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Chimpanzee conservation status in the World Heritage Site Taï National Park, Côte d'Ivoire

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ABSTRACT: Effective conservation of African ape populations that have dramatically declined over the last decades requires updated information on the population status and habitat. However, at many sites, the densities and the spatial distribution of chimpanzees as well as the threats faced by the species are poorly described and not updated. To contribute towards filling these gaps, we conducted a survey along a total of 701.5km line transects to collect signs of chimpanzee and human activities over two years in the Taï National Park, Côte d'Ivoire. Encounter rates for signs of chimpanzee presence were low in most locations with less than two signs observed per kilometer walked. This was notably true within and around areas subject to the permanent existence of illegal human activities, such as the presence of plantations in the peripheral eastern regions. Using distance sampling methods, we estimated that the overall density of chimpanzees in 2008 was 0.087 individuals/km2 and 464 weaned individuals in the park. Taï National Park is a world heritage site but its biodiversity is threatened by human pressures. We further suggested work on the spatio-temporal modeling of the factors influencing the distribution and abundance of species to improve management and to optimize conservation decision-making.

KEYWORDS: Abundance estimates, encounter rates, Pan troglodytes, spatial distribution, transect counts.

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1 INTRODUCTION

There is a general consensus among conservationists concerning the evidence of the dramatic decline of wild populations of chimpanzee (*Pan troglodytes*) and other African great apes throughout the last decades across their range countries, caused mainly by habitat loss, commercial hunting and disease [1], [2], [3], [4]. All four species of African apes are recognized as being threatened by extinction, with the chimpanzee, the bonobo (*Pan paniscus*) and the eastern gorilla (*Gorilla beringei)* listed by the IUCN-International Union for Conservation of Nature as endangered species, and the western gorilla *(Gorilla gorilla*) listed as critically endangered [5]. The importance of each of these species and their survival is, however, many-faceted. Such aspects of importance include their role in the functioning of tropical ecosystems [1], [6], their vital role for the understanding of human evolution and human disease [7], [8] and their importance in the development of ecotourism [9].

Even though chimpanzees are the most abundant and widespread of the apes, with the larger populations found within protected areas, the declines that have occurred and that are expected to continue, justify the criteria for ranking them as endangered [10].

In Côte d'Ivoire, from 1995 to 2007, the population of chimpanzee rapidly declined by an alarming 90%, in the country thought to be one of the final strongholds for this subspecies [2]. Although, the Taï National Park (TNP) which harbors long-term research and tourism sites is believed to represent one of the main refuges for chimpanzees within Côte d'Ivoire [2], [11], information about the species' spatial distribution and the threats to its population has remained scarce and poorly known. However, the risk of deforestation of the rainforest in the southwest of Côte d'Ivoire, which includes the Taï region, and the unavoidable loss of biodiversity become increasingly high with human population growth associated with the poaching pressure for the bushmeat trade [12], and the unsustainable use of land for agricultural activities such as cocoa, rubber and coffee plantations [13].

Locating the remaining populations of chimpanzee in individual sites and gaining a better understanding of how humans interact with them in nature is crucial for guiding management and conservation strategies [8], [14], [15]. TNP is part of the Upper Guinean forest and represents one of the world's 25 biodiversity hotspots with a high level of endemism [16]. Improvement of knowledge of illegal activities occurring in the park and other factors affecting species distribution is therefore vital to contribute to meeting global conservation targets [17].

Despite the indisputable importance of the above-mentioned information for conservation, collecting data for accurately estimating chimpanzee distribution and density is a notoriously challenging task in large tropical rainforests. In addition to the large areas of thousands of square kilometers, other factors such as low visibility, the cryptic behavior of the species, the difficulties of accessing most locations and the necessity of training several surveyors are all aspects which add to the initial complexity of collecting sufficient data for the aforementioned estimates [15]. Inaccessible locations and non-sampled areas have rarely been described in terms of their animal densities and distributions. Such aspects can be further affected by political instability for example, which may temporarily block international funding, as has been experienced in Côte d'Ivoire due to the civil unrest since 2002, as well as in other range countries of *P. troglodytes verus* in the past (e.g, Liberia, Sierra Leone). As a result, research and management activities in protected areas may be hindered during such periods of crisis. In the TNP, however, funding since 2005 has provided an opportunity to train local assistants from various towns surrounding the park to implement an efficient monitoring program across the park. This program was designed by the Wild Chimpanzee Foundation and the Office Ivoirien des Parcs et Réserves [18] to inform park managers about the status of the TNP's large mammal populations [19].

