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Seasonal distribution of duikers in the different vegetation types of Taï National Park (Côte d'Ivoire)

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Abstract

Knowledge of species occurrence in a particular habitat and determining factors limiting its expansion are important in ecology and conservation planning. This study was carried out at Taï National Park, aims to determine the spatio-temporal distribution of duikers with a particular focus on seasonal habitat occupancy by duikers. We collected yearly data about species' presence and their habitat of occurrence along 184 line transects of two kilometers each from 2005 to 2017. Each recorded duiker observation took into account habitat description. In total, seven sympatric species of duikers were observed with 1303 sightings of individuals. Significant differences are found between the monthly observation means of *Cephalophus dorsalis* ($F = 2.7462$, $p = 0.0018$) and *Philantomba maxwelli* ($F = 3.031$, $p = 0.0006$). For the other five species did find any difference, it is about *Cephalophus jentinki* ($F = 1.6269$, $p = 0.0877$), *Cephalophus niger* ($F = 2.27$, $p = 0.01$), *Cephalophus ogilbyi* (F = 0, 99, $p = 0.45$), *Cephalophus silvicultor* ($F = 1.18$, $p = 0.29$) and *Cephalophus zebra* ($F = 1.81$, $p = 0.049$). According to the canonical analysis of redundancy, it appears that *Cephalophus niger* and *Cephalophus silvicultor* were mainly observed in inselberg forests as well as in forests on hydromorphic soils. *Cephalophus jentinki*, *Cephalophus zebra* and *Cephalophus ogilbyi* do not have any particular preferences in the selection of habitats. Ecological monitoring and anti-poaching strategies must therefore integrate the ecology and activity rhythms of these duikers to improve the conservation of Taï National Park and its biodiversity.

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Introduction

Understanding of the type of habitat uses by a particular species under different temporal conditions has become a concern for ecologists (Rabeil, 2003). As a result, it is no longer a question of describing only the habitat and species distribution, but rather of studying its selection and use by a given population (Burger and Zappalorti, 1988; Dubois, 2003). Habitat is defined as the immediate biotic and abiotic environment in which an organism lives (Ramade, 2008).

It determines the availability of resources, refuges, breeding sites, partners, abundance of individuals of the same species and interspecific competitors, risks of predation, parasitism, disease and factors influencing reproduction (Morris, 1987). To better understand these features, many authors have examined the factors that influence mammals' distribution within their different habitats. For Hill and Hamer (2004) habitat modification has an impact on the diversity of tropical forest fauna. Changes of environmental conditions at a given area in space and time may also have an impact on the presence of animal species.

The work of Amahowe *et al.* (2012) on the spatio-temporal distribution of wildlife and anthropogenic pressures in the Nazinga Game Ranch in Burkina Faso indicate a fluctuation of animal populations in time and space with sometimes large variations that are mainly due to ecological factors. Steinhauer-Burkart (1987) investigated the seasonal variability of herds of 15 mammal species within the Comoé National Park in Côte d'Ivoire.

For this author, the maximum average sizes of herds in the different habitats are recorded at the beginning of the rainy seasons. With regard to duikers, Feer (1989) has shown that the occupation of space by *Cephalophus callipygus* and *Cephalophus dorsalis* in dense African forests is related to seasonal activity patterns.

It is clear from these studies that the presence of an animal species in a given ecosystem can be linked to the quality of the habitat as well as to the seasons. Despite the numerous scientific works carried out at Taï National Park (TNP), the knowledge of the spatio-temporal distribution of the known seven sympatric species of duikers remains unclearly documented.

Theseven species of duikers from TNP include *Philantomba maxwelli*, *Cephalophus dorsalis*, *Cephalophus niger*, *Cephalophus jentinki*, *Cephalophus silvicultor*, *Cephalophus ogilbyi* and *Cephalophus zebra* (Monfort and Monfort, 1973, N'Goran, 2015). The objective of this study is to determine the distribution of duikers in different vegetation type of TNP at different time periods or seasons of the year.

Material and methods

Study site

Taï National Park is located in the southwest of Côte d'Ivoire between 5°15' - 6°7' N and 7°25' - 7°54' W. It covers an area of 536,016 hectares and remains the largest protected rain forest in West Africa. The relative humidity ranges between 85% and 90% while the annual precipitation and temperature are respectively 1800 mm and 24°C (Anderson *et al.*, 2005). It is part of the UNESCO World Heritage Sites. TNP was included by UNESCO in the Network of "Man and Biosphere Reserves" in 1978 and since 1982 has been on the list of sites of the "World Natural Heritage of Humanity". TNP is characterized by exceptional species diversity and the high level of endemism that makes it one of the world's biodiversity hotspots (Myers *et al.*, 2000).

