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Social structure of the forest elephant, *Loxodonta cyclotis* in the Taï National Park, South-West Côte d'Ivoire

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Abstract

The elephant is an essential species in its living environment. Despite this undeniable role, this species is endangered on Ivorian territory. The present work aims to determine the social structure of the forest elephant in the Taï National Park (TNP), one of the last refuge sites for this species. The method used consisted of installing 87 camera traps (CT) on the elephants' distribution area in the TNP, with an equidistance of 6 km between two neighbouring CTs. At the end of this work, it appears that the forest elephant population of the TNP contains 19% solitary individuals and 39% juveniles. The mean group size was estimated to be 2.7 ± 0.75 individuals (including solitary individuals) and 4.5 ± 1.04 individuals (excluding solitary individuals). These characteristics are comparable to or even better than those obtained before the 1980s, when elephant poaching in the TNP intensified. This similarity of the characteristics of the elephant population noted by this study and those obtained before the 1980s, could reflect a reconstitution of the population of the forest elephant population in the TNP, following the takeover by the Ivorian Office of Parks and Reserves, since 2002.

Keywords: Taï National Park; Forest Elephant; Social Structure; Camera Trap

1. Introduction

The elephant is one of the main species in the ecosystem in which it lives [1, 2]. In fact, the elephant participates in the dissemination of diaspores, an essential step in plant regeneration, particularly in tropical forests where the chances of survival of the seedling in the vicinity of the parent plant are reduced [3, 4]. Also, it has been shown that the passage of seeds of certain species through the digestive tract of elephants helps to improve the speed and rate of germination and promotes the growth of young plants [4, 5]. In the Taï National Park (TNP), the spread of 37 plants species by elephants has been revealed. Of these species, only seven are also efficiently spread by other animals. For all the other species encountered, the elephant appears to be the appropriate disseminator [5]. Therefore, the disappearance of the elephant from the TNP could slow down the recovery of these species. According to McConkey et al. [6], the disappearance of Asian elephants will lead to a loss of income for the reproduction of flora that other animals may not be able to compensate. This could have an impact on the entire ecosystem and ecosystem services such as carbon dioxide (CO2) sequestration. Thus, Berzaghi et al. [7] had reported that the extinction of the elephant in African rainforests would result in a loss of 7% of their carbon storage capacity, hence the acceleration of climate change. In addition, the elephant is also considered to be an architect of the environment in which it lives. It opens passages in closed vegetation, thus creating passages for other animals. It digs water holes, which are practical and favourable for other herbivores [2, 8].

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Despite this undeniable contribution of the elephant to the good maintenance and rejuvenation of the forest [9, 10], elephant populations are experiencing a sharp decline in the Ivorian territory [11, 12]. The country now ranks last among African elephant range countries, in terms of population abundance [13]. The main causes of this decline are the accelerated loss of forest cover and poaching [13, 14, 15].

TNP is one of the last refuges for the forest elephant, *Loxodonta cyclotis*, in Côte d'Ivoire. However, despite its status as a protected area, the park has also experienced a significant decrease in its elephant population. Once estimated at 800 individuals between 1978 and 1980 [16], the population declined by more than 90% before 1990 [14, 17]. To curb this trend, the Ivorian government has adopted several measures at the national level, including the creation of the Ivorian Office of Parks and Reserves in 2002. This office, through various management activities, in particular the monitoring of PAs, including the TNP, contributes to better management of PAs, hence the reduction of pressures [18].

In view of the improvement in the management of PAs in Côte d'Ivoire since 2002 and the fact that the last studies on the social structure of elephants in TNPs date back to before 2002 [19], the objective of this study is to update the information on the social structure of forest elephants in TNP. Specifically, it aims to determine the average group size, the proportion of solitary individuals, juveniles and adults within the elephant population of the TNP.

2. Methodology

2.1. Study site

The Taï National Park is in the southwest of Côte d'Ivoire. It extends over three administrative regions, namely: the Nawa region, to the east and northeast, the Cavally region, to the north and northwest, and the San-Pedro region, to the southwest and south. It is located between 5°08' and 6°24' north latitude and 6°47' and 7°25' west longitude. The TNP covers an area of 536016 ha, 99.5% of which is forested [20]. This park stands out for its floristic richness [5, 10, 21] and its faunal richness [9, 10]. Among the emblematic animal species of the PNT is the forest elephant, *Loxodonta cyclotis* (Matschie, 1900). Despite its protected area status, the TNP is subject to various anthropogenic pressures, including poaching [17].