2 OBJECTIVES

This study aims to provide information on the conservation status of one key population of the western chimpanzee and contribute to a better understanding of the current threats to the distribution of its population in the TNP, which is a prerequisite for the design of an efficient conservation strategy. More specifically, the objectives of our work were to:

1) Determine the population size and spatial distribution of the western chimpanzee in the Taï National Park;
2) Determine the spatial distribution of human illegal activities in the TNP.

3 METHODS

3.1 STUDY SITE

Our work was carried out in the Taï National Park (TNP) during two main data collection phases which included the periods from September 2006 to April 2007 (2006-2007) and from August 2007 to March 2008 (2007-2008). The TNP is located in the south-west of Côte d'Ivoire (Fig. 1a.) between 5°15'-6°7'N and 7°25'-7°54'W. TNP, including the adjacent N'Zo Fauna Reserve, covers 5,360 km² and remains the largest protected rainforest in West Africa. The relative humidity in the TNP is high, ranging between 85% and 90% while the annual rainfall and temperature are 1800mm and 24°C, respectively [20]. TNP is managed by the OIPR and is a recognized UNESCO World Heritage Site with extraordinary species diversity and a high level of endemism making it one of the world's 25 biodiversity hotspots [16]. Details of the location, climate, flora and fauna can be found elsewhere [7], [21], [22].

3.2 SURVEY DESIGN AND SAMPLING METHODS

Our survey design covered the entire park, and consisted of forty-six systematically spaced clusters of line transects with a random start in the TNP. The distance between the centroids of consecutive clusters of transects was 11 km (Fig. 1b.). This systematic design provided equal coverage probability over the entire park, i.e. each location in the study area has the same probability of being sampled, which one assumes during a standard line transect analysis [23], [24]. More precisely, clusters of transects consisted of four sampling units or transects with the length of each unit measuring 2 km subdivided into four segments of 0.5 km each (Figure 1c.). Others details about the survey design are given by [19].

Transects were located in the field using a map and a GPS (Global Positioning System) and each transect was visited once in each data collection phase by five experienced survey teams to record all signs of chimpanzee activities (hereafter chimpanzee signs) as well as signs of human activities. Signs of chimpanzees included sleeping nests, feeding signs, vocalization and direct observations that can be used to identify the presence of the species at any location in the park. We used the same definition for human activities which included illegal activities such as flora aggression, fauna aggression and other threats to wildlife. For each sign detected, the GPS coordinates were recorded to allow determination of the spatial distribution of the species. In order to estimate the density of the chimpanzee population, for each sleeping nest detected, we measured perpendicular distances from the nest to the transect line. Further details about transect data collection including chimpanzee nest counts along line transects can be found elsewhere [25], [26].

3.3 DATA ANALYSIS

3.3.1 ESTIMATION OF CHIMPANZEE POPULATION SIZE FROM TRANSECTS NEST COUNTS

We calculated nest encounter rates by dividing the number of nests encountered by the total length of transects. We used conversion factors (nest production rate and nest mean lifetime) with their associated errors estimated by [25] for chimpanzee densities and abundance estimates using the package DISTANCE 6.0 with the equation:

$$\widehat{Dc} = \frac{\widehat{Dn}}{r.t} = \frac{n}{2wL.r.t.\hat{P}_a}$$

where $\widehat{Dc}$ is the estimated chimpanzee density, n is the number of nests detected in the surveyed area a with $a = 2wL$; $\widehat{Dn}$ is the estimated nest density, r is the nest production rate; t nest mean lifetime; L is the total length of transects or survey effort, w is the distance from transect line beyond which no nests were detected; $\hat{P}_a$ is the probability that a randomly chosen nest within the surveyed area is detected [23].