The management of this park is the responsibility of the *Office Ivoirien des Parcs et Reserves* (OIPR) through its *Direction de Zone Sud-Ouest*.

Collection of data

Data were collected during the execution of a biomonitoring program between 2005 and 2017. The survey design consisted of on a network of 184 circuit (square) transects making in total 368 kilometers (Fig. 1).

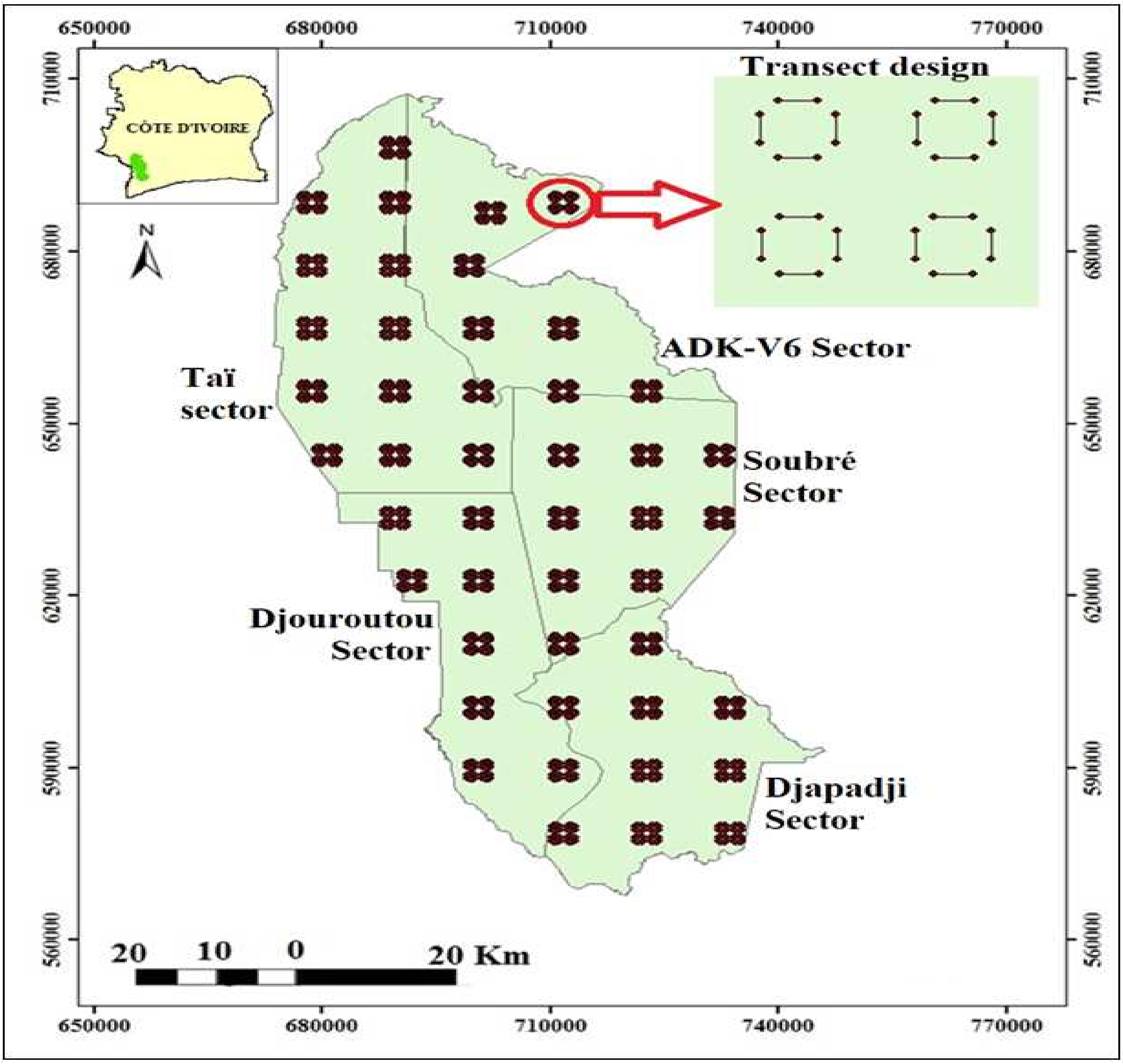

Fig. 1. Location of Taï national Park with the data collection device.

