

Spatiotemporal Distribution of *Eidolon helvum* (Kerr, 1792) Near-threatened Species (Côte D'Ivoire, West Africa)

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Abstract

The straw-colored fruit bats population, *Eidolon helvum* (Kerr, 1792), a near-threatened species has been studied from August 2005 to July 2006 in the District of Plateau in Abidjan. That study has been carried out through direct observations and reckoning of tree used by straw-colored bats as roosts in the dormitory site in order to establish the habitat using way. Results show that the straw-colored bats prefer the dormitory site of *Hevea brasiliensis* Kunt. (Euphorbiaceae) and *Mangifera indica* L. (Anacardiaceae). The straw-colored bats number varied with the site, the tree species and the season.

Keywords: Straw-colored bats, habitat, season effect, urban area, Côte d'Ivoire.

1. Introduction

Chiropters distribution area stretches over the whole globe apart from the Antarctic. They are one of the most diversified groups of vertebrate and have interests in systematic, ecologic, pharmacologic, veterinary, medical, economics and conservation point of view (Kunz *et al.*, 2011; Adams and Pedersen, 2013; IUCN, 2015; Fenton and Simmons, 2015; Niamien *et al.*, 2015; Plowright *et al.*, 2015; Saéz *et al.*, 2015; Herkt *et al.*, 2016; Voigt and Kingston, 2016). Despite such a multiple interests, little bio-ecologic data are available because of their nocturnal activities and their way of active flies, which make difficult their study (Kunz and Parson, 2009; Herkt *et al.*, 2016). Studies upon the ecology of the fauna have a significant aspect for the establishing of conservation strategy (Fleming and Racey, 2010; Voigt and Kingston, 2016). In Côte d'Ivoire, the District of Plateau (Abidjan) shelters a great population of straw-colored bats, *Eidolon helvum* (Kerr, 1792), an endangered species (IUCN, 2015). They use that urban site respectively as roosting site, maternity and nursery. Despite that ecologic interest, this colony of straw-colored bats have been a subject of a little interest by

scientific community (Huggel-wolf and Huggel-wolf, 1965; Thomas, 1983; Niamien *et al.*, 2009, 2010, 2015, 2017). However, that fruits-eaters, by their feeding contribute, to give pollen to flowers and to the reconstitution of ecosystems, through the dispersion of the eaten fruits grains (Kunz *et al.*, 2011; Moratelli and Calisher, 2015; Myers *et al.*, 2015; Voigt and Kingston, 2016). In addition, it is one of the rare animal groups able to ensure the dispersion and to favor the germination of grains of Iroko *Milicia excelsa* Welw. (Moraceae), a forest threatened essence because of its over exploitation in West Africa (Hawthorne, 1995; Taylor *et al.*, 2000). Then, the District of Plateau by the remarkable presence of straw-colored fruit-eater bats community should be considered as a strategic site, essential for the conservation of the biodiversity. To succeed in doing so, a better understanding of the distribution of that near threatened species of straw-colored fruit bats is proved to be indispensable (Herkt *et al.*, 2016), on one hand because of its distinctiveness of habitat (Threlfall *et al.*, 2013) and on the other hand, in the reason of its gregarious attitude, which increases its vulnerability to poaching (Kamins *et al.*, 2011; Niamien *et al.*, 2015).

The present said study, the first of that kind, is a contribution to a better knowledge of chiropters in order to ensure a rational and a sustainable management. It specifically aims to analyze habitats using ways (sites and dormitory tree species) by the straw-colored fruit bats of the District of Abidjan-Plateau and to examine seasons influence on that repartition to draw off implications for its protection of that near threatened species.

2. MATERIAL AND METHODS

2.1 Study site

Abidjan is located in the South of the Côte d'Ivoire. It is made up with many communes included that of Plateau, which stretches between longitude 4°10' and 4°50' West

and between latitude 5°10' and 5°40' North on an area of 2.5 km². That commune shelters in its central part a large community of fruit-eater straw-colored bats, which use the different tree species growing in its avenues as roosting place. Those straw-colored fruit bats are object to poaching (Niamien *et al.*, 2015).

The climate of the town of Abidjan and that of the South of the country, is characterized by four seasons: The small dry season (from August to September), the small rainy season (from October to November), the long dry season (from December to March) and the long rainy season (from April to July) (Brou, 1997; Niamien, 2011).

