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New observations in nut cracking behavior of chimpanzees (*Pan troglodytes verus*) in Djouroutou, Taï National Park

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ABSTRACT: Among the variety of activities in which wild chimpanzees use tools, some of the most complex behaviors are seen during nut cracking. As studies of nut cracking have been limited to a few habituated groups of chimpanzees located in a specific area in Taï National Park, we now question whether other groups without contact with the previously studied groups develop the same behavior of nut cracking. Thus, we conducted this study on a group of partially habituated chimpanzees (*Pan troglodytes verus*) in Djouroutou in the southwest of Taï National Park, Côte d'Ivoire. Over a one year period, we collected observational data on chimpanzee feeding behavior, mainly on nut cracking activities. Evidence was found that these chimpanzees crack five species of nuts (*Coula edulis, Parinari excelsa, Panda oleosa, Sacoglottis gabonensis and Detarium senegalensis*) using only stones as hammers for opening the nuts to gain access to the nutritious kernel. This chimpanzee group spends 21.43% of the year cracking one type of nut *Sacoglottis gabonensis*. These findings revealed that other groups in Taï National Park developed nut cracking behaviors with some unique features compared to other groups living in the same forest block. These results contribute to the understanding of the origin and evolution of ecologically driven behavioral adaptations in wild chimpanzees.

KEYWORDS: *Chimpanzees, Sacoglottis gabonensis*, tool use, stones, wood.

1 INTRODUCTION

Nut cracking is one of the most sophisticated activities among the diverse tool-using behaviors found in wild chimpanzees[1],[2],[3]. It is performed to open a nut species to gain access to its nutritious kernel by using specific tools such as stones, wood, or both [4].Nut cracking has been reported by researchers at several sites in West African countries such as Sierra-Leone[5],[6], Liberia[7], Guinée[8] and Côte d'Ivoire[9],[10],[11],[12]. In East and Central Africa, nut cracking have been reported for a single group of chimpanzees that live in the Ebo forest of Cameroon[13].

The studies mentioned above, highlight the variety of behaviors shown by different groups of chimpanzees to successfully forage.

Some few studies [14] showed that chimpanzees use hammers and anvils for nut cracking at 14 sites in Africa. The behaviors necessary for nut cracking chimpanzees include the ability of locating and identifying nut species, choosing the appropriate shape and size of a hammer and anvil, and sometimes even making tool modifications[15],[16],[4].

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Previous research has indicated that many populations of chimpanzees do not crack nuts and the availability of the material is not a limiting factor for tool choice in their habitat[17],[18],[1][12][19].

Studies of nut cracking activities at several sites or at distinct areas from a particular forest block are critically in assessing whether the observed nut cracking behavior is due to cultural differences or environmental conditions.

This study aimed to describe the nut cracking activities by a social group of chimpanzees in the Djouroutou area located in the southwest of Taï National Park. This particular group of chimpanzees in this park has never been studied before. We'll specifically (1) identify the nut species cracked by this group of chimpanzees and (2) determine and characterize the tools used by this group of chimpanzees.

2 METHODS

2.1 STUDY SITE

We conducted our study in Djouroutou area in the southwest of Taï National Park **(Fig. 1**), the largest remaining tropical rain forest in West Africa and covers 536.000 ha. This park is an UNESCO World Heritage Site, and represents one of the world's 25 biodiversity hotspots[20]. The landscape of this park is gradual from the south to the north; the average altitude is 150 meters, with emergence in the south at the *Niénokoué* Mountain, which peaks at 396 meters. Details of the location, climate, flora and fauna can be found in other studies[21],[4],[22].

Our study site, Djouroutou area is located in this park at 12 kilometers east of the nearest town, Djouroutou (5°21'N, 7°17'W). The hydrographic network in this area is dominated by the *Hana* river and is the natural northern border of the territory of the group studied. The chimpanzees sometimes have been observed traversing it, passing on the trunks of trees present in this river as a "foot-bridge".