It is based on a systematic grid of locations through the survey region, with a circuit of four sections of lines located around each location Each section of a transect was a line of 500 meters in length and the four sections were considered as a transect line. Such a design has the advantage that the observer can start from any location on the circuit, e.g., where access is easiest, and finishes at the same place (Buckland *et al.*, 2001). Data collection was carried out simultaneously by five teams with each composed of six technicians investigating each circuit transect throughout TNP each. These transects have 4 sections of 500 meters each, making in total 368 kilometers of transects per year of the study period. Surveyors recorded only direct observations or sightings of duikers. Each recorded duiker observation took into account the description of the habitat in which it was encountered. These different vegetations of the park described on the basis of the works of N'Goran (2015) are presented in Table 1.

Information on the park management areas (Fig. 2) has also been recorded. These are areas dedicated to research and ecotourism and those impacted by illegal human activities, including gold mining and agriculture. The georeferenced observation points were imported into the Arcgis 10.5 software to extract the number of observations per zone.

Data analysis

Monthly averages of observation of duikers were compared. The purpose of this analysis was to verify if the monthly averages of observations recorded for each species of duiker, are significantly different. Before making these comparisons, the normality of the distributions was verified by the Shapiro-Wilk test. Afterward, an analysis of variance (ANOVA) was carried out. The one-way ANOVA applies when one wishes to take into account a single factor of variability.