2.2 Data collection

Data collection has been done from August 2005 to July 2006, in the 16 roosting sites of straw-colored fruit bats in a global area of 0.006 km² (Figure 1). Visits took place on Saturdays, in order to take into account the poaching activities, which take place on the other no working days (Niamien *et al.*, 2015).

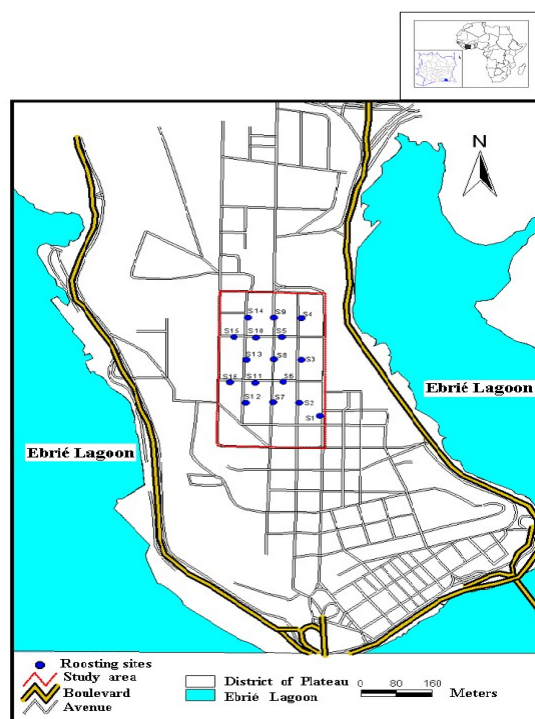


Fig. 1 Cartography of 16 roosting sites of straw-colored fruit bats in the District of Plateau in Abidjan from August 2005 to July 2006.

Four monthly counting of perched and sleeping straw colored bats have been done per site and per tree species during day light apart from football match days at Felix Houphouët Boigny stadium, adjoining the study zone. In fact, during the football match, the spectators cry caused massive flights of bats (Tidemann and Flavel, 1987; Mann

et al., 2002; Grimm *et al.*, 2008; Nordt and Klenke, 2013). That counting has been done between 7 Am and 5 Pm, before they get up and start their massive activity. The perched bats were counted on every branches of every roosting tree, from the base of branches towards the extremities, whatever the sex and age, thanks to binoculars and to manual counter (O'Shea *et al.*, 2003; Vanhof and Fenton, 2004; Sutherland, 2006; Kunz and Parson, 2009; Niamien *et al.*, 2010; Hayman *et al.*, 2012). Besides, the usage frequencies of roosting tree species were also determined.

2.3 Statistical analysis

After checking data normality with the test of Shapiro-Wilk, the analysis of variance was done to compare the average numbers of straw-colored fruit bats per site and per tree species. After this analysis, the Post-Hoc test of comparison and classification of Newman-Keuls permitted to determine the sites and roosting tree species sheltering the most straw-colored bats. Tree species usage frequencies were compared by using the non-parametric test of Khi-two. The seasonal distributions of bats per site and per tree species were done thanks to correspondences analysis. At last, the site effects, tree species and season on the distribution of straw-colored bats were tested by using the generalized linear model. All the statistical analysis was done with *STATISTICA* software (version 7.1).

3. Results

3.1 Floristic inventory of roosting sites

The 16 roosting sites (Figure 1) are planted with 274 trees belonging to four species: 147 trees of *Samanea saman* Merr. (Mimosaceae) (53.65%), 46 trees of *Terminalia catappa* L. (Combretaceae) (16.79%), 45 trees of *Hevea brasiliensis* Kunt. (16.42%) and 36 trees of *Mangifera indica* L. (Anacardiaceae) (13.14%). The number of trees per site varied from six (6) to 34. The floristic planting is dominated by *Samanea saman*, apart from sites 2, 3 and 4 where *Hevea brasiliensis* is the most abundant species; sites 13 and 14 where *Terminalia catappa* is the most represented species whereas the sites 9 and 12, *Mangifera indica* is the preponderant tree species. The densities varied from 5 to 28 trees / 1000 m² (Table 1).

3.2 Global distribution of the number of bats

• Per Site

Globally, bats average numbers exhibited a significant variability difference with the site (ddl= 15; F = 7.62; p < 0.001). Indeed, the test of Newman-Keuls showed that the most high numbers of bats were observed in sites 3, 5, 8 and 9. However, the other processed sites sheltered a moderate (sites 1, 2, 4, 10 and 12) and a weak (sites 1, 2, 4, 10 and 12) bats numbers (Figure 2).