The study group's territory is about 25 km^2 and contains around 60 individuals. This group has been in contact with field assistants since 1994 for an ecotourism project initiated by the authorities of Côte d'Ivoire. Since 2010, the chimpanzees were followed regularly and daily observations of their feeding behavior were recorded.

Currently, this region of the park is efficiently protected and poaching is low.

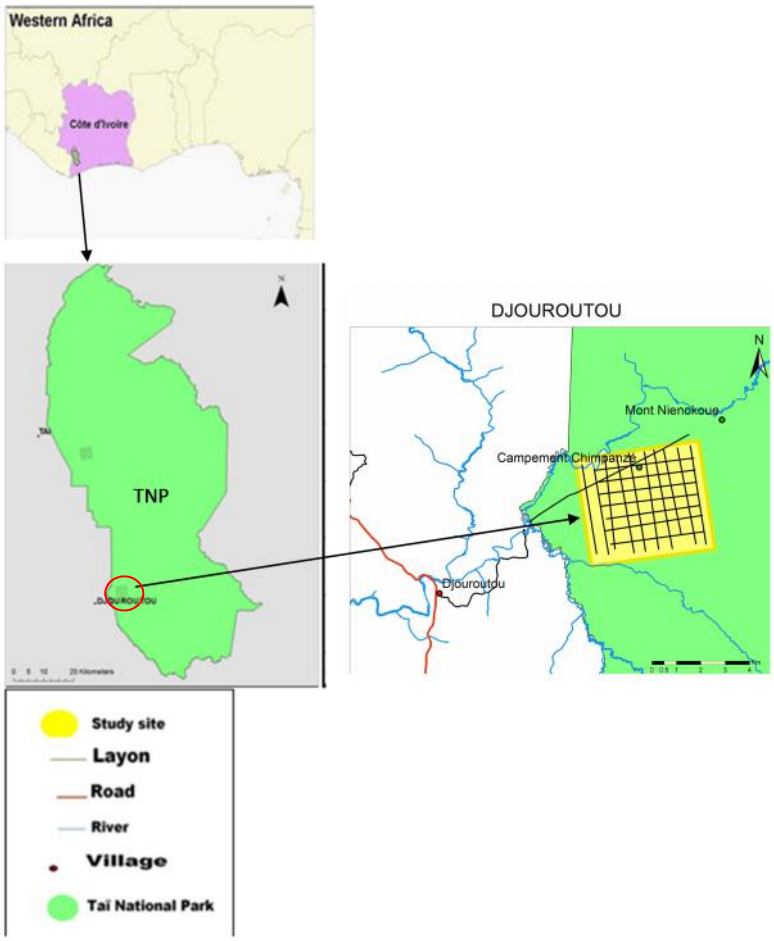

Fig.1. Territory of the chimpanzee group in the Djouroutou area, Taï National Park (TNP)

2.2 DATA COLLECTION

We collected data in the study site between January and December 2012. Data collection was made possible by identifying the active area of the chimpanzee group. One advantage we had in our study was that the chimpanzee group is partially habituated to human presence. The chimpanzees were followed by us, and behavioral data were taken when possible.

Additionally, at the nut cracking sites, we recorded data on the nut shells, the anvil and the presence or absence of a hammer. A cracking site was defined as an anvil plus the remaining shells of cracked nut[15]. Also one species cracking site is one with shells from only a single nut species.

With four field assistants specifically trained in this data collection procedure, we followed individual chimpanzees from nest to nest from 6:00 am to 19:00 pm. We observed each focal chimpanzee from an approach distance of 10 to 12 meters. We recorded feeding data on standardized check-sheets each month. Data were collected according to the *continuous focal animal sampling* method [23]. We recorded data related to the nut cracked species **(Fig. 2)**, and the time spent during this activity. The nut cracking activity for the year 2012 was approximately 62 hours of data.