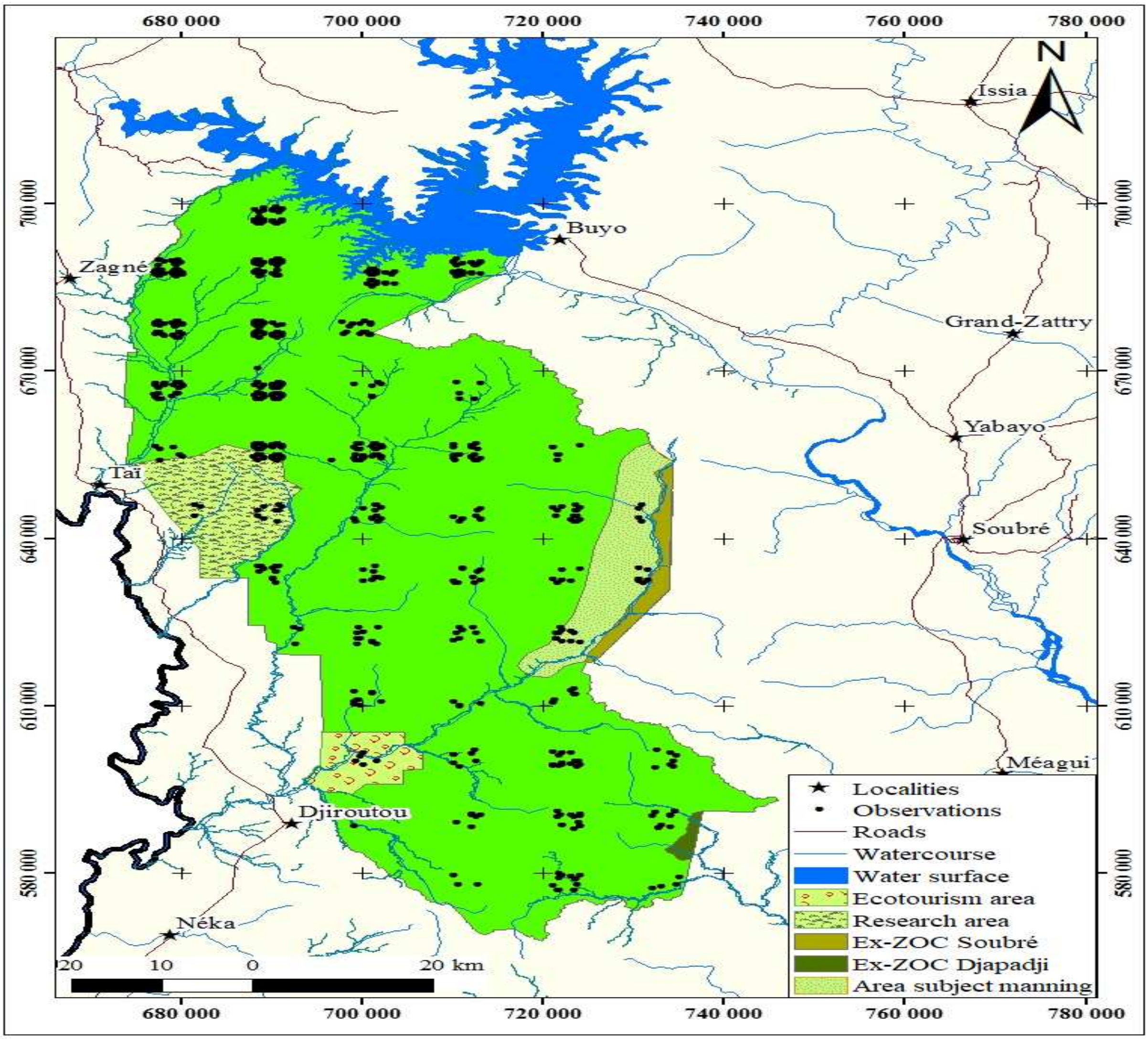

Fig. 2. Breakdown in TNP following management areas.

The different types of analysis of variance were followed by post hoc tests (multiple comparison tests) to determine which distributions were statistically different. Several tests exist; we chose Tukey's Honestly Significant Difference (HSD) test (Sokal and Rohlf, 1995). This one is considered conservative because it is the most rigorous in the differentiation of two groups. As a result of the comparison test, an ordination was made. The purpose of the ordinations is to condense the information contained within a large number of variables into a restricted set of new composite dimensions while ensuring a minimal loss of information (Bouxin, 2008). These techniques make it possible to better understand the relationships that could exist between the species of a given site and the parameters of presence, abundance or frequency (Bouxin, 2008). Among the various ordination methods that exist, Canonical Analysis in Redundancy has been retained.

It is a multivariate regression analog that links two sets of data; a set of independent variables that explain as much as possible the variance of another set of dependent variables. This is one of the most used methods for analyzing ecological data (Makarenkov and Legendre, 1999). We collected data on duikers (dependent variables), and also extracted or collected data on the physiognomy of vegetation and the variation of sunshine (independent variables). This method is therefore suitable to explain the relationships between these two sets of variables and at the same time to know the relationships between the explanatory variables. Explanation and interpretation of the results of redundancy analysis take into account the angle between the arrows representing the eigenvectors defined by each variable (Ter Braak and Verdonschot, 1995).

The sharper the angle (0° ≤ α <90°) between the vectors of two variables, the stronger the correlation between the two variables. A right angle (90°) denotes a zero relation, while an angle between 90° and 180° (90° <α ≤ 180°) has a negative correlation; this correlation will be all the stronger and significant as the angle will tend towards 180°. To perform these analyses, the CANOCO for Windows version 4.5 software (Ter Braak and Smilauer, 2002) was used.

Results

Of the total transects distributed in the TNP, 1303 direct observations concerning the 7 sympatric species of duikers were carried out (Table 2 and 3).

Monthly frequencies of encounter with each species of duiker have been compiled. The results show that *Cephalophus niger* and *Cephalophus ogilbyi* were not observed during the months of July during the entire period of data collection. As for *Cephalophus silvicultor*, no observations were made during the months of April, May and June. Then, *Cephalophus zebra* was not observed during the months of May, June, July and September. In contrast, *Cephalophus dorsalis, Cephalophus jentinki* and *Philantomba maxwelli* were observed every month.

Table 1. Types of vegetations in Tai National Park (N'Goran, 2015).

Vegetations	Description
Mixed forest with open undergrowth (MFOU) or "Primary Forest"	- High and big trees, - unbroken canopy totally closed, uninterrupted, - sparse vegetation in undergrowth composed mainly of shrubs, - visibility greater than 10 meters.
Mixed forest with closed undergrowth (MFCU)	- Presence of high and big trees, - dense undergrowth dominated by the Marantaceae or Lianas, - visibility less than 10 meters.
Hydromorphic Soils Forests (HSF)	- Lowlands (swamps), - riparian formations, - periodic flooding in places.
Inselberg or Mountain Forests (IMF)	- rocky outcrops, - altitude formations with shrubs and herbaceous plants.
Young or Thickened Secondary Forests (YTSF)	- formation dominated by young shrubs with high density, - closed undergrowth, difficult to penetrate.
Bush or non-woody vegetation (BNWV)	- undergrowth dominated by herbaceous plants with some trees and shrubs, - low density of woody plants.
Plantations or farms (EXPA)	- Presence of perennial crops (coffee, cocoa, rubber) or annual crops (yams, rice, banana, cassava).