Table 1: Distribution of tree species in the 16 roosting sites of *Eidolon helvum* in the commune of Plateau Abidjan from August 2005 to July 2006.

Roosting Sites	<i>Samanea saman</i>	<i>Terminalia catappa</i>	<i>Hevea brasiliensis</i>	<i>Mangifera indica</i>	Total	Densities (tree / 1000 m ²)
Site 1	7	0	0	1	8	6,73
Site 2	10	0	11	0	21	17,6
Site 3	12	0	16	0	28	23,5
Site 4	9	0	16	0	25	21
Site 5	8	0	0	0	8	12,3
Site 6	9	0	0	0	9	13,8
Site 7	5	0	0	1	6	5,05
Site 8	28	0	0	6	34	28,6
Site 9	8	2	0	15	25	21
Site 10	8	0	0	0	8	12,3
Site 11	13	0	0	0	13	10,9
Site 12	0	9	1	10	20	16,8
Site 13	0	22	0	0	22	18,5
Site 14	0	13	1	2	16	24,6
Site 15	13	0	0	1	14	21,6
Site 16	17	0	0	0	17	26,2
Total	147	46	45	36	274	
Proportions (%)	53,65	16,79	16,42	13,14	100	

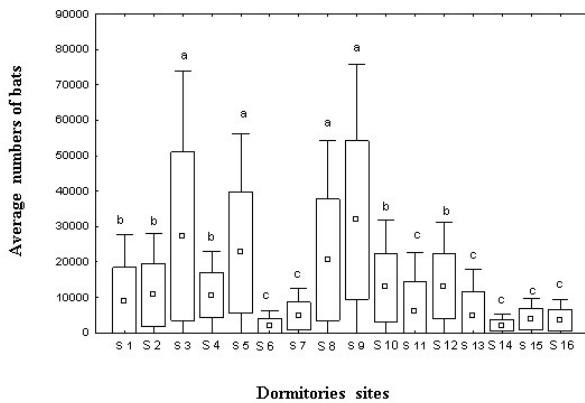


Fig. 2 Global variations of moderate amount of straw-colored fruit bats per dormitories sites in the District of Plateau in Abidjan from August 2005 to July 2006 (a: Frequently used sites; b: moderately used sites; c: weakly used sites; S1 : site 1, S2 : Site 2, S3 : Site 3, S4 : Site 4, S5 : Site 5, S6 : Site 6, S7 : Site 7, S8 : Site 8, S9 : Site 9, S10 : Site 10, S11 : Site 11, S12 : Site 12, S13 : Site 13, S14 : Site 14, S15 : Site 15 et S16 : Site 16).

• Per tree species

The average numbers of bats significantly varied with the species (ddl = 3; $F = 17.59$; $p < 0.001$). The test of Newman-Keuls showed that *Mangifera indica* has hosted the large number of bats. The same analysis suggested, *Samanea saman* as sheltering a moderate numbers of bats, whereas weak numbers were observed for *Hevea brasiliensis* and *Terminalia catappa* tree species, which do

not significantly defer according to the test of Newman-Keuls (Figure 3).

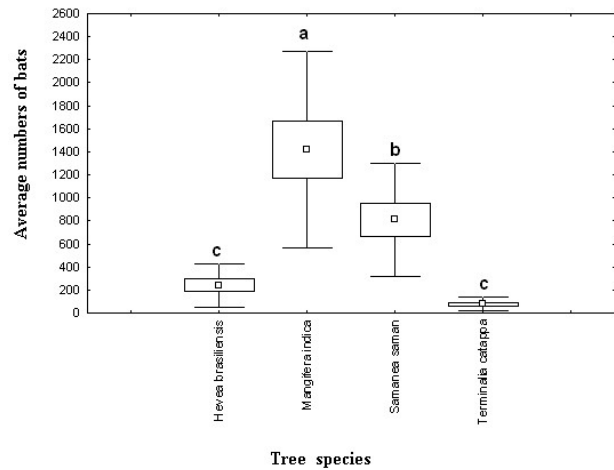


Fig. 3 Global variations of moderate amount of straw-colored bats per tree species in the commune of Plateau in Abidjan from August 2005 to July 2006 (a: frequently used tree species, b: moderately used tree species, c: weakly used tree species).