2.2.1 IDENTIFICATION AND CHARACTERIZATION OF TOOLS USED FOR NUT CRACKING

We identified and characterized the tools used and recorded the weight and the type of hammers (wooden or stone) used. Hammer used was defined as stones or wood which show evident wear due to nut cracking. To measure stone hardness, we first struck the hammer with the force necessary to crack a nut; friable stones were thus eliminated. Additionally, we randomly choose stone hammers to make an experimental test by placing a 10-cm steel nail on a stone and stabilized it using a disc. We then dropped a 2-kg hammer five times, through a cylinder, onto the nail from a height of 50 cm. We measured the depth of the depression on the surface of the stone using a slide caliper with a capacity of 150 mm and an accuracy of 0.02 mm. This test allowed us to categorize the relative hardness of each stone material. We classified the stones according to their resistance. We measured the width of the used anvil i.e., substrates on which the nut was placed to be hammered. To better understand preferences for the types of root anvils of this group of chimpanzees, we pooled the anvils used at the cracking site into two categories: the first contains the anvils of the nut producing tree "*Tree roots*" and the second contains the anvils of all other trees"*Other tree roots*". For the definition of "*tools used*" see [15],[16],[12].

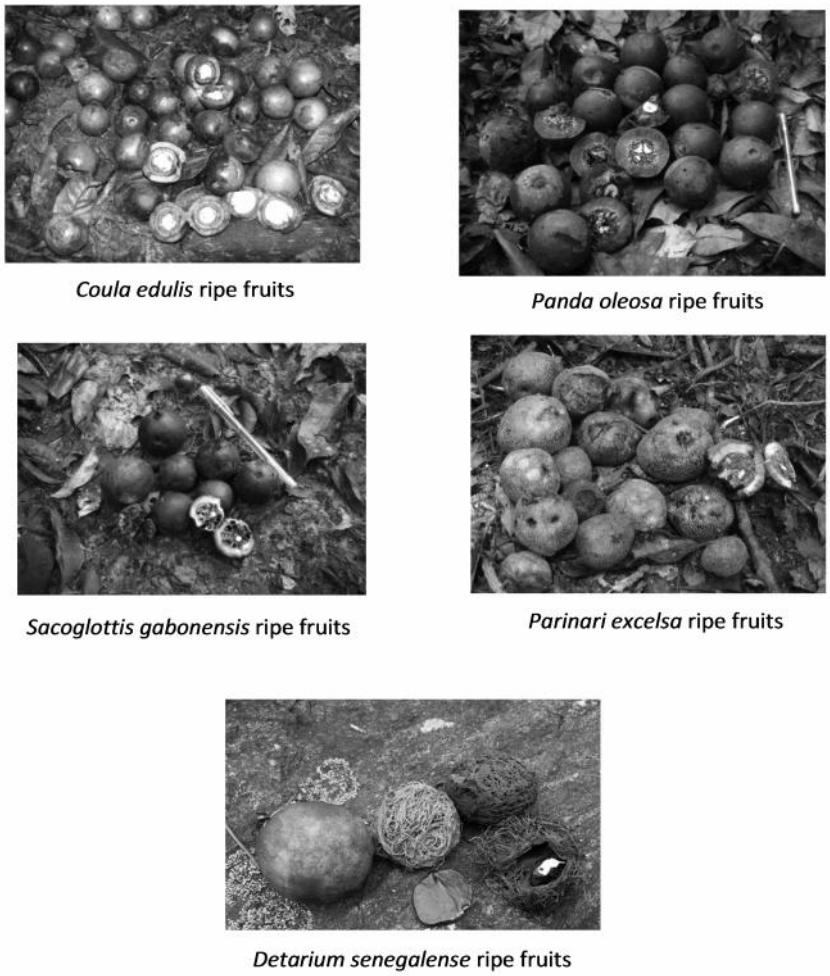

Fig.2. Photographic views of ripe fruits whose kernels are eaten after being cracked by chimpanzees In Taï National Park

2.3 DATA ANALYSIS

The percentage of time spent during one year to crack each nut species was calculated with the following formula:

$$T = [\sum_i t_i / \sum t] \times 100$$

Where **T** is the percentage of time spent cracking each distinct nut species, t_i is the sum of the time chimpanzees were observed cracking each distinct nut species and **t** is the total time spent cracking all species of nuts combined.