To allow robust estimations of densities and animal abundance, we pooled nest count data from the first and second visits on transect. Each visit was defined as a stratum in the DISTANCE 6.0 software, and calculations were made following [23].

3.3.2 MAPPING THE SPATIAL DISTRIBUTION OF HUMAN SIGNS AND CHIMPANZEE PRESENCE

To indicate the spatial distribution visually, we used the encounter rates of chimpanzee signs as well as for human signs calculated for each sampling unit. We performed mapping analysis using the deterministic interpolation method of Inverse

Distance Weighted [27]. This method assumes that the influence of a known data point is inversely related to the distance from the unknown location that is being estimated. We carried out all mapping analysis using the Geographic Information System software ArcGIS 9.2 (Environmental Systems Research Institute, Redlands, USA).

3.3.3 STATISTICAL ANALYSIS

To compare the signs of chimpanzee presence and human activities in the two related sampling phases namely from 2006-2007 and 2007-2008, we used the non-parametric *Wilcoxon* signed-rank test of the Statistical Package for Social Sciences (SPSS 13.0). Since the recorded chimpanzee signs were not normally distributed, we used the Poisson regression function in a Generalized Linear Model (GLM) to test the effects of human activities on chimpanzee density and distribution, using the R for Windows software (R 2.12.0). In this test, the response variable was the encounter rates of chimpanzee signs and the independent variables were the encounter rates of fauna aggression signs and flora aggression signs by considering each data collection phase.

4 RESULTS

4.1 CHIMPANZEES DENSITY AND ABUNDANCE IN THE TAÏ NATIONAL PARK (TNP)

We walked 701.5km during the visits of transects with the survey effort being 362 km and 339.5km for the first and second visits, respectively. Overall, during the two visits, we detected 270 sleeping nests of chimpanzees implying the encounter rates of 3.85 nests for ten kilometers walked in the TNP. Among various models, the half normal detection function model in combination with the cosine adjustment term of order two produced the best fit for pooled nest data for the two visits (AIC= 842.35). The density of chimpanzee nests in the TNP over the entire study period was 9.02 nests per km^2 and conversion to individual densities was made with nest decay time t= 91.22 days and nest production rate r=1.14 nests per day. This resulted in a density estimate of 0.087 weaned chimpanzee individuals per km^2, CV= 14.04 % and the confidence limits (CL) ranging from 0.057 to 0.132 individuals per km^2. We estimated 464 weaned chimpanzee individuals (CV= 14.04%) with the CL ranging from 305 to 707 individuals during the entire study period.

However, the CV of the point estimates per stratum (i.e for each visit) was relatively higher than the one from the pooled data mentioned above. Indeed, during the first visit (year 2006-2007) the mean estimates of chimpanzee population size was 504 weaned individuals with CV= 24.79% and CL varying from 312 to 815 individuals. During the second visit, we found that the population size of chimpanzee was 422 weaned individuals with CV= 26.32% and CL ranging from 253 to 702 individuals.

4.2 ENCOUNTER RATE AND SPATIAL DISTRIBUTION OF CHIMPANZEE SIGNS OF PRESENCE IN THE TNP

The presence of chimpanzees in the TNP was confirmed during transect surveys by sleeping nests of individuals, nut cracking sites, direct observations, vocalizations and footprints with the encounter rates being 0.39 nests per km, 0.24 nut cracking sites per km, 0.09 individuals per km, 0.07 vocalizations per km and 0.003 footprints per km walked (Table 1).

While comparing the data of the two visits, we did not find any significant decrease of chimpanzee nests from 2006-2007 to 2007-2008 (Wilcoxon test, Z = -1.15, P-value = 0.25). Moreover, the relative increase of all chimpanzee signs was not statistically significant (Wilcoxon test, Z = -1.33, P-value = 0.18).

We found that the encounter rate of chimpanzee signs along transects was generally higher in the western and the northern parts of the park than in other locations. Areas of lower encounter rates (0.30 signs observed per km walked) were located in the peripheral areas, and more specifically in the eastern region around the plantation areas (Fig. 2). Furthermore, higher encounter rates of chimpanzee sings in the park generally ranged from 1.5 to 10.5 signs per kilometers walked.

