

*Research Paper*

## **Abundance of large mammals and distribution of illegal activities in the Taï National Park, Côte d'Ivoire**

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### **Abstract**

The management of protected areas remains a major concern as it implies to use appropriated methods to establish best policies for the conservation. One of these methods concerns the ecological monitoring which allows following entities trends in an area. In Taï National Park, high human pressures are regularly reported, especially as immigration around the park and the need of animal proteins continue to increase. So, to understand how large mammal's trends (the most hunted animals in the forest) evolve over time, we used line transects methodology to collect data on large mammals as well as illegal activities to determine their relative abundances. We compared relative abundances over years, as well as between the research area (a priority site in the park) and the rest of the park. Results showed an increase of relative abundance of duikers, monkeys and pygmy hippopotamuses in the research area compared to the rest of the park. Also, we found a decrease of relative abundance of illegal activities in the research area over time while that of the rest of the park remained globally constant in the same period. Our findings provide to managers information on the general ecological situation of the park and highlight the necessity for them to undertake urgent actions to better orientate policies which can help reducing threats on animals in the park.

**Keywords:** Ecological monitoring, trend, relative abundance, Large mammals, Taï National Park

### **Introduction**

The impact of humans on the biodiversity is considerable nowadays. The need of animal proteins continue to increase while natural resources decline<sup>1</sup>. Therefore, the need to find appropriated strategies for conservation become a challenge. One of these conservation strategies is the ecological monitoring which is an important tool widely used to assess spatial and temporal variations in biodiversity, with a focus on assessing the effectiveness of management policies<sup>2-5</sup>. Due to field-level difficulties, there are several sampling methods for counting animal species, such as line transects<sup>6-8</sup>. In Taï National Park, the ecological monitoring program based on the counting of direct and indirect observations are done by line transects method. It started in 1977 in the five sectors of the park<sup>9</sup>. The survey has focused on the estimation of mammal density between 1977-1983 and 1995-2004. However, these estimates were only based on 6 transects of 4 km in each area. Moreover, these transects were located on the periphery of the park, making it difficult to interpret estimates and spatial distribution of species across the park.

Since 2006, a new design covering the entire park has been used, in order to improve estimates of species and their spatial distribution<sup>5,10,11</sup>. Apart from studies of these authors<sup>5,10,11</sup> about monkeys

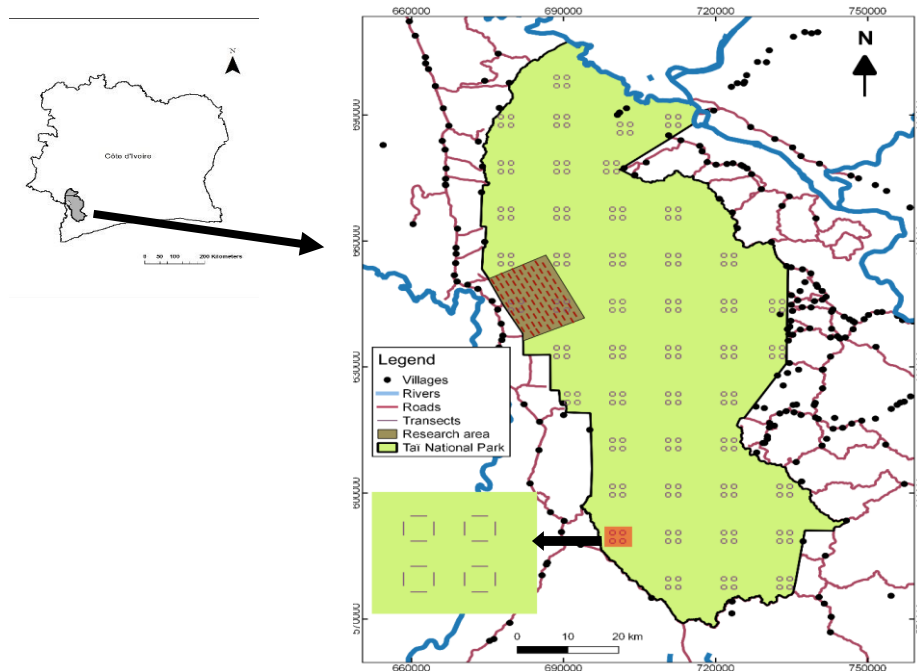
and chimpanzees distributions between 2006 and 2008, few studies have been undertaken to update information on the distribution of large mammals in the park. Here, we assess the trend of large mammals and illegal activities in two areas of Taï National Park (a research area considering by park managers as a priority site and the rest of the park) and compare the ecological situations between these areas. The aim of this study is to provide information about the “health” of large mammals in the park in order to help managers to take accurate decisions for the management of the park.