Statistical analysis was made using the Student's t-test to compare the mean of stone anvil used and root anvil used for cracking nuts. The Kruskal-Wallis (X^2) test was used to compare the mean hardness of stone between stone type, and between the weight of the hammer used and the time spent to crack different nut species. We calculated the mean stone weight to make comparisons between the stone used and the nut species.

All the statistical tests were done using R software (R 2.15.3) [24].

3 RESULTS

3.1 NUT SPECIES CRACKED BY DJOUROUTOU CHIMPANZEES AND TIME SPENT FOR THIS ACTIVITIES

3.1.1 NUT SPECIES CRACKED

Based on specific nut tree species, we identified five sites of nut cracking in the Djouroutou area (**Table 1)**. We found 108 cracking sites for *Sacoglottis gabonensis* (Humiriaceae) (**Fig. 3**), 107 for *Parinari excelsa* (Chrysobalanaceae), 100 for *Coula edulis* (Olacaceae), 85 for *Panda oleosa* (*Pandaceae)* and 1 for *Detarium senegalense (Caesalpiniaceae)*.

Table 1. Distribution of anvil and hammer in one species cracking site found in Djouroutou area

		Anvils		Hammers	
Cracking site	**Total number of cracking site**	**roots**	**stones**	**wooden**	**stones**
Sacoglottis gabonensis (Humiriaceae)	108	79	29	0	59
Parinari excelsa (Chrysobalanaceae)	107	73	34	0	73
Coula edulis (Olacaceae)	100	79	21	0	59
Panda oleosa (*Pandaceae)*	85	47	38	0	77
Detarium senegalense (Caesalpiniaceae)	1	1	0	0	1

Fig.3. Cracking site of Sacoglottis gabonensis nuts made by Djouroutou chimpanzees on a root anvil (A) without the hammer and a stone anvil (B) with the stone hammer

3.1.2 MONTHLY NUT CRACKING ACTIVITIES AND TIME SPENT

During 12 months of chimpanzee observations, we noticed two *Coula* nut cracking seasons (January to March and November to December). *Coula* is cracked first on the ground and then in a tree (14 observations) or vice-versa. *Panda* nut was cracked almost all year except for the months of May and June. *Sacoglottis* trees are generally found in swampy areas. *Sacoglottis* dry nut was cracked in March and from May to November and *Parinari* dry nut from February to March and May to November. Time spent by Djouroutou chimpanzees during the year to crack the different species of nuts was similar X^2 = 7.41, df = 3, P = 0.059. The percentage of time spent cracking each nut during the year was as follows: *Parinari* = 32.35%, *Coula* = 30%, *Sacoglottis* = 21.43% and *Panda* = 16.22%. We did not observe chimpanzees cracking *Detarium* nuts. (**Fig. 4)**

For both (*Sacoglottis* and *Parinari*) ripe fruits, chimpanzees create a wadge (consisting of pulp, nut and skin) by choosing ripe fruit that contains a sticky pulp, putting it in their mouth and repeatedly masticating the fruit while sucking the juices from the fruit. They sometimes remove the wadge with their hand, take new fruits, and then put the wadge into their mouth again. For the *Sacoglottis* fruits, chimpanzee sometimes plunges the wadge slightly in water and then back into its mouth to extract the residual juice. When the extraction is finished, the wadge is not swallowed but rejected onto the ground. These activities occurred for *Sacoglottis* from January to April and from August to December and for *Parinari* from January to May and September to December. The nut cracking occurs later when the nut is dried to extract the kernel.