The comparison of monthly averages of direct observations over the entire period are indicated in Fig. 3. Significant differences ($F = 2.7462$, $p = 0.0018$) are found between the monthly observation means of *Cephalophus dorsalis*. April is the month of the year during which *Cephalophus dorsalis* is more observed. Then comes the intermediate period during which the species is moderately observed. These are the months of March, May, July, September and December. Finally, it is during the months of January, February, June, August, October and November that the species is less observed.

The analysis of the periodic distribution of *Philantomba maxwelli* makes it possible to distinguish three statistically different groups (F = 3.031, p = 0.0006). The period with most observations is the month of April. Then, the months of August, September and July present averages of intermediate observations.

The months of January, February, March, May, June, October, November and December are the periods of low observations of *Philantomba maxwelli*.

Table 2. Number of observations per duiker per year.

Month	*Cephalophus dorsalis*	*Cephalophus jentinki*	*Cephalophus niger*	*Cephalophus ogilbyi*	*Cephalophus silvicultor*	*Cephalophus zebra*	*Philantomba maxwelli*	Total by month
January	45	8	9	3	5	1	69	140
February	33	3	7	2	4	6	60	115
March	46	9	7	1	4	3	65	135
April	35	8	6	1	-	5	62	117
May	23	2	3	1	-	-	21	50
June	9	3	2	1	-	-	15	30
July	14	2	-	-	1	-	17	34
August	15	1	7	1	3	2	36	65
September	34	4	19	4	4	-	56	121
October	28	11	10	7	10	5	73	144
November	30	11	19	4	7	4	88	163
December	66	5	13	6	6	2	91	189
Total by species	378	67	102	31	44	28	653	1303

Comparisons between the monthly observations of *Cephalophus jentinki* (F = 1.6269, p = 0.0877), *Cephalophus niger* (F = 2.27, p = 0.01), *Cephalophus ogilbyi* (F = 0, 99, p = 0.45), *Cephalophus silvicultor* (F = 1.18, p = 0.29) and *Cephalophus zebra* (F = 1.81, p = 0.049) showed no significant differences The observation frequencies of *Cephalophus jentinki*, *Cephalophus niger*, *Cephalophus ogilbyi*, *Cephalophus silvicultor* and *Cephalophus zebra* are therefore not related to the periods of the year.

Table 3. Direct observations of duikers in TNP human activity sectors.

Species	Ecotourism area	Research area	Illegal mining area	Ex ZOC Soubré	Ex ZOC Djapadji
Cephalophus dorsalis	2	15	-	2	-
Cephalophus niger	1	1	-	-	-
Cephalophus jentinki	3	2	-	-	1
Cephalophus silvicultor	-	1	-	-	-
Cephalophus ogilbyi	1	1	-	-	-
Cephalophus zebra	-	1	-	-	-
Philantomba maxwelli	2	12	-	3	1

Direct observations of duikers made it possible to record 1303 observation points related to the type of plant formation. In primary forests, 340 duiker observations were made. As for forests on hydromorphic soils, there are 198 observations of duikers. There is less abundance of duikers in closed mixedwood forests, bush or non-woody vegetation, and inselberg or montane forests with 96, 59 and 56 duiker encounters, respectively.

Cephalophus niger has higher observations in forests on hydromorphic soils compared to other biotopes. Concerning *Cephalophus dorsalis*, *Cephalophus jentinki*, *Cephalophus ogilbyi*, *Cephalophus silvicultor*, *Cephalophus zebra* and *Philantomba maxwelli* observations are higher in primary forests. As for *Cephalophus ogilbyi*, all observations have been made in primary forests. *Cephalophus zebra* is observed 10 times in primary forest and 6 times in forests on hydromorphic soils.