**Materials and Methods**

**Study site**

The study was conducted in Taï National Park (Figure 1), the largest protected primary forest in south western of Côte d'Ivoire. This site covers a 5360 km<sup>2</sup>-area and harbours a research area of 210 km<sup>2</sup> including four research camps devoted on chimpanzee and monkeys studies<sup>12,13</sup>. The climate is distinguished by two dried seasons (December to March and September) and two rainy seasons (April to July and October to November)<sup>14</sup>. Rainfall are abundant with about 1400 to 2500 mm<sup>15</sup> with average temperature between 24 to 28°C and humidity which can reach 100%.

The RA is one of the priority sites for park managers in the light of numerous studies that are conducted for decades. Several chimpanzees and monkeys are habituated to human presence to facilitate their observations during the different studies. But these animals, more or less habituated to human presence are extremely threatened by poachers whose infiltrations around the camps were regularly reported by researchers to park managers.



**Figure 1: Map of Taï National Park and the sampling design**

**Data collection**

Data were collected each year between 2009 and 2014 on 75 line transects covering the RA and 176 line transects in the rest of the park (Figure 1). Using a GPS (Global Positioning System), these transects were walked once a year. Data collection started from 7:30 am to 17:00 pm. Two types of data were collected on mammals such as direct observations and indirect observations. Direct observations concerned animals really seen by one or more observers on transects and indirect observations concerned all signs left by animals that allow their specific identification or group to which they belong. Indirect observations concerned dungs, footprints, vocalizations, activity traces (nutcracking tools, tracks and nests). For duikers, elephants, pygmy hippos and chimpanzees, difficult to observe directly, we recorded dungs, footprints, traces of activity, vocalizations. However, the few direct observations were also considered. For monkeys, the most directly encountered animals, direct observations and vocalizations were recorded.

### Data analysis

Data collected were reported in an Excel database. We determined the encounter rate for each species/taxon and illegal activities per year, as index of relative abundance. Encounter rate is the number of signs observed per kilometer walked. We used a *Generalized Linear Model* (GLM) to compare relative abundance averages over years. The two dependent variables are therefore the relative abundance of each taxon and the relative abundance of illegal activities. The independent variable is the time factor "Year" (qualitative variable). To evaluate changes in relative abundances over time, 2009 was used as the reference year. Also, Welch test was used to compare encounter rate of each species/taxon and illegal activities between the research area and the rest of the park. We used this statistical test because of the size and the variance of data which were different [16,17]. Statistical analysis was executed using R (version 3.2.0).

## Results and Discussion

### Trends in the relative abundance in the research area and the rest of the park

#### Case of the research area

During our study period, we noted in the research area a variation in relative abundances according to species/taxa (Table 1). Comparisons were made with 2009 as the reference. For duikers, a significant increase in relative abundance was observed in 2011 ( $p < 0.05$ ), 2012 ( $p < 0.05$ ). This increase was accentuated in 2013 ( $p < 0.001$ ) and 2014 ( $p < 0.001$ ). For the monkeys, no significant variation was found from 2009 to 2012, ( $P > 0.05$ ). However, relative abundance increased in 2013 ( $p < 0.001$ ) and 2014 ( $p < 0.001$ ). For the pygmy hippopotamus, a significant increase in relative abundance was observed in 2011 ( $p < 0.05$ ), 2012 ( $p < 0.01$ ), 2013 ( $p < 0.05$ ) and increased in 2014 ( $p < 0.001$ ). For the chimpanzee, the analysis revealed no significant variation in relative abundance during the study period ( $p > 0.05$ ). Finally, for the elephant, the results indicate two significant peaks in relative abundance in 2012 ( $p < 0.05$ ) and in 2014 ( $p < 0.05$ ). This abundance did not change in 2010, 2011, 2013 and 2015 ( $p > 0.05$ ). With regard to illegal activities, the results indicated a downward trend in the encounter rate during the study period (Table 1). This decline was significant in 2012 ( $p < 0.001$ ), 2013 ( $p < 0.001$ ) and 2014 ( $p < 0.001$ ).