The exploitation of tree species by processed bats, varied during the study period ($\chi^2 = 16.92$; ddl = 3; $p < 0.001$). Then, comparison as well as classification survey, based on the Khi-two test revealed *Hevea brasiliensis* and *Mangifera indica* tree species as the most exploited by bats. *Samanea saman* was moderately used whereas *Terminalia catappa* was less colonized (Figure 4).

3.2 3.3 Relationship between bats number and seasonal variation

• Per site

The correspondences analysis applied to the seasonal proportions of straw-colored fruit bats per roosting site (Figure 5), exhibited roosting sites located on the left of the first axis (93.51 % of contribution) as the less used in every season (sites 1, 2, 4, 6, 7, 11, 13, 14, 15 and 16).

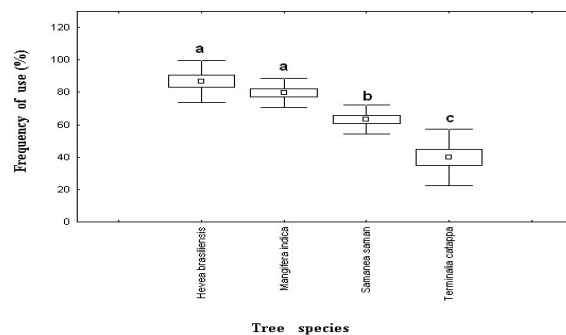


Fig. 4 Global variations of tree species usage frequencies by the straw-colored fruit bats in the District of Plateau in Abidjan from August 2005 to July 2006. (a : frequently used tree species, b : moderately used tree species, c : weakly used tree species).

Taking into account the second axis (3.52 % of contribution), a more neat classification is made concerning the most exploited sites by the bats. Thus, during the long dry season and the small rainy season, sites 3, 5 and 9 have sheltered the greatest numbers of bats whereas during the small dry season and the long rainy season the sites 8, 10, and 9 took precedence over the other considered sites (Figure 5). As a result, an influence of the season appears in the exploitation of roosting sites. The Generalized Linear Model confirm that observation by noticing that the distribution of straw-colored fruit bats per site significantly varied with the season (GLM: ddl = 3; W = 1815.9; $p < 0.05$).

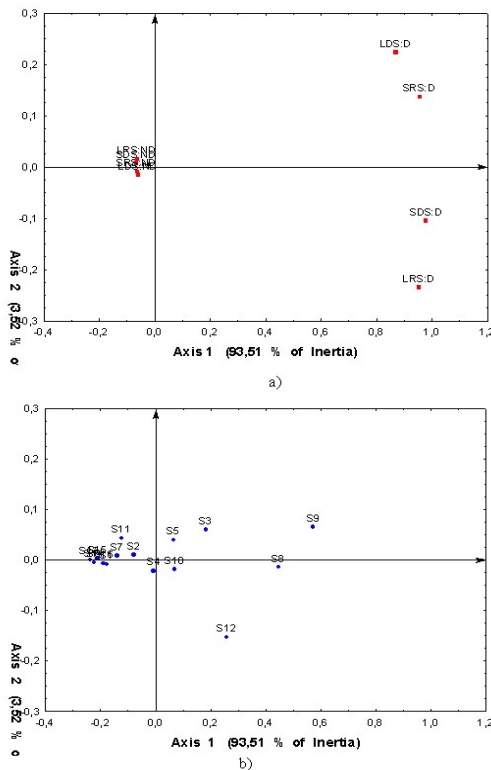


Fig. 5 Seasonal spatial distribution of straw-colored fruit bats of the District of Plateau in Abidjan from August 2005 to July 2006.

(SDS : small dry season, SRS : small rainy season, LDS : long dry season, LRS : long rainy season ; D : more used, ND : moderately used ; S1 : site 1, S2 : site 2, S3 : site 3, S4 : site 4, S5 : site 5, S6 : site 6, S7 : site 7, S8 : site 8, S9 : site 9, S10 : site 10, S11 : site 11, S12 : site 12, S13 : site 13, S14 : site 14, S15 : site 15 et S16 : site 16).

- Per tree species

The study of the seasonal distribution of straw-colored bats per roosting tree species by the means of correspondences

analysis (Figure 6), permitted to distinguish two sets when considering the first axis (97.79 % of contribution). At the right of that axis, the first set gathered *Terminalia catappa* and *Hevea brasiliensis* tree species, which sheltered the lowest proportions of straw-colored fruit bats.