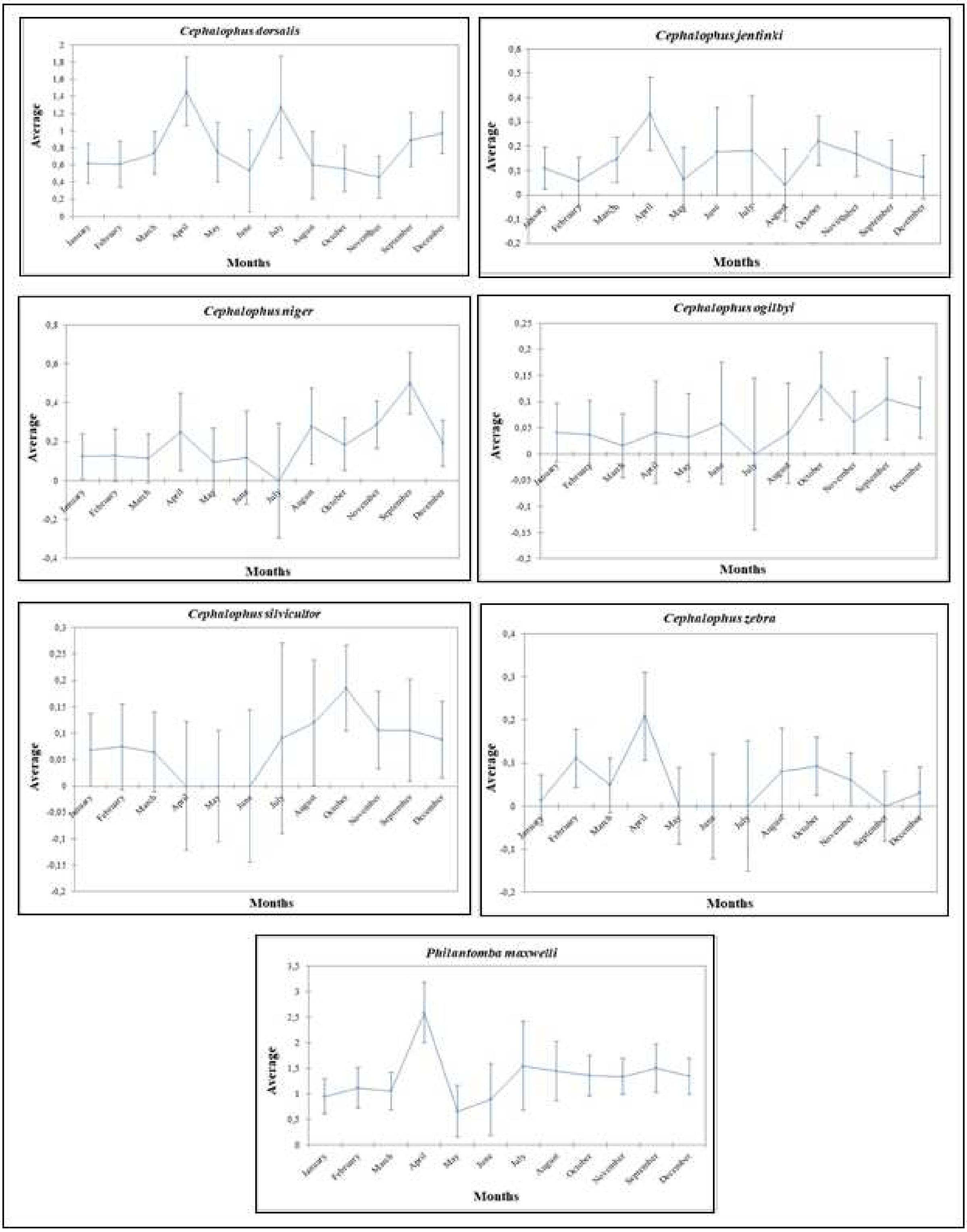

Fig. 3. Rate of duiker encounters in TNP.

The seven duiker species of TNP have all been observed in the research area. In the ecotourism zone, *Cephalophus silvicultor* and *Cephalophus zebra* have not been observed. Regarding the former controlled occupation areas of Djapadji and Soubré, the data collection missions did not indicate the presence of *Cephalophus niger*, *Cephalophus silvicultor*, *Cephalophus ogilbyi* or *Cephalophus zebra* throughout the observation period. In areas affected by illegal gold panning activities, no direct observations of duikers were made.