#### Case of the rest of the park

In the Rest of the Park, we also noted variations over time in the relative abundance of the species/taxa (Table 2). The result of duikers indicated a significant increase in relative abundance in 2012 ( $p < 0.01$ ), 2013 ( $p < 0.05$ ), and 2014 ( $p < 0.01$ ). However, for chimpanzees and monkeys, relative abundances declined during the study period. For both, the decrease was significant from 2011 and continued until 2014. Concerning elephants, relative abundance remained constant between 2009 and 2013 ( $p > 0.05$ ), then increased significantly in 2014 ( $p < 0.05$ ). For pygmy hippopotamuses, there is no significant variation in relative abundance during the study period ( $p > 0.05$ ). Finally, as for illegal activities, relative abundance did not vary significantly over years in comparison to 2009 ( $p > 0.05$ ) except in 2012 where there was a peak in illegal activities ( $p < 0.05$ ) (Table 2).

**Table 1: Comparisons of relative abundances in the research area between 2009 and other years.**

Species/taxa	Years	Estimates	StandardError	t value	p-value
Duikers	(Intercept)	6.27	0.87	7.18	<b>0.0000</b>
	2010	2.19	1.30	1.683	0.0932
	2011	2.65	1.25	2.125	<b>0.0341</b>
	2012	2.83	1.24	2.284	<b>0.0229</b>
	2013	6.28	1.23	5.089	<b>0.0000</b>
	2014	10.01	1.23	8.112	<b>0.0000</b>
Chimpanzees	(Intercept)	1.62	0.32	5.143	<b>0.0000</b>
	2010	-0.65	0.47	-1.39	0.1651
	2011	-0.84	0.45	-1.873	0.0617
	2012	-0.39	0.45	-0.877	0.3812
	2013	0.10	0.45	0.22	0.8262
	2014	-0.13	0.45	-0.282	0.7777
Elephants	(Intercept)	0.16	0.14	1.182	0.238
	2010	0.11	0.21	0.549	0.5833
	2011	-0.10	0.20	-0.478	0.633
	2012	0.48	0.20	2.45	<b>0.0147</b>
	2013	-0.11	0.17	-0.565	0.5726
	2014	0.50	0.20	2.546	<b>0.0112</b>
Pygmy Hippopotamuses	(Intercept)	0.06	0.10	0.617	0.5378
	2010	0.003	0.15	0.022	0.9823
	2011	0.33	0.14	2.266	<b>0.0240</b>
	2012	0.40	0.14	2.775	<b>0.0058</b>
	2013	0.34	0.14	2.367	<b>0.0184</b>
	2014	1.18	0.14	8.257	<b>0.0000</b>
Monkeys	(Intercept)	3.41	0.35	9.801	<b>0.0000</b>
	2010	0.05	0.52	0.088	0.9300
	2011	0.23	0.50	0.453	0.6506
	2012	0.64	0.49	1.297	0.1955
	2013	1.64	0.49	3.33	<b>0.0009</b>
	2014	2.63	0.49	5.339	<b>0.0000</b>
Illegal activities	(Intercept)	2.18	0.22	9.905	<b>0.0000</b>
	2010	-0.41	0.33	-1.252	0.2114
	2011	-0.24	0.31	-0.755	0.4505
	2012	-1.20	0.31	-3.825	<b>0.0002</b>
	2013	-1.37	0.31	-4.394	<b>0.0000</b>
	2014	-1.76	0.31	-5.654	<b>0.0000</b>