4.3 HUMAN AGGRESSION SIGNS IN THE PNT

We observed various signs of human activities distributed throughout the park (Table 1). They were mostly observed in the peripheral areas of the park with encounter rates globally ranging from 1.5 to 8 signs per km (Fig. 3). But, in a few locations from the north, encounter rates reached 8 signs to 24.2 signs per km. Signs of human activities are less likely to be detected in the central and western areas of the park where they tended to be absent with encounter rates ranging from 0 to 1.5 signs per km walked. Human signs observed during transect surveys were classified into three categories: signs of flora aggression, signs of fauna aggression by humans and other human signs (Table 1).

Signs of flora aggression by humans included signs such as forest clearing for farming, plantations, abandoned fields and cutting of plant stems or branches for teeth brushing. The encounter rates of all signs of flora aggression were 0.48 signs per km walked during the entire study period; flora aggression signs did not significantly decrease from the phase 2006-2007 to the phase 2007-2008 (Wilcoxon test, Z = -1.87, P-value = 0.06). The signs of fauna aggression by humans included observations of poaching camps, gun shells, gunshots and traps with a total encounter rate of 2.37 signs per km. As obtained for the flora aggression signs, fauna aggression signs remained statistically stable (Wilcoxon test, Z = -0.17, P-value = 0.87). Other signs of humans included humans being heard, objects left, good panning locations, patrols and research trails with the last mainly observed in the western area of the park around the research station and Djouroutou. We also noticed that all human signs significantly decreased from the phase 2006-2007 to the phase 2007-2008 (Wilcoxon test, Z = -3.84, P-value < 0.001).

When comparing the spatial distribution of chimpanzee presence signs (Fig.2) to the spatial distribution of human signs (Fig. 3), we found that areas of higher chimpanzee densities - the central and the western areas - showed low signs of illegal human activities. However, in the northern areas, we found higher densities of anthropogenic disturbance although chimpanzees were relatively abundant.

This impact of human activities on chimpanzee density is negatively significant during the phase 2006-2007 through the fauna aggression signs (coefficient = -0.423, Standard Error = 0.117, Z value = -3.624, P-value < 0.001) but not negative for the flora aggression signs (coefficient = 0.236, Standard Error = 0.050, Z value = 4.724, P-value < 0.001). The effects seemed to be reduced in 2007-2008: the negative effects were significant for the fauna aggression signs (coefficient = -0.214, Standard Error = 0.089, Z value = -2.392, P-value =0.017) but not for the flora aggression signs (coefficient = -0.158, Standard Error = 0.109, Z value = -1.446, P-value =0.148).

5 DISCUSSION

The findings of the present study provide updated information on the estimates of chimpanzee population size and distribution in the Taï National Park (TNP), the largest protected rainforest in West Africa. In addition, we contributed to the discussion about the extent of human influence on biodiversity in protected areas [28].

Firstly, our results strongly suggest that there are low densities of chimpanzees observed in the TNP (0.087 weaned individuals per km^2), and these densities were 20 times lower than the estimates from [29] at the same site. This observed negative trend of densities is consistent with the general catastrophic decline of the Ivorian population of chimpanzees [2]. The relatively higher densities of chimpanzee in the central areas of the park could be explained by the difficulty or the higher risk for hunters to access these locations. The mean estimates of the population size of the species can be extended to 464 weaned individuals. However, following [26] who found that 17.5% of chimpanzees in the population do not build nests, the total size of the population including infants can be estimated at 562 individuals. Despite the negative trend observed, the size of the current chimpanzee population can be considered as viable.