Due to the harmonization of the management method of the Taï National Park and the N'Zo Wildlife Reserve, the two entities are grouped under the name "Taï National Park".

2.2. Data collection

Data collection was done by camera trapping, one of the most appropriate methods for the study of wildlife in the rainforest [22, 23, 24]. To this end, 87 camera traps were set up on the elephant's distribution area in the TNP (Figure 1). The traps were arranged according to a systematic system, with an equidistance of 6 km between two neighbouring CTs [25].

Data were collected over a 120-day period, divided into two phases of 60 days each. Phase 1 took place from June 9 to August 8, 2016, and phase 2 from October 10 to December 9, 2017. The CTs were set to hybrid mode, allowing alternating video sequences of photos to be recorded. The length of the video sequences was 60 seconds during the day and 15 seconds at night. The interval between two successive detections was set to 1 seconds, to allow all details of a group of elephants moving in the CT's field of view to be recorded [24, 26, 27].

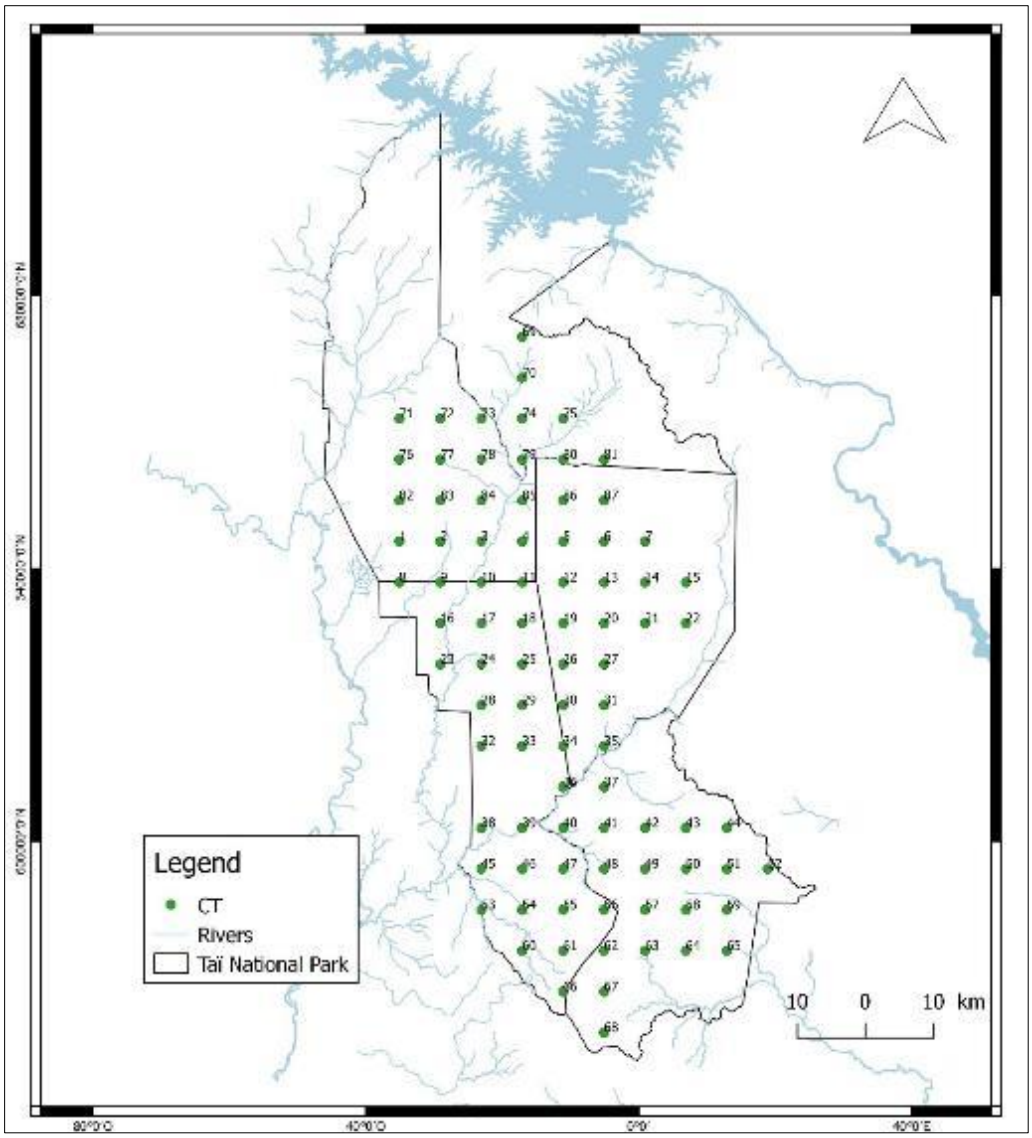


Figure 1 Elephant sampling plan in the Taï National Park

2.3. Data analysis

For a given trapping position and on the same date, successive detections occurring in a period of less than 30 min were considered as a single capture or visit event [27, 28, 29]. However, for the same position, a detection that occurs after a time interval greater than or equal to 30 minutes from the first detection of the previous visit, is considered independent and marks the beginning of a new visit [28, 30].