**Table 2: Comparisons of relative abundances in the rest of the park between 2009 and other years**

Species/taxa	Years	Estimates	Standard Error	t value	P-value
Duikers	(Intercept)	4.63	0.38	12.318	<b>0.0000</b>
	2010	0.24	0.53	0.448	0.6544
	2011	0.88	0.53	1.659	0.0975
	2012	1.58	0.53	2.979	<b>0.0030</b>
	2013	1.17	0.53	2.202	<b>0.0279</b>
	2014	1.65	0.53	3.113	<b>0.0019</b>
Chimpanzees	(Intercept)	1.57	0.17	9.434	<b>0.0000</b>
	2010	-0.52	0.23	-2.232	0.0562
	2011	-0.83	0.24	-3.545	<b>0.0004</b>
	2012	-1.13	0.23	-4.824	<b>0.0000</b>
	2013	-1.00	0.23	-4.247	<b>0.0000</b>
	2014	-0.94	0.24	-3.983	<b>0.0000</b>
Elephants	(Intercept)	1.00	0.26	3.913	<b>0.0000</b>
	2010	0.69	0.36	1.924	0.0547
	2011	-0.32	0.36	-0.894	0.3713
	2012	0.47	0.36	1.309	0.1909
	2013	0.58	0.36	1.615	0.1066
	2014	0.77	0.36	2.131	<b>0.0333</b>
Pygmy Hippopotamuses	(Intercept)	0.82	0.09	9.574	<b>0.0000</b>
	2010	-0.10	0.12	-0.833	0.405
	2011	0.07	0.12	0.614	0.5400
	2012	0.01	0.12	0.065	0.9480
	2013	-0.17	0.12	-1.415	0.1570
	2014	0.18	0.12	1.478	0.1400
Monkeys	(Intercept)	2.22	0.15	14.694	<b>0.0000</b>
	2010	0.13	0.21	0.6	0.5480
	2011	-0.91	0.21	-4.254	<b>0.0000</b>
	2012	-1.48	0.21	-6.933	<b>0.0000</b>
	2013	-1.38	0.21	-6.449	<b>0.0000</b>
	2014	-1.36	0.21	-6.336	<b>0.0000</b>
Illegal activities	(Intercept)	1.88	0.26	7.366	<b>0.0000</b>
	2010	0.10	0.36	0.272	0.7855
	2011	0.30	0.36	0.83	0.4068
	2012	0.65	0.36	1.804	<b>0.0415</b>
	2013	0.35	0.36	0.969	0.3326
	2014	0.37	0.36	1.035	0.3008

**Comparison of relative abundance between the research area and the rest of the park**

We compared the situation of mammals and illegal activities between the research area and the rest of the park. Welch's test showed differences in relative abundances according to species/taxa and by years. For duikers and monkeys, the relative abundance was significantly higher in the research area during the study period (Table 3); contrary to that of elephants, which remained significantly higher in the rest of the park (Table 3). The case of chimpanzees indicates that the relative abundance remained similar in both areas between 2009 and 2011. However, it was significantly higher in the research area between 2012 and 2014 (Table 3). With regard to the pygmy hippopotamuses, the relative abundance was significantly lower in the research area between 2009 and 2012. However, this abundance did not vary between the two zones in 2013 and 2014 (Table 3).

Finally, for illegal activities, the results showed similar relative abundance in the two zones between 2009 and 2011; while from 2012 to 2014, illegal activities were significantly high in the rest of park compared to the research area (Table 3).