Secondly, we found that the species is facing many threats compromising its survival in the park. Indeed, the decline in chimpanzee density is most likely due to intense human pressure on the park with a human population increasing at a high rate and an uncontrolled influx of migrants from the northern regions of the country and from the Sahel belt [13]. The resulting increase in demand for protein may drive bushmeat hunting in the park and has already led to the 'empty forest syndrome' in the eastern parts of the park [19]. Hunting is not only motivated by food/protein needs of local populations, but unfortunately also by the illegal trade in bushmeat supply for the urban centers as a source of income. The relatively higher encounter rates of signs of fauna aggression in comparison with the other human signs and signs of flora aggression support the idea that poaching activities are the major threat in the park [30]. Though hunting for bushmeat is illegal in Côte d'Ivoire and even more so in national parks, in reality, bushmeat is a common part of the local communities' diet. Nowadays, hunting has reached an unsustainable level in the Taï region and is causing the depletion of local wildlife (see also [31]). The persistence of farming activities or plantations in part of the protected area, even in the peripheral areas, remains hardly understandable as it can substantially affect biodiversity as partly illustrated by the distribution of chimpanzees in Fig. 2. Indeed, previous studies demonstrated that the presence of humans in protected areas represent important threats to biodiversity as they may leave potentially infectious fluids that can infect wild chimpanzees and other wild primates [31]. For instance, human feces are a particular problem because fecal micro and macro-parasites are typically more resistant to environmental degradation than are other parasites (e.g. respiratory viruses).

Due to the prominence of human activities in the park, more specifically on the eastern areas, there is a need for urgent research investigation and conservation actions in order to guarantee the conservation of this threatened ape. For instance, spatio-temporal modeling may be required to determine the locations and the key periods of interaction between poachers

and the primates in the park. The spatial distribution of the social groups of chimpanzees at the scale of the entire TNP is not yet well-known and requires additional research, in particular in the other areas of the park excluding the territories of the four habituated groups studied by the Taï Chimpanzee Project [32].

In line with our research, we suggest that the conservation researchers and park managers should improve communication or work closely to efficiently pursue the common aim of biodiversity conservation. There is an urgent need for more active patrolling in the park to try to keep under control the pressure resulting from poaching. This has to be implemented as quickly as possible, and through our data the areas of priority are clearly indicated (see fig. 2). Indeed, patrols of rangers employed by the park managers need to continue using such results to orientate their activities as shown by [19]; this may lead to higher significant decrease in the impact of human aggression signs, and on the other hands favors the increase of wildlife populations. Furthermore, the activities should include rigorous assessments of wildlife population status in a cost-effectiveness manner with special emphasis on a long- term monitoring program.

6 TABLES AND FIGURES

Table 1. Numbers and encounter rates of signs of chimpanzee presence and human signs recorded during the study period at Taï National Park

Type of observation		Number of signs			Encounter rates (n/km)		
		2006-2007	2007-2008	Total	2006-2007	2007-2008	Total
Signs of chimpanzee presence	Nuts cracking sites	19	147	166	0.052	0.433	0.236
	Vocalizations	22	27	49	0.061	0.080	0.070
	Direct observations	46	14	60	0.127	0.041	0.085
	Footprints	0	2	2	0.000	0.006	0.003
	Nests	151	119	270	0.417	0.351	0.385
Total of chimpanzee signs		238	309	547	0.657	0.910	0.779
Indices of flora aggression	plantations	27	54	81	0.074	0.159	0.115
	Abandoned plantations	5	35	40	0.014	0.103	0.057
	Cleared land	3	0	3	0.008	0.000	0.004
	Cutting of plants as teeth brush	166	49	215	0.458	0.144	0.306
Total of flora aggression		201	138	339	0.554	0.406	0.483
Indices of fauna aggression	Empty cartridge cases	115	144	259	0.317	0.424	0.369
	Gunshots	39	34	73	0.108	0.100	0.104
	Poacher camps	22	7	29	0.061	0.021	0.041
	Traps	207	186	393	0.571	0.548	0.560
	Hunting trails	564	343	907	1.556	1.010	1.292
Indices of fauna aggression		947	714	1 661	2.612	2.103	2.366
Other signs of human presence	Human heard	1	0	1	0.003	0.000	0.001
	Items or objets left	0	4	4	0.000	0.012	0.006
	Gold panning locations	13	6	19	0.036	0.018	0.027
	Other human trails (for patrols, etc.)	11	48	59	0.030	0.141	0.084
	Research trails	29	19	48	0.080	0.056	0.068
Total of other signs of human presence		54	77	131	0.149	0.227	0.187
Total of human signs		1 202	929	2 131	3.316	2.736	3.036