After grouping the detections into events, number of individuals were first counted for each capture event. This number is considered to be the size of the observed group [27, 30]. The mean size of elephant groups at the TNP was calculated, with and without solitary individuals [19, 31]. Capture events featuring two or more individuals were considered as observations of "family units" [32, 33]. A graph showing the frequency distribution of group sizes was created. [31, 34].

Based on morphological traits such as the relative size of individuals [30] and the absence or size of ivory, two age classes were established

- The adult class, composed of relatively large individuals, on average 2.25 m [35] and/or individuals with very long ivories;
- The juvenile class, composed of individuals whose height at the withers does not exceed 70% of that of an adult female, estimated at a maximum of 2.70 m [36, 37] and devoid of ivories or having small ivories.

The number and proportion of individuals in each age class were determined for each capture event and for the overall population. The Mann–Whitney U test was used to compare the number of adults and juveniles across different groups.

Statistical comparisons were performed using PAST version 3.24. Tests were considered significant at $P \leq 0.05$.

3. Results

At the end of the two trapping phases, 676 videos and photos of elephants were recorded in the TNP. These videos and photos were grouped into 37 capture events. For the 37 events, 100 individuals were counted. This corresponds to an average of 2.7 ± 0.75 individuals per capture event. Solitary detections were the most frequent with 19 events, corresponding to 51.35% (N= 37) of elephant capture events in the TNP. Also, the number of detections decreased with increasing group size (Figure 2).

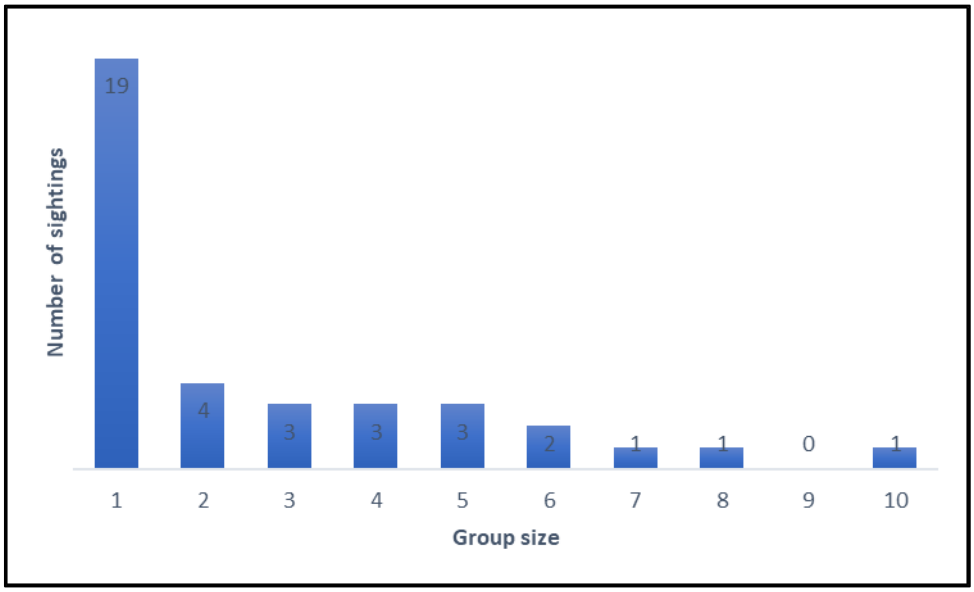


Figure 2 Frequency of distribution of forest elephant group sizes in the Taï National Park