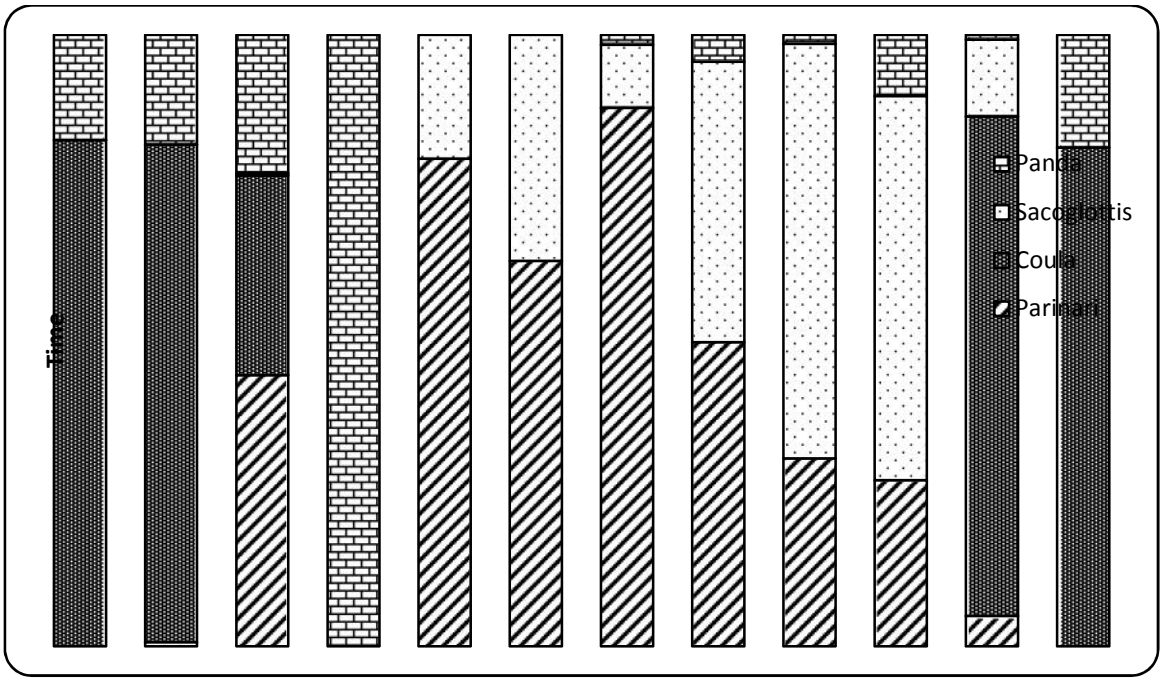

Fig.4. Percentage of time spent per month to crack each species of nuts

3.2 IDENTIFICATION AND CHARACTERIZATION OF TOOLS USED FOR NUT CRACKING BY DJOUROUTOU CHIMPANZEES

3.2.1 HAMMERS

We found 269 stone hammers used by Djouroutou chimpanzees, distributed in four raw types of stone. We found, by order of abundance, *quartzite* (N = 195), the *granito gneiss* (N = 51), *granite* (N = 18), and *laterite* (N = 4). We found one rare stone hammer used for *Panda* nut cracking that had an iron aspect of 1.35 kg. *Quartzite* stone was most frequently found but weighed the least (mean=1.93±0.12), followed by *granito gneiss* (mean=4.91 ± 0.53), *granite (*3.71± 0.41) and *laterite* (mean= 1.43±0.46). The results of the weight of the stone hammers used as a function of the nut reveal highly significant differences (X^2 = 22.82, df = 3, P < 0.001). *Panda* nuts are cracked with *quartzite* stone and it was also the only nut cracked with a majority of the heaviest stones. All nuts were cracked systematically with stone hammers. *Quartzite* is the hardest stone (impact depth mean = 1.15*±0.08)*, followed by *granite* (impact depth mean = 1.25*±0.19)*, *granito gneiss* (impact depth mean = 5.26±0.38), and lastly *laterite* (impact depth mean = 5.5±0.86) **(Fig. 5)**.

The experimental test of the hardness of the stone hammers type used showed a significant difference (X^2 = 35.27, df = 3, *P*<0.001).