On the other hand, the second set made up with two tree species (*Mangifera indica* and *Samanea saman*), which resulted constantly solicited during the different seasons. In fact, considering the axis 2 (2.19 % of contribution), a segregation is high lightened. Thus, during the long rainy season, *Mangifera indica* has sheltered the greatest number of bats as opposed to *Samanea saman* tree species during the other seasons (Figure 6). Considering as a whole, the present survey advised that straw-colored fruit bats distribution per roosting tree species, was significantly influenced by the season (GLM: ddl = 3; W = 13.81 ; $p < 0.05$).

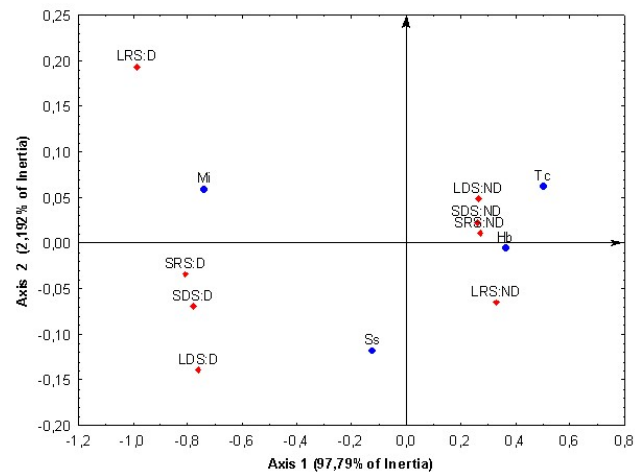


Fig. 6 Seasonal distribution of straw-colored bats per roosting tree species in the District of Plateau in Abidjan from August 2005 to July 2006 (Hb : *Hevea brasiliensis*, Mi : *Mangifera indica*, Ss : *Samanea saman*, Tc : *Terminalia catappa* ; LDS : long dry season LRS : long rainy season ; SRS : small rainy season ; SDS : small dry season ; D : more used, ND : moderately used).

The projections of seasonal exploitation frequencies of tree species colonized by the straw-colored fruit bats, obtained from the correspondences analysis (Figure 7), according to the axis 1 (98.08 % of contribution), discriminated two distinct groups of the former's. The first group included two tree species (*Terminalia catappa* and *Samanea saman*), which resulted to be less exploited during the different seasons. The second group is made up with two trees species; *Hevea brasiliensis* and *Mangifera indica*, which were different by their blazed exploitation during the seasons.

Considering the axis 2 (1.8 % of contribution), it appears a segregation in the exploitation of trees species mostly colonized by straw-colored fruit bats. Thus, during the

long dry season and the small rainy season, *Hevea brasiliensis* was the most exploited while during the long rainy season and the small dry, *Mangifera indica* was more frequently used (Figure 7). Therefore, a season effect is displayed since the distribution of bats per tree species varied significantly with the season (GLM: ddl = 3; W = 69.22 ; $p < 0.001$).

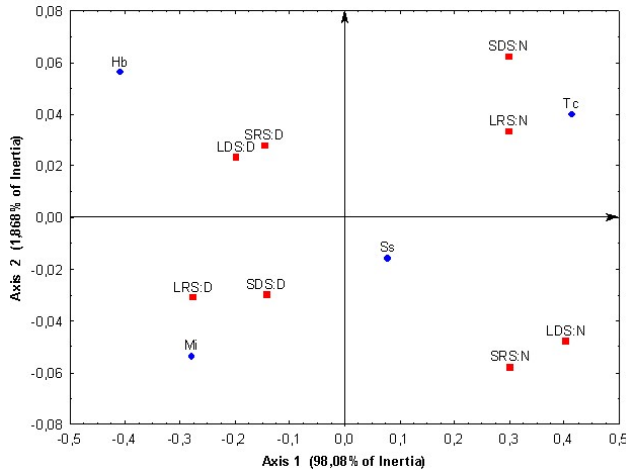


Fig. 7 Distribution of tree species use frequencies by straw-colored fruit bats in the District of Plateau in Abidjan from August 2005 to July 2006 (Hb : *Hevea brasiliensis*, Mi : *Mangifera indica*, Ss : *Samanea saman*, Tc : *Terminalia catappa* ; LDS : long dry season ; LRS : long rainy season ; SRS : small rainy season; SDS : small dry season; D : more exploited , N : moderately exploited).