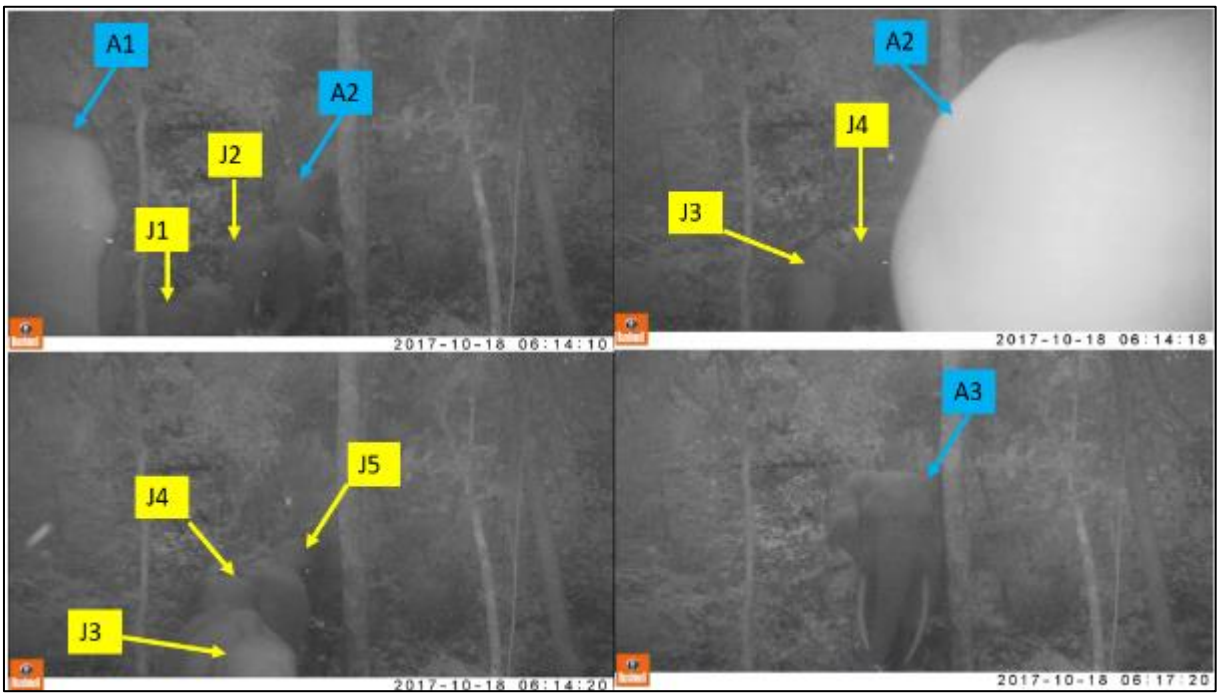
"Family units" (group size greater than or equal to two) were observed on 18 occasions, corresponding to 48.65% (N= 37) of capture events. Considering the total number of individuals observed (100), 81% (N=100) of individuals live within a "family unit", while 19% (N=100) of individuals live alone. For "family units", the modal group size observed was two individuals, recorded in four capture events, representing 22.22% (N= 18) of the group observations. The average size of the "family units" was 4.5 ± 1.04 individuals, with a maximum group size of 10 individuals.

Following the distribution of individuals by age class, 39 individuals were juveniles, representing 39% (N= 100) of the population and 61 individuals were adults, representing 61% (N=100) of the population. All solitary individuals observed were adults (Table 1). Considering "family units" only, 48.15% (N=81) were juveniles and 51.85% (N=81) were adults. Only three "family units", corresponding to 16.67% (N= 18), were composed exclusively of adults, all of which were groups of two individuals. The rest of the "family units", i.e. 83.33% (N = 18), were mixed, made up of adults and juveniles.

Table 1 composition of elephant groups recorded in Taï National Park

Group size	Group composition	Frequency
1	1 Adult	19
2	2 Adults	3
	1 Adult + 1 Juvenile	1
3	1 Adult + 2 Juveniles	1
	2 Adults + 1 Juvenile	2
4	2 Adults + 2 Juveniles	3
5	2 Adults + 3 Juveniles	3
6	3 Adults + 3 Juveniles	2
7	3 Adults + 4 Juveniles	1
8	3 Adults + 5 Juveniles	1
10	6 Adults + 4 Juveniles	1

The "family units" were made up of an average of 2.33 ± 0.25 adults, for an average of 2.17 ± 0.34 juveniles. The number of young was not significantly different from the number of adults in "family units", according to the Mann-Whitney test (P = 0.93). Figure 3 shows a group of eight elephants, including three adults and five juveniles.