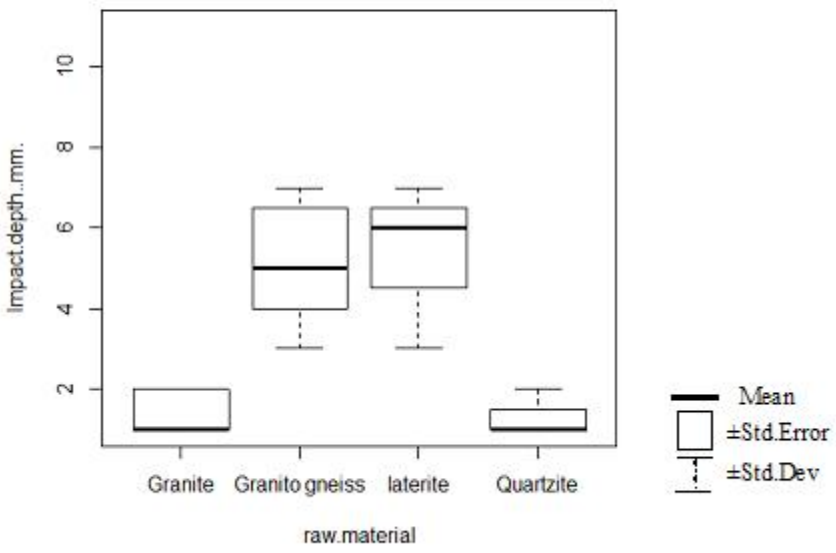

Fig.5. Hardness of the stone material according to the depth of the impact (experimental test)

3.2.2 ANVILS

We found that Djouroutou chimpanzees used more root anvils (N = 279) than stone anvils (N = 122) t = -4.60, df = 4.312, P <0.001 **(Table 1)**. For the preferences of the root anvils, we excluded the *Detarium* cracking site because of the small sample size of one. Of the 91 anvils used for *Sacoglottis*, 57 were anvils of the nut producing tree (mean width = 7.60±0.37 cm) and 16 were anvils of other trees (mean width = 7.09±0.66 cm). Of the 69 anvils used for *Coula,* 40 were anvils of the nut producing tree (mean width = 5.64±0.30 cm) and 22 were anvils of other trees (mean width = 5.94±0.42 cm). Among the 67 anvils used to crack *Parinari* nuts, 42 of them were anvils of the nut producing tree (mean width = 8.57±0.52 cm) and 13 were anvils of other trees (mean width = 6.69±0.77 cm). Of the 54 anvils used for cracking *Panda* nuts, 20 were anvils of the nut producing tree (mean width = 11.84±3.09 cm) and 21 were anvils of other trees (mean width = 7.79±0.63 cm) (**Table 3**). The percentage of stone anvils used was higher for *Panda* (24.07 %) than for *Sacoglottis* (19.78 %), *Parinari* (17.91 %) and *Coula* nuts (10.14%).

Table 3. Percentage (%) of stone anvils and total of root anvils used with mean width (cm) according to the trees species. (): indicate the mean width of root anvils

	Anvils					
Trees species	**Total anvils**	**(%) stone**	**Tree roots**		**Other tree roots**	
			Number	**Mean width±Std.Dev**	**Number**	**Mean width±Std.Dev**
Sacoglottis gabonensis	91	19.78	57	7.60±0.37	16	7.09±0.66
Coula edulis	69	10.14	40	5.64±0.30	22	5.94±0.42
Parinari excelsa	67	17.91	42	8.57±0.52	13	6.69±0.77
Panda oleosa	54	24.07	20	11.84±3.09	21	7.79±0.63