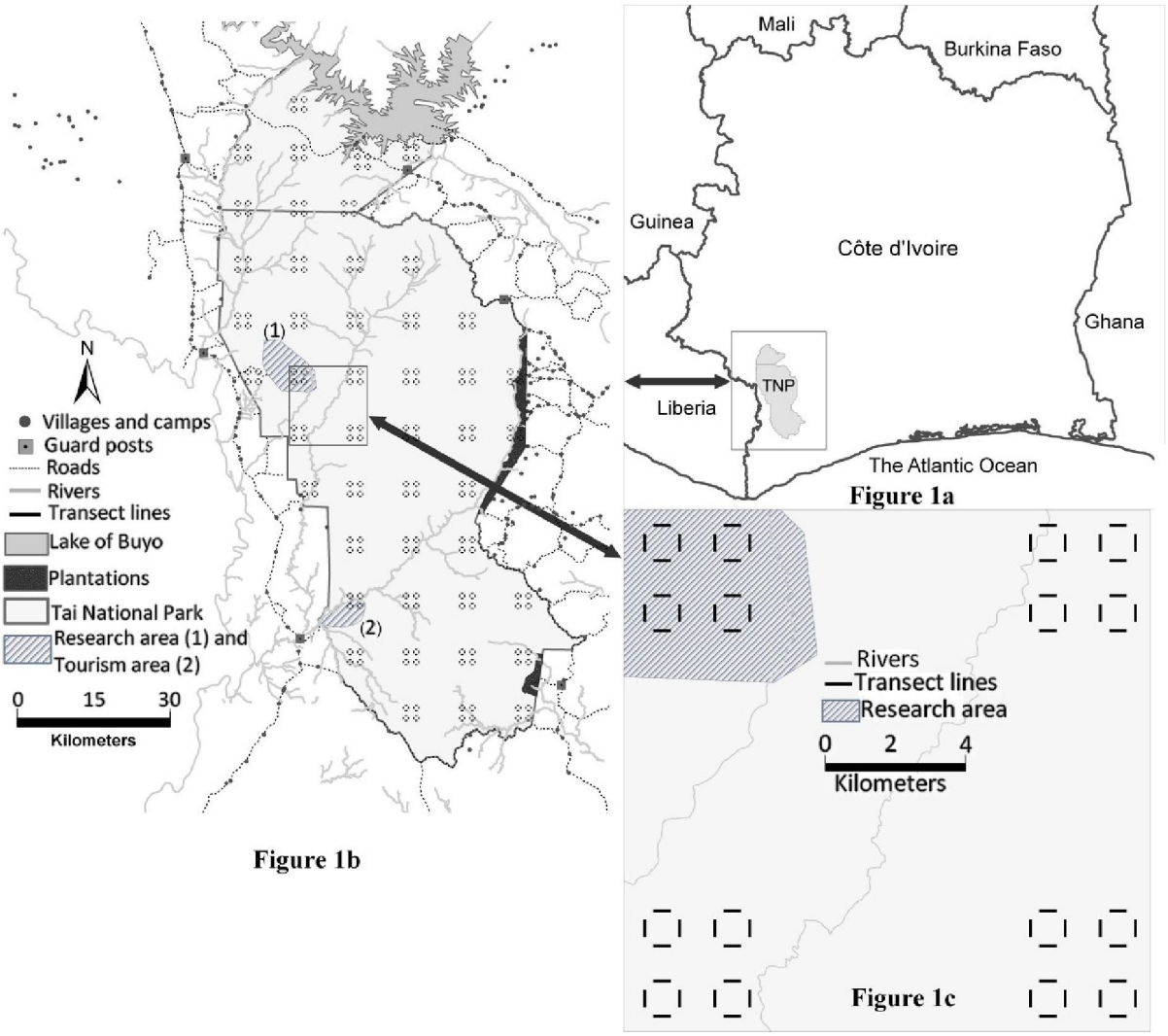

Fig. 1. Location of Taï National Park (1a) in southwestern Côte d'Ivoire, survey design (1b) within the park, and a detail viewing of one group of transects (1c).