A: Adult and J: Juvenile

Figure 3 Images from a video showing a group of eight elephants, including three adults and five juveniles

4. Discussion

Analysis of the social structure of forest elephant in TNP from camera trap images shows that the average group size, including solitary individuals, is 2.7 individuals. The value is similar to that obtained between 1978 and 1980, which was 2.44 individuals per group in the TNP [19]. Also, it remains close to those obtained for forest elephant at other sites in Africa, ranging from 2.1 to 3.0 individuals per group [31, 32, 33, 34, 38, 39]. In addition, excluding solitary individuals, the average elephant group size in the TNP is 4.5 individuals, higher than the value of 3.4 recorded by Merz between

1978 and 1980. In addition, the study obtain 19% solitary individuals and 39% juveniles in the population, compared to 16% solitary individuals and 30.5% of juveniles reported by Merz [19] in the same park, that is TNP. All of the above shows that the social structure of the forest elephant population in the TNP obtained from this study is similar or even better than that recorded by Merz [19] between 1978 and 1980. However, the 1980s were marked by strong pressures on elephants in the TNP, due to poaching [14]. The initial population in the 1970s lost about 90% of its numbers by 1990 [14, 17]. Thus, the recovery of social characteristics comparable to or better than those recorded before the period of intense poaching indicates a possible reconstitution of the population. Poaching not only reduces population size but also disrupts elephant social structures [40]. Poachers targeting large individuals for their more developed ivories are more inclined towards solitary individuals, which are adult males or older females. As a result, they affect their numbers within the population [41]. Therefore, the increase in the proportion of solitary elephants in the TNP would indicate the reduction or cessation of poaching targeting elephants. For example, on sites heavily subject to poaching such as the Bossématié classified forest, solitary individuals have been estimated at 5% of the population [31]. Moreover, the value of 19% recorded in the TNP is still lower than those obtained at sites such as the Dzanga clearing in the Central African Republic and the Maya clearing in Congo, where 29% and 35% of solitary individuals were recorded, respectively [38,39].

In terms of the frequency of distribution of group sizes, it was found that the number of detections decreases with increasing group size. Thus, groups larger than seven individuals are rare in TNP elephants. This confirms Payne's findings [42], according to which groups of forest elephant up to seven individuals in size are not common. This finding also corroborates the results of White et al. [32] and Merz [19], which state that associations of more than eight elephants are exceptional in forest elephant, particularly in the TNP and the Lopé reserve in Gabon. According to these authors, elephant groups tend to be smaller in tropical forests than in grassy savannahs, which are more open. Small groups would find it easier than large groups to exploit resources available in small quantities in places in the forest, such as fruits [1].

Observations of solitary individuals have been found to be the most frequent, as in several other sites, including Lopé Reserve in Congo [32], Dzanga Glade in the Central African Republic [38], Odzala National Park in Congo [34] and Maya Glade in Congo [39]. These solitary individuals are mostly adult males, as they leave the family unit where they were born to lead a solitary existence [42]. However, females remain fused in matriarchal family units of varying size [34, 42]. Thus, according to White et al. [34] Mixed groups, consisting of adult and juvenile elephants, are those of females and their offspring. This is because the males are not involved in the care of the young and only very temporarily associate with groups of females for reproduction [42]. Groups consisting solely of adults are likely temporary associations of males [1].

One of the major limitations of this study would be the imperfect detection, linked to any study involving camera trapping [22, 43]. This may have led to partial determination of the members of a group. Also, the study coulf not establish the sex ratio of the elephant population in the TNP.

5. Conclusion

At the end of this study, it appears that the average size of elephant groups in the TNP, with solitary individuals, is 2.7 individuals/group and 4.5 individuals/group without solitary individuals. This population is made up of 19% solitary individuals and 39% young individuals. These characteristics are comparable to those recorded before 1980. However, the 1980s were marked by an intensification of poaching pressure on elephants in the TNP. Therefore, we can conclude that the elephant population of the TNP has been reconstituted, in terms of the social structure of the population.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest for this article.

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