4 DISCUSSION

Direct observation showed that, Djouroutou chimpanzees cracked four nut species during variable periods of the year. They cracked *Coula* and *Panda* nuts during the same period as well as another group of chimpanzees living in this national park "the Taï group"[15]. This group is located in the north west at 20 kilometers east of the nearest town, Taï. In the Taï group *Parinari* nuts were cracked from June to October [15]. However this seems not to be the case in Djouroutou where this nut is cracked within a total of nine months per year. *Sacoglottis* nuts were commonly cracked eight months of the year by Djouroutou chimpanzees. Hence, based on this observation, the *Sacoglottis* nuts represents a preferred food for this group and not a fallback foods[25], whereas Cracking *Sacoglottis* nuts was only heard once in October in the Taï group [15]. With regards to the *Detarium* we did not observe nut cracking sessions, but we found evidence for one cracking site of this nut, due to the rarity of this nut producing trees in the Djouroutou area. Similar result was found with the Taï chimpanzees group, with a low frequency too, related to the rarity of the nut producing tree in this area [15]. Thus so far we can confirmed that Djouroutou chimpanzees cracked five species of nuts. Five is also the number of nut cracked by the Taï group (four species of nuts frequently and one specie rarely)[15]. However, the Taï group does not seem to like the kernel of *Sacoglottis* nut but instead prefer only the juice in the pulp [4]. Our results showed a local difference in feeding habit compared to the Taï group where despite to the high density of *Sacoglottis* trees in this area, the latest chimpanzees group do not crack this nut species [15],[16],[12], but a similarity with chimpanzees living in Sapo National Park, Liberia. Djouroutou chimpanzees frequently crack *Sacoglottis* nuts. Thus, the *Sacoglottis cracking* behaviour was observed as well in the chimpanzees group of Sapo National Park[26]. This observation is surprising seeing that the Taï and Djouroutou chimpanzee groups are present in the same forest block and live only 60 km apart.

Another area which is likely to yield worthwhile comparisons across groups is the use of tools. The used of wooden hammers was common in the Taï group, mainly to crack *Coula* nuts[15][27]. Our results clearly demonstrated that the chimpanzees of Djouroutou do not use wooden hammers to crack nuts. All of the hammers found by us were stone. Djouroutou chimpanzees used four types of stone hammers to crack nuts. *Quartzite* stones were used most often and in addition are the most abundant stone spread over the territory. Studies conducted of wild chimpanzees [28] and of captive chimpanzees [29] showed that chimpanzees tend to use heavy stone hammers to crack hard nuts. Djouroutou chimpanzees showed evidence of this trend. They used hard and heavy stone hammers to crack *Panda oleosa* which are the toughest than any nut exploited as food in Africa [30][16]. The use of rare, raw stone hammer with a heavy weight to crack this nut, attests to this trend.

Aside from cracking nuts on stone anvils, Djouroutou chimpanzees preferred to crack on root anvils. These results are the same with the study carried out on the anvils used by chimpanzees of the Taï group where 89.9 % of the anvils used are root anvils when 8.8% are stone anvils[31]. For *Parinari, Coula* and *Sacoglottis* nuts, Djouroutou chimpanzees preferred to crack on the root of the nut producing tree rather than other trees. The width of the anvil of a nut producing tree was higher than other trees except for *Coula* trees where the width of the nut producing tree was lower than that of other trees. *Panda* nuts were cracked more often on the roots of other trees that had a smaller width than the roots of the nut producing tree which had a greater anvil width. Djouroutou chimpanzees cracked more *Panda* nuts on stone anvils compared to other nuts. This is probably due to the presence of stone supports around these trees and also the hardness of this nut.

5 CONCLUSION

Our study is the first one which describe the nut cracking activities in this particular group of chimpanzees in the Taï National Park. The group of chimpanzees in Djouroutou cracked five nut species and only used stone hammers. Furthermore, they cracked *Sacoglottis* nuts more than any other nuts, in contrast to other chimpanzee groups present in this national park that do not crack *Sacoglottis* despite its pervasiveness and high abundance. However, numerous questions remain unanswered for this newly habituated group such as why do they crack frequently *Sacoglottis* nuts while the Taï groups do not? Why do they use only stone hammers to crack the five nut species while the Taï groups use stone and wooden hammers? Extensive and long-term research is necessary to answer these questions. Studying the Djouroutou chimpanzees will help us to contribute to the understanding of the behavioral differences between chimpanzee groups living in the same forest block.

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