Forest elephant distribution and habitat use in the Bossematié Forest Reserve, Ivory Coast

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Abstract

We studied the influence of human presence and habitat structure on the distribution and habitat use of forest elephants (*Loxodonta africana cyclotis* Matschie, 