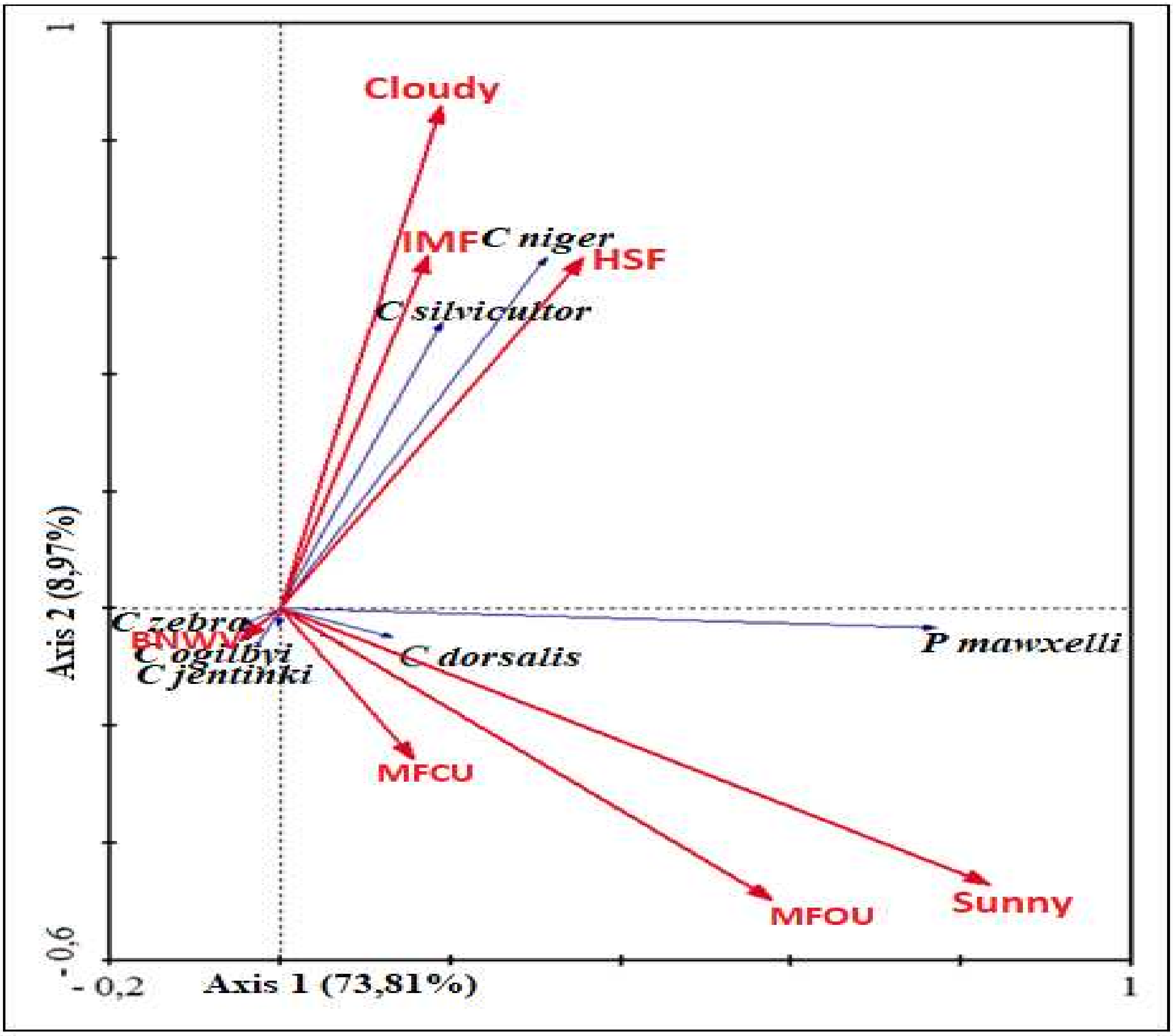

Fig. 4. Graph showing correlations between duiker encounters and forest ecosystems of TNP.

Legend :

IMF : Inselbergs or Mountain Forest HSF : Hydromorphic Soils Forests

BNWV : Bush or non-woody vegetation MFCU : Mixed forest with closed undergrowth

MFOU : Mixed forest with open undergrowth (Primary Forests).

In order to better understand the cumulative influence of vegetation type and sunshine level on duiker encounters, a canonical analysis of redundancy was performed (Fig. 4). *Philantomba maxwelli* has its own vector that almost coincides with axis 1. Its presence is not influenced by vegetation type or sunshine. It is found in all habitat types of the TNP and is presented as the most common species. *Cephalophus zebra*, *Cephalophus ogilbyi*, *Cephalophus jentinki* and *Cephalophus dorsalis* are very close to the center of the graph. However, they have no particular preference either in sunny weather or cloudy weather.