4. Discussion

The choice of roosting sites would be guided by the existence of better security and feeding conditions. In fact the bats of the District of plateau were the numerous around the direction of the judiciary police (Sites 5 and 9), the national assembly (Site 3) and some private home (Site 8), where a dissuasion seems to be exercised on the poachers by the presence of police and militaries in guard duty. The bats are poached by the residents, who used sling-short (Niamien *et al.*, 2015). That could explain why we often find them in areas where poaching pressure is more weak (Koné, 2004; Threlfall *et al.*, 2013). Besides the poaching pressure, the sites choice seems to be guided by food considerations. In fact, the rounding-up of straw-colored fruit bats on *Mangifera indica* was marked despite that tree species is not abundant and has less displayed branches compared with *Samanea saman* which structure offers more perching possibilities to a great numbers of straw-colored fruit bats. That also reveals the preference of bats for that tree species (Thomas, 1982; Fahr and Kalko, 2011). The presence of ripe mangoes in that aforementioned roosting sites or nearby, during the long rainy season and the small dry season, seems to be the deciding factor in the habitats choice made by the fruit-

eater mammals (Gautier-Hion, 1990; Fahr and Kalko, 2011; Adams and Pedersen, 2013). The colonization of sites made up with *Mangifera indica* would also have three advantages, because these sites would serve them as roosts, nutrition site and nurseries. This choice then would contribute to reduce the energetic cost linked to the locomotion and would increase for their reproductive success (Richter and Cumming, 2006; Fahr and Kalko, 2011; Durant *et al.*, 2013; Cisneros *et al.*, 2015).

The greatest numbers of straw-colored fruit bats observed on the tree species *Samanea saman*, seems to be linked to the fact that this roosting tree species is the more abundant (53.65 %) and because of its structure (Thomas, 1982). Although the average numbers of straw-colored fruit bats per tree species is in favor of *Mangifera indica*, the greatest numbers of the colonized tree species correspond to *Samanea saman*. That species comes secondly after *Mangifera indica* by referring to the average numbers of bats par tree. Thus this tendency would reverse, seeing the large number of the tree species *Samanea saman* ($n = 147$) colonized during the study.

The use of *Hevea brasiliensis* as roosting tree species seems to be linked to light intensity. The intensity of light plays an important role in the fruit-eater bats' choice of habitats. Then, certain fruit-eater bats colonized dark places (Jung and Threlfall, 2016). In the straw-colored fruit bats community of plateau, this adaptation would be expressed by the colonization of dense foliage tree species. On one hand that choice would contribute in reducing the loss of water by the creation of humid microclimate and on the other hand it would not impact its physiology and therefore its circadian activity by the fact of their nocturnal activity (Nordt and Klenke 2013; Dominoni *et al.*, 2014). Otherwise, the poaching activity would contribute to the colonization of that tree species. In fact, as response to this practice pressure the straw-colored fruit bats would look for shelter. The dense foliage of *Hevea brasiliensis*, would offer a bad sight to poachers, who look for locating them, because for animals the best way to escape from a human predictor is to be hidden (Koné, 2004; Threlfall *et al.*, 2013).

4. Conclusions

The study of the habitat way of the straw-colored fruit bats of the District of plateau in Abidjan revealed potential 16 sites and proposed four tree species as dormitory since providing best security and food condition by processing sites 3, 5, 8 and 9. Among these tree species, *Hevea brasiliensis* and *Mangifera indica* were resulted the most colonized. During the long dry season and the small rainy season, sites 3, 5 and 9 were discriminated as the most colonized, whereas sites 8, 10 and 12 were the most solicited during other seasons. During the long rainy

season, *Mangifera indica* sheltered the most bats whereas respectively in small dry season, small rainy season and long dry season, *Samanea saman* sheltered the most bats. Concerning the use frequencies of tree species, *Hevea brasiliensis* was the most exploited during the small rainy season and in long dry season compared to *Mangifera indica*, which was the most used during the small dry season and in the long rainy season. To ensure the maintenance of the integrity of that near-threatened population of bats, sites 3, 5, 8 and 9 are protected because it is question of reproduction site and have therefore sheltered the greatest numbers of bats. In addition, these sites must be exempted from all poaching activity, which is the greatest threat for that population of weak rate of reproduction. In addition the tree species of *Hevea brasiliensis*, *Mangifera indica* and *Samanea saman*, which roosted the most numbers of bats and must be protected from all felling because of their sheltering capacity. The conditions of security, of food and the necessity of the reproduction would interfere and guide straw-colored fruit bats population of the District of plateau in Abidjan, choice of habitats.

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