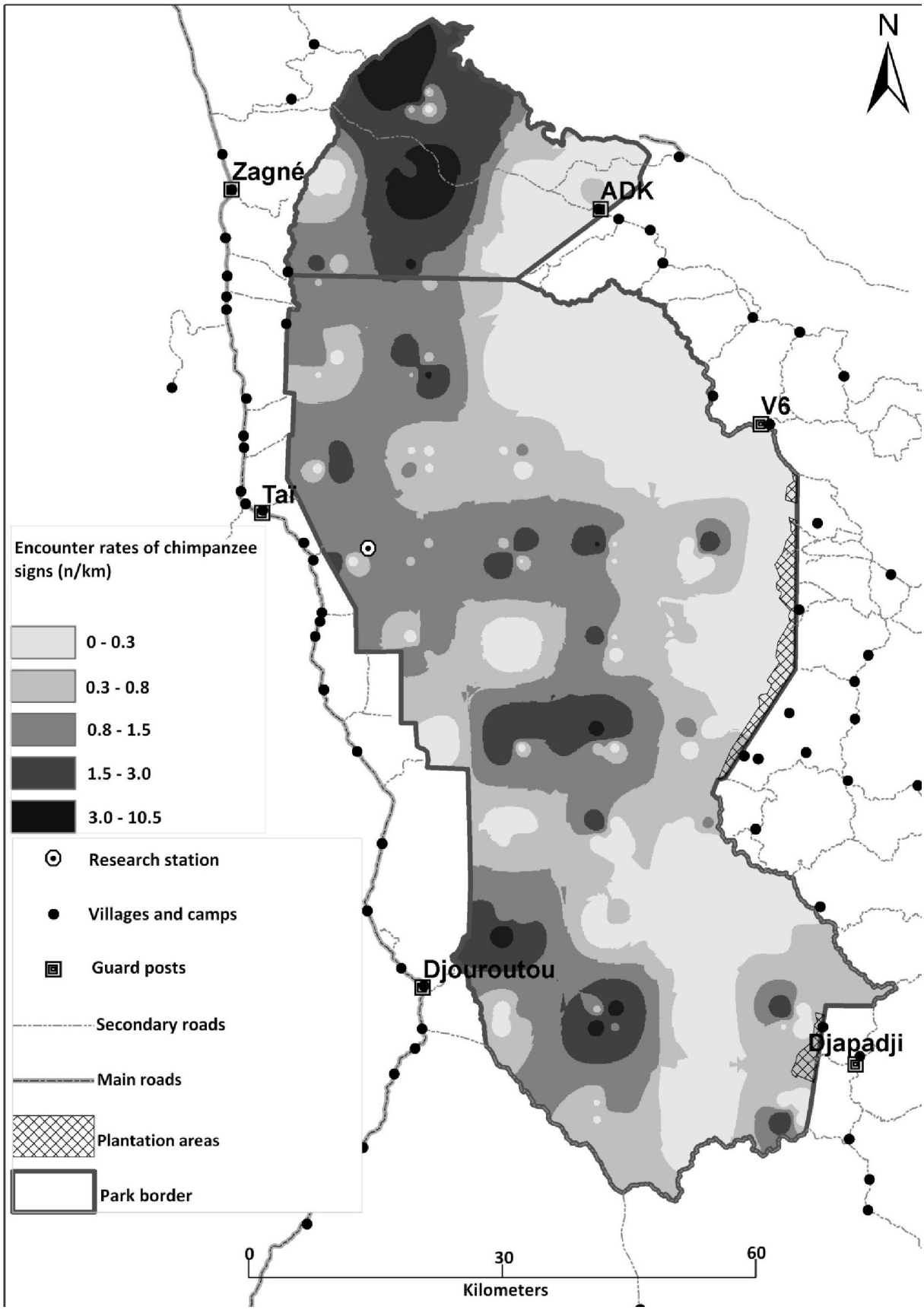

Fig. 2. Spatial distribution of chimpanzee presence signs in the Taï National Park