The eigenvectors of *Cephalophus niger* and *Cephalophus silvicultor* are strongly correlated with those of inselberg or montane forests, and forests with hydromorphic soils in cloudy weather. However, they tend to be less observed, in sunny weather, in mixed woodland with closed undergrowth as well as mixed forests with open undergrowth (Primary Forests).

Discussion

The observation frequencies of duikers in TNP differ according to the seasons, the type of vegetation and the areas of human activity. These results support the work of Lwanga (2006) in Uganda's Kibale National Park, which indicates that variations in duiker distribution may be related to the type of plant formation, poaching and proximity to research centers. Areas of high densities of duikers in TNP remain the areas of research and ecotourism. Indeed, the permanent presence of research staff or tourism is a protective or surveillance element of these areas (Hoppe-Dominik, 1997; Campbell *et al.*, 2011; N'Goran *et al.*, 2013).

Seasonality of observations shows significant differences in duiker encounter rates. Indeed, the probability of meeting *Cephalophus dorsalis* and *Philantomba maxwelli* is much greater during the month of April. This pace of activity could be related to the availability of food.

The work of Moupela (2013) in Gabon has shown that *Cephalophus dorsalis* plays an important role in the predation of *Coula edulis* fruits as well as in their dispersal. For this author, the months of February and March correspond to the fruiting peak of *Coula edulis*, the month of April is the period of high availability of fruit on the ground. In addition, Dubost (1984) indicates that *Cephalophus dorsalis* is the only species that consumes *Coula edulis* fruit. Despite the peak of sighting of *Philantomba maxwelli* in April in all seasons of the year its encounter rate is the highest of all the duikers of TNP. This could be explained by its fairly varied diet and its ability to adapt to environmental conditions by becoming more folivorous during the fruit shortage season (Newing, 2001).

It is therefore possible that *Cephalophus dorsalis* and *Philantomba maxwelli* have a rhythm of activity related to the availability of certain seasonal fruits constituting essential elements of their diets. Dubost and Feer (1992) observe an adjustment of the perinatal period to field conditions. According to these authors, these duikers may have regulated their reproductive cycle to the availability of food.

According to these authors, these duikers may have regulated their reproductive cycle to the availability of food. Farrowing always occurs at a time shortly before the best seasonal conditions of wealth or accessibility of food. This suggests that variations in the activity patterns of *Cephalophus dorsalis* and *Philantomba maxwelli* may be related to diets and breeding periods. The encounter rates of other TNP duikers appear to be less influenced by ecological variations during the year.

Cephalophus niger and *Cephalophus silvicultor* seem to have developed a preference for inselberg or mountain forests as well as for hydromorphic soils. For *Cephalophus silvicultor* this information corroborates the work of Kingdon (2015) which indicates that this species is found in forests on hydromorphic and mountainous soils in Gabon. This mode of habitat selection for these two duikers could be linked to both sheltering and foraging primarily consisting of fruits and green leaves, fungi, young shoots, and herbaceous.

Very few duikers were observed in sunny weather. In addition, several authors *viz.* Dubost (1980), Dubost (1984), Feer (1989), Nummelin (1990), Estes (1991), Kingdom (1997) and Hema (1998) indicate that most duikers are nocturnal. Our data were collected during daytime; this could be a source of bias in the results and explain the low observation of some nocturnal duiker species. However, these results provide useful information for managers to take steps to adapt anti-poaching strategies to protect duiker community. The use of camera traps will undoubtedly improve the knowledge of the spatio-temporal distribution of TNP mammals including duikers.

Conclusion

The seven sympatric species in TNP presents some adaptations to habitat diversity. *Cephalophus dorsalis* and *Philantomba maxwelli* have a seasonal rhythm of activity. However, the other duikers are observed indifferently according to the seasons of the year.

These particular adaptations could be related to the internal biological rhythms of duikers or to the availability of food. More specific studies need to be conducted to characterize the factors that influence the activity patterns of duikers in TNP.

Duikers are also not observed in sunny weather in open understory forests. Duikers tend to withdraw from habitats strongly impacted by human activities. However, duiker observations are more important in ecotourism and research areas in which poaching is weak. Otherwise, *Cephalophus niger* and *Cephalophus silvicultor* appear to be retiring to the most conserved forests of the park, located at its heart. It is an adaptation of these species in the face of anthropic pressure, which is mainly manifested by poaching.

A better protection policy for duikers implies a strong knowledge of their ecology as well as their activity rhythms.

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