**Table 3: Comparison of relative abundance between the research area and the rest of the park**

Species	Years	Research area	Rest of park	<i>Welch-test parameters</i>		
		Averages (number of signs/km)		<i>t</i>	<i>df</i>	<i>p</i>
Duikers	2009	6.26	4.62	3.83	378.31	<b>0.0001</b>
	2010	8.46	4.86	4.03	82.555	<b>0.0001</b>
	2011	8.92	5.51	3.95	124.46	<b>0.0001</b>
	2012	9.09	6.20	3.52	131.54	<b>0.0006</b>
	2013	12.55	5.79	6.56	99.607	<b>0.0000</b>
	2014	16.23	6.47	6.94	84.63	<b>0.0000</b>
Chimpanzees	2009	1.62	1.57	0.13	388.71	0.8959
	2010	0.97	1.05	-0.25	109.38	0.8034
	2011	0.78	0.73	0.16	122.84	0.8731
	2012	1.23	0.44	2.28	89.211	<b>0.0251</b>
	2013	1.72	0.57	2.56	81.992	<b>0.0122</b>
	2014	1.48	0.63	2.59	95.736	<b>0.0110</b>
Elephants	2009	0.16	1	-4.21	197.52	<b>0.0000</b>
	2010	0.28	1.69	-3.80	222.09	<b>0.0002</b>
	2011	0.07	0.68	-4.12	210.69	<b>0.0001</b>
	2012	0.65	1.47	-2.52	244.94	<b>0.0124</b>
	2013	0.05	1.58	-5.69	177.29	<b>0.0000</b>
	2014	0.65	1.77	-3.15	231.46	<b>0.0018</b>
Pygmy hippopotamuses	2009	0.06	0.82	-10.30	193.64	<b>0.0000</b>
	2010	0.07	0.72	-8.17	224.52	<b>0.0000</b>
	2011	0.39	0.89	-3.85	233.74	<b>0.0002</b>
	2012	0.46	0.82	-2.77	176.92	<b>0.0061</b>
	2013	0.4	0.65	-1.90	150.48	0.0596
	2014	1.23	0.99	1.17	125.66	0.2456
Monkeys	2009	3.41	2.22	4.75	378.9	<b>0.0000</b>
	2010	3.46	2.35	2.48	148.46	<b>0.0141</b>
	2011	3.64	1.31	6.67	87.14	<b>0.0000</b>
	2012	4.05	0.74	9.78	82.28	<b>0.0000</b>
	2013	5.05	0.85	9.85	80.43	<b>0.0000</b>
	2014	5.99	0.87	11.69	79.98	<b>0.0000</b>
Illegal activities	2009	2.18	1.88	1.26	394.78	0.2067
	2010	1.77	1.98	-0.70	97.34	0.4835
	2011	1.94	2.18	-0.68	98.85	0.4969
	2012	0.99	2.53	-6.73	162.53	<b>0.0000</b>
	2013	0.81	2.23	-4.32	247.85	<b>0.0000</b>
	2014	0.41	2.25	-3.78	184.21	<b>0.0002</b>

## Discussion

In this paper, we analyzed the variations in the relative abundances of large mammals and illegal activities and compared the situations between the research area and the rest of the park. Our results, first, showed that the relative abundance of duikers and monkeys increased over the years in the research area (160% increase for duikers and 77% for monkeys between 2009 and 2014). During the same period, the relative abundance of duikers also increased in the rest of the park, although it remains low compared to the research area (36% increase between 2009 and 2014). However, that of monkeys decreased over time (62% reduction during the same period) in the rest of park. Like for monkeys, similar results were found for chimpanzee. This situation suggest that primates showed the same pattern in the rest of park (a decreasing trend). According to some authors, the density of primates in Taï National Park is higher in the research area because they are positively influenced by the presence of researchers<sup>5,18</sup>. The findings for pygmy hippopotamus revealed a stability of the abundance of the species in the whole park even if this abundance globally remained low, confirming results found by prior studies<sup>19,20</sup>. As for the elephant, the research area does not seem to be a preferred site, given the very low values fluctuating over time in comparison with the rest of the park. Previous studies revealed that their presence signs were most distributed in the south and the center of the park<sup>10</sup>.

At the same time, our results showed a significant decrease in illegal activities in the research area while in the rest of the park, apart a peak in 2012, they remained almost constant during the study period. The reasons are probably the presence of researchers in the research area<sup>18,21</sup>, but also, the increase of rangers patrols in that area<sup>22</sup> in comparison to the rest of park where there was a discontinuity in the surveillance during the political crisis in the country in 2010-2011. The peak of illegal activities observed in the rest of the park in 2012 is the result of insufficient patrols in previous years. The park faced to serious financial difficulties in 2009-2011 and all activities to manage the park were affected. However, from 2013, the observed reduction of illegal activities in the rest of the park (although not significant) witness that park authorities have undertaken actions to maintain the park under protection after the political crisis and stabilize the abundance of animals. It is very likely that a sustained increase in patrol effort could contribute at long term to a significant reduction in illegal activities as observed in the Gonarezhou National Park, northern Zambia<sup>23</sup>.

From the general observation, it appears that the research area always represented an important refuge for the animals of the Park especially for primates and duikers<sup>5,9,18,21</sup>. The rest of the park, especially the eastern part remained a long time less rich in fauna because of the high aggression in this area<sup>9</sup>. However, although they benefit from the presence of researchers, mammal species still are vulnerable due to their habituation<sup>22</sup> to human presence and risks of zoonoses<sup>21</sup>.

## Conclusion

The present study showed trends of large mammals as well as illegal activities inside the park. It presents a look of what happen in the park during the considered period. Considering our findings, it's urgent to increase law enforcement patrols as well as awareness campaigns of local communities to help improving the protection of the park and all animals living inside.

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