the maximum value of 20% on the Meno river during the dry season. The median values for the presence of plant debris on the rivers did not vary significantly (Kruskal-Wallis test, $p > 0.05$). Velocity values did not vary significantly (Kruskal-Wallis tests, $p > 0.05$), with the minimum value (0.01 m/s) observed in both Palabod and Meno rivers during both seasons, while the maximum value (0.2 m/s) was recorded only in the Meno river during the rainy season. In the TNP watercourses, the minimum wetted width (3.2 m) was recorded in the Bran river during the dry season, while the maximum value (50 m) was observed in both Hana and Meno rivers during the rainy season. The median values of this parameter varied significantly (Kruskal-Wallis test, $p < 0.05$).

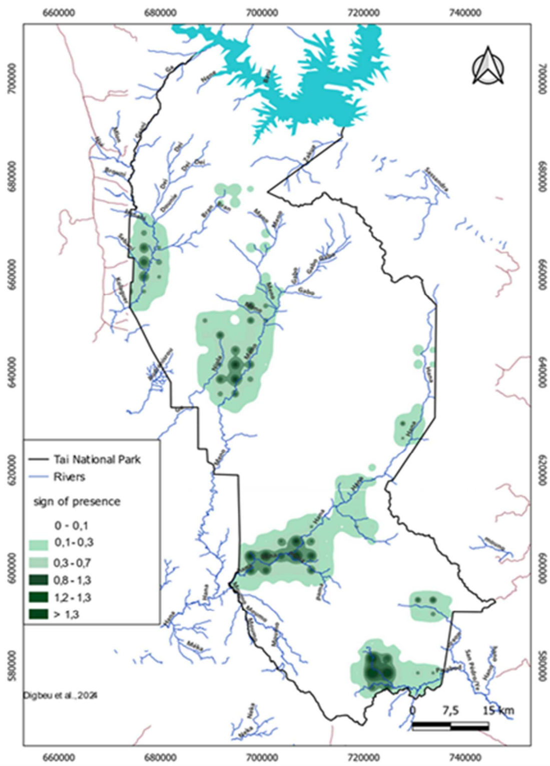

Fig. 2. Distribution map of pygmy hippopotamus along the rivers of the TNP

Distribution of the pygmy hippopotamus population along the watercourses of Taï national park

The analyses carried out as part of this study reveal that the spatial distribution of the pygmy hippopotamus population is a function of the proximity of the river within the Taï National Park (Fig. 2). There are areas of high concentration throughout the park, particularly in the central and western part downstream of the N'se, Meno, Nipla, Hana and Pama river, and in the southern part of the park downstream of the Palabod and San pedro river. However, the eastern zone, mainly upstream of the Hana and Meno rivers, has a relatively small pygmy hippopotamus population (Fig. 3).

Fig. 3. Two pygmy hippopotamuses captured by automatic cameras (A) on the banks of the Meno River; (B) on the banks of the Nipla River in the Taï National Park (TNP) between March 2022 and February 2023

Relationship between physicochemical parameters and the distribution of the pygmy hippopotamus population in the TNP

Principal Component Analysis (PCA) (Fig. 4) of the physicochemical variables and the rivers that support pygmy hippopotamuses in the TNP was carried out. The results of the PCA show that the correlation between the environmental factors and the rivers in the TNP is mainly explained by the first two axes, which account for 60% of the total variance Axis 1 (32%) represents the first principal component and explains 32% of the total variance in the data.

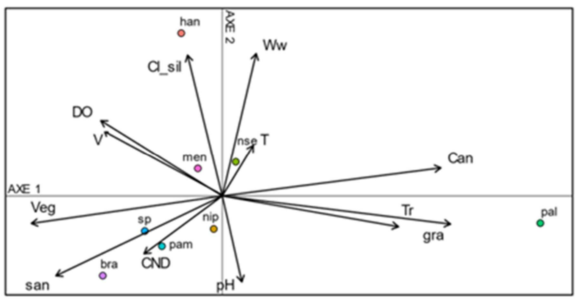

Fig. 4. Principal Component Analysis (PCA) showing the relationship between physicochemical variables and rivers in the TNP

Ww= width of wetted bed, gra = gravel, Cl_sil = (Clay-silt) complex, CND = conductivity, san = sand, Veg =

plant debris, T = temperature, Can = canopy, DO = dissolved oxygen, V= velocity, Tr = transparency, men = Meno, nip = Nipla, pam = Pama, pal = Palabod, sp = San pedro, nse = N'se, han = Hana, bra = Bran