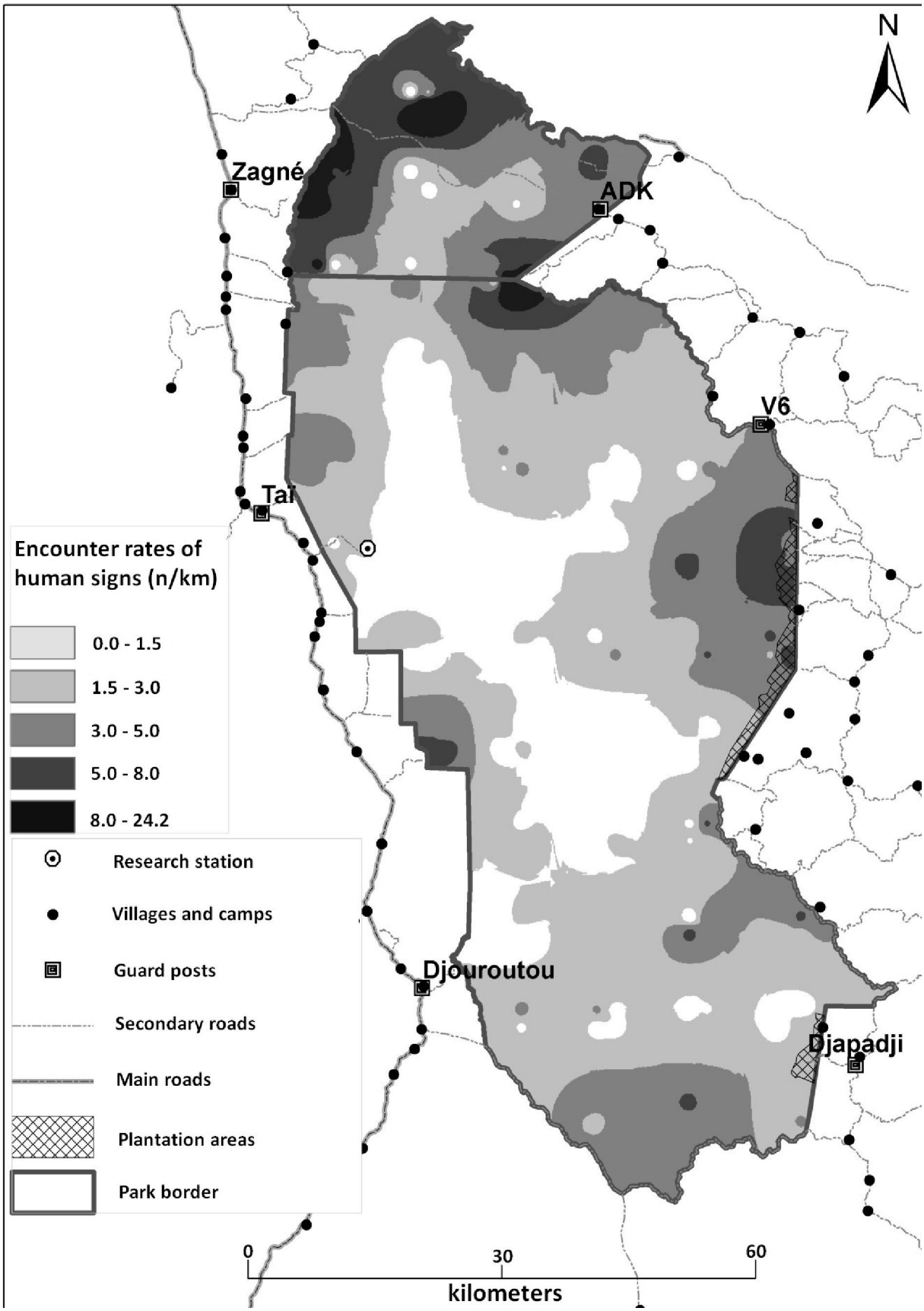

Fig. 3. Spatial distribution of human signs in the Taï National Park

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