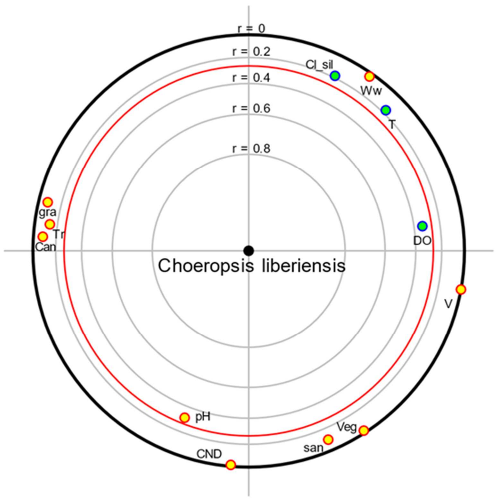

Fig. 5. Focused Principal Component Analysis (FPCA) based on the presence of the pygmy hippopotamus as the dependent variable and the environmental variables as the independent variables. Yellow dots indicate variables negatively correlated with the presence of the pygmy hippopotamus; green dots indicate variables positively correlated with the presence of the pygmy hippopotamus. The points inside the red circle represent variables significantly correlated ($p < 0.05$) with the presence of the pygmy hippopotamus

Axis 2 (28%) represents the second principal component and explains 28% of the total variance in the data. The width of the wetted bed, the rate of opening of the canopy, transparency, pH, conductivity, the proportion of plant debris, dissolved oxygen, current speed, and the substrate (sand, clay-lime complex, gravel) are the variables that strongly influence the distribution of pygmy hippopotamuses in the rivers studied. Ordering along the factorial axis I separates the rivers into 2 groups. The first group, associated with the Palabod and N'se rivers, is positively correlated with the I axis. This group is characterised by high values of water transparency, gravelly substrate and canopy opening rate. On the other hand, group 2, comprising the Meno and Hana rivers, is negatively correlated with the I axis. These rivers are characterised by low values of water transparency, gravelly substrate and canopy opening rate. The Meno, N'se and Hana rivers are characterised by a high wetted bed width. The ordination of the correlations along the factorial axis II isolates the rivers into two groups. The first group, made up of the Hana and Meno rivers, is positively correlated with axis II and is characterised by high values for current speed, dissolved oxygen levels and clay-silt substrate. The second group, made up of the San Pedro, Bran and Nipla rivers, is negatively correlated with axis II, and is characterised by high values for the proportion of plant debris, sandy substrate and pH. The Focused Principal Component Analysis (FPCA) (Fig. 5) was carried out by linking the presence of the pygmy hippopotamus and the parameters influencing the presence of the HP.

The results show that physico-chemical parameters such as water transparency, canopy openness, current speed, and proportion of plant debris, conductivity, sandy and gravelly substrate do not significantly influence and are negatively correlated with the presence of pygmy hippopotamus. However, the presence of the pygmy hippopotamus was positively correlated with temperature and the clay-loam substrate, although there was no significant variation. However, the presence of the pygmy hippopotamus population was significantly and positively influenced by dissolved oxygen and negatively and significantly correlated with pH ($p < 0.05$).

Discussion

The analyses carried out as part of this study revealed that the waters of the TNP are relatively warm. These rivers are characterised by a temperature typical of tropical forests. In fact, the vegetation on the banks of rivers in tropical forests has a relatively open canopy over the main bed, and this openness favours the penetration of solar rays, which heats them up (Kressou, 2020). Moreover, the temperatures recorded in the rivers of the TNP are within the range of those measured in the tropical rivers of West Africa and Côte d'Ivoire (Nyamsi *et al.,* 2014; Coulibaly, 2022). The high dissolved oxygen values obtained during the rainy season are thought to be due to the high current speeds measured when the water rises.

According to Barendregt and Bio (2003) strong currents help oxygenate rivers. In addition, this high value could be linked to the photosynthetic activities of aquatic plants when they receive light (Dongo *et al.,* 2013). The highest water transparency values were obtained during the dry season due to the mineralisation of suspended soil particles and plant debris from run-off water during the rainy season. This result during the dry season is confirmed by Binta *et al.,* (2019), who state that the high transparency observed during the dry season is linked to the cumulative effect of the presence of the forest. This effect limits erosion in the catchment area and reduces rainfall, allowing the rivers to stabilise. The rivers in Taï National Park tend to be more acidic (3.5) in the dry season and basic in the rainy season (8.70). The same observation was made by Kressou (2020) on the state of ecological integrity of aquatic environments in the Haut-Bandama Fauna and Flora Reserve. In fact, the basicity of the rivers recorded during the rainy season is attributable to the phenomenon of water dilution due to the considerable increase in flow rates (Bengeni *et al.,* 2005). The acidity of the rivers during periods of drought can be explained by the drop in water level during the dry season. During the study period, high conductivity values were recorded during the dry season. This high value can be explained by low renewal of the rivers when they reach their lowest point (low water), as explained by Koumba *et al.,* (2017); Kressou (2020). This reduction in river levels leads to the concentration of river components or to low water levels in certain rivers upstream.

This study has enabled us to highlight the distribution of pygmy hippopotamuses and their proximity to rivers in the TNP. Our results show that the majority of HP are concentrated near rivers. This result is in line with those of Conway (2013); Bogui *et al.,* (2016); Ouattara *et al.* (2018); Tiedoue *et al.* (2023) showing the distribution of the pygmy hippopotamus population in TNP. The presence of pygmy hippopotamuses on the banks of rivers shows that physico-chemical characteristics have a major influence on their distribution.

The results of the Principal Component Analysis (PCA) enabled the rivers to be divided into four groups. These analyses concluded that Group I, consisting essentially of the Palabod and N'se rivers, has high water transparency, a gravelly substrate and a much more open canopy. This result can be explained by the low presence of suspended solids in these rivers. Group 2, made up of the Meno, N'se and Hana rivers, however, stands out because of its large expanse of wetted bed. On the other hand, the waters of the Hana and Meno rivers, which make up group III, stand out from the others because of their very good ecological quality. They are characteristic of relatively well-oxygenated rivers. Focused Principal Component Analysis (FPCA) showed that the presence of pygmy hippopotamuses is positively and significantly correlated with dissolved oxygen. This could be explained by the fact that they live in unpolluted water. In fact, this species prefers areas free from illegal human activity, particularly illegal gold panning (Bogui *et al.,* 2016; Monket *et al.,* 2022). This finding is confirmed by the study by Diallo *et al.* (2003) on the impact of disturbance of the environment by direct pollution of the rivers, noise from gold panners and destruction of habitats.

Conclusion

This study has demonstrated the influence of physicochemical parameters on the distribution of the pygmy hippopotamus population in the Taï National Park. Parameters such as dissolved oxygen and pH are the environmental variables that most influence the distribution of the pygmy hippopotamus population. We note that the life of the hippopotamus is strongly linked to certain characteristic states of water quality. It is therefore necessary to assess this quality regularly to prevent any risks to the survival of this species in the wild.

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References

Allouko J, Kressou A, Djéné KR, Bony KY. 2022. Influence des paramètres physico-chimiques sur la distribution des mollusques aquatiques dans les étangs rizicoles et piscicoles de la ville de Daloa (Centre-ouest, Côte d'Ivoire). International Journal of Innovation and Applied Studies **35**, 513–522.

Arab A, Lek S, Lounaci A, Park YS. 2004. Spatial and temporal patterns of benthic invertebrate communities in an intermittent river (North Africa). Annales de Limnologie. International Journal of Limnology **40**(4), 317–327. https://doi.org/10.1051/limn/2004029.

Barendregt A, Bio AMF. 2003. Relevant variables to predict macrophyte communities in running waters. Ecological Modelling **160**(3), 205–217. https://doi.org/10.1016/S0304-3800(02)00254-5.

Bengeni D, Lim P, Belaud A. 2005. Qualité des eaux de trois bras morts de la Garonne variabilité spatio-temporelle. Revue des Sciences de l'Eau **5**(2), 131–156. https://doi.org/10.7202/705125ar.

Binta EPGB, Tanoh MK, Kouassi BK, Siaka B, Essetchi PK. 2019. The spatio-temporal dynamics of the fish assemblage of the man-made Lake Buyo (Côte d'Ivoire, West Africa). International Journal of Fisheries and Aquaculture **11**(3), 72–85. https://doi.org/10.5897/IJFA2018.0720.

Bogui EB, Koffi AD, Koné I, Ouattara K, Yao C, Gnagbo A. 2016. Distribution of pygmy hippopotamus (*Choeropsis liberiensis*) in Taï National Park, Ivory Coast: Influences of natural and anthropogenic factors. **5**, 27–35.

Brou Y. 2009. Impacts des modifications bioclimatiques et dès l'amenuisement des terres forestières dans les paysanneries ivoiriennes: quelles solutions pour une agriculture durable en Côte d'Ivoire. Cuadernos Geográficos **45**(2), 13–29.

Conway AL. 2013. Conservation of the pygmy hippopotamus (*Choeropsis liberiensis*) in Sierra Leone, West Africa. [Thèse de Doctorat]. Athens, University of Georgia. 209 p.

Coulibaly M. 2022. Diversité et structure fonctionnelle des macroinvertébrés de deux rivières péri-urbaines du sud-est de la Côte d'Ivoire: Anguededou et Djibi. [Thèse de Doctorat]. Abidjan, Côte d'Ivoire: Université Nangui Abrogoua. 192 p.

Diallo A, Wade F, Kourouma. 2003. Effets de l'exploitation artisanale de l'or sur les ressources forestières à Siguiri, République de Guinée. 32 p.

Digbeu H. 2020. Rythme de dégradation de crottes: Outil d'évaluation de l'abondance de l'hippopotame pygmée (*Choeropsis liberiensis*) (Morton, 1849) dans le Parc national de Taï en Côte d'Ivoire [Mémoire de Master]. Abidjan, Côte d'Ivoire: Université Félix Houphouët-Boigny. 52p.

Dongo KR, Niamke BF, Adje AF, Britton BGH, Nama LA, Anoh KP, Adima AA, Atta K. 2013. Impacts des effluents liquides industriels sur l'environnement urbain d'Abidjan - Côte d'Ivoire. International Journal of Biological and Chemical Sciences **7**(1), 404–420. https://doi.org/10.4314/ijbcs.v7i1.36.

Erazo-Mera E, Younes N, Horwood PF, Paris D, Paris M, Murray N. 2024. Forest loss during 2000–2019 in pygmy hippopotamus (*Choeropsis liberiensis*) habitats was driven by shifting agriculture. Environmental Conservation **51**(1), 55–63. https://doi.org/10.1017/S0376892923000310.

Falissard B. 1999. Focused Principal Component Analysis: looking at a correlation matrix with a particular interest in a given variable. **8**, 906–912.

Garteh JC. 2014. Studying the distribution and abundance of the endangered pygmy hippopotamus (*Choeropsis liberiensis*) in and around the Gola Rainforest National Park in southeastern Sierra Leone [Mémoire de Master]. Sierra Leone: Njala University. 66p.

Gooré Bi G. 2009. Impact des activités humaines sur les communautés de poissons dans les systèmes aquatiques de la zone côtière ivoirienne: Établissement d'un Indice d'Intégrité Biotique (IIB) [Thèse de Doctorat]. Abidjan, Côte d'Ivoire: Université Félix Houphouët-Boigny. 176p.

Hendier A, Chatelain C, Du Pasquier P, Paris M, Ouattara K, Koné I, Croll D, Zuberbühler K. 2021. A new method to determine the diet of pygmy hippopotamus in Taï National Park, Côte d'Ivoire. African Journal of Ecology **59**(4), 809–825. https://doi.org/10.1111/aje.12888.

Houa NA, Cappelle N, Bitty EA, Normand E, Kablan YA, Boesch C. 2022. Animal reactivity to camera traps and its effects on abundance estimate using distance sampling in the Taï National Park, Côte d'Ivoire. PeerJ **10**, e13510. https://doi.org/10.7717/peerj.13510.

Kingdon J. 2020. The Kingdon Pocket Guide to African Mammals. 2nd ed. London: Helm. 304p.

Kolongo TS, Decocq G, Yao CYA, Blom EC, Van Rompaey RSAR. 2006. Plant species diversity in the southern part of the Taï National Park (Côte d'Ivoire). Biodiversity and Conservation **15**(7), 2123–2142. https://doi.org/10.1007/s10531-004-6686-1.

Koné T, Teugels G, N'Douba V, Kouamélan E, Bi GG. 2003. Fish assemblages in relation to environmental gradients along a small West African coastal basin, the San Pedro River, Ivory Coast. African Journal of Aquatic Science **28**(2), 163–168. https://doi.org/10.2989/16085910309503780.

Koumba M, Mipounga HK, Koumba AA, Zinga CR, Mboye BR, Liwouwou JF, Mavoungou JF. 2017. Diversité familiale des macroinvertébrés et qualité des cours d'eau du Parc National de Moukalaba Doudou (sud-ouest du Gabon). Entomologie Faune **70**, 14p.

Kressou A. 2020. Diversité, structure des communautés de macroinvertébrés aquatiques et état d'intégrité écologique des milieux aquatiques de la Réserve de Faune et de Flore du Haut-Bandama (Centre-nord, Côte d'Ivoire) [Thèse de Doctorat]. Daloa: Université Jean Lorougnon Guédé. 150p.

Mallon CD, Wightman C, Ornellas PD, Collen B, Ransom C. 2011. Conservation strategy for the pygmy hippopotamus. Gland, Switzerland, and Cambridge, UK: IUCN Species Survival Commission. 48p.

Monket A, Kablan YA, Kouakou C, Kely R, Tiedoue MR, Diarrassouba A, Tondossama A, Bene JC. 2022. Facteurs de distribution de *Cephalophus zebra* Gray, 1838 et de *Cephalophus jentinki* Thomas, 1892 au Parc national de Taï, Sud-Ouest de Côte d'Ivoire. Journal of Animal and Plant Sciences **51**(1), 9173–9186. https://doi.org/10.35759/JAnmPlSci.v51-1.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature **403**(6772), 853–858. https://doi.org/10.1038/35002501.

N'Goran NSP, Cappelle N, Bitty EA, Normand E, Kablan YK. 2020. Détermination par caméra piège des périodes d'activité de quelques mammifères terrestres au Parc National de Taï. Orig Papers **14**(5), 1673–1688.

N'Guessan A, Berté K, Kamelan, Kouamelan. 2021. Impacts des activités anthropiques sur l'ichtyofaune de la rivière N'zè en zone tropicale forestière (Parc National de Taï, Côte d'Ivoire). Orig Papers **6**(2), 25–36.

Nyamsi T, Foto M, Zébazé Togouet, Onana F, Tchakonté, Yémélé T, Kodji E, Njiné T. 2014. Indice multimétrique des macroinvertébrés benthiques yaoundéens (IMMY) pour l'évaluation biologique de la qualité des eaux de cours d'eau de la région du Centre-Sud Forestier du Cameroun. European Journal of Scientific Research **123**(4), 412–430.

OIPR. 2014. Plan d'aménagement et de gestion du Parc national de Taï, patrimoine mondial réserve de biosphère 2014–2018. Soubré, Côte d'Ivoire: Office Ivoirien des Parcs et Réserves/Direction de Zone Sud-Ouest. 103 p.

Ola O, Benjamin E. 2019. Preserving biodiversity and ecosystem services in West African forest, watersheds, and wetlands: A review of incentives. Forests **10**(6), 479. https://doi.org/10.3390/f10060479.

Ouattara K, Gba BC, Koné I, Paris M. 2018. Habitat use in wild pygmy hippopotamus (*Choeropsis liberiensis*) in Taï National Park, Côte d'Ivoire. International Journal of Biological and Chemical Sciences **12**(6), 2578–2588. https://doi.org/10.4314/ijbcs.v12i6.9.

Philip GM, Watson DF. 1982. A precise method for determining contoured surfaces. APPEA Journal **22**(1), 205. https://doi.org/10.1071/AJ81016.

R CT. 2019. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org.

Ransom C, Robinson P, Collen B. 2015. *Choeropsis liberiensis*: The IUCN Red List of Threatened Species 2015: e.T10032A18567171 [Internet]. [Accessed 2024 Mar 20]. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T10032A18567171.en.

Rios SL, Bailey RC. 2006. Relationship between riparian vegetation and stream benthic communities at three spatial scales. Hydrobiologia **553**(1), 153–160. https://doi.org/10.1007/s10750-005-0868-z.

Rodier J, Legube B, Nicole M. 2016. L'Analyse de l'Eau. 10th ed. Paris: Dunod. 31p.

Roth HH, Hoppe-Dominik B, Mühlenberg M, Steinhauer-Burkart B, Fischer F. 2004. Distribution and status of the hippopotamids in the Ivory Coast. African Zoology **39**(2), 211–224. https://doi.org/10.1080/15627020.2004.11657218.

Tiedoue MR, Diarrassouba A, Tondossama A. 2023. Etat de conservation du Parc national de Taï : Résultats du suivi écologique, phase 15. Soubré, Côte d'Ivoire: Office Ivoirien des Parcs et Réserves/Direction de Zone Sud-Ouest. 36p.

Van Heukelum MJ, Van Hooft PWF, Paris MCJ. 2010. In search of the elusive pygmy hippo; establishment of methods to determine population structure of pygmy hippos in Taï National Park, and assessment of their role in seed dispersal. Netherlands: Wageningen University. 23p.

WCF. 2020. Mise en place d'une nouvelle méthode de suivi écologique par camera-pièges dans le Parc National de Taï (phase pilote 2019–2020): Quelques résultats préliminaires. Abidjan, Côte d'Ivoire: Wild Chimpanzee Foundation (WCF). 55p.

Zurkinden D. 2017. Etude de l'abondance relative et de la structure d'une communauté de carnivores dans un écosystème de forêt sèche sur une base de données de pièges photographiques [Memoire de Master]. Genève, Suisse: Haute Ecole Spécialisée de Suisse Occidentale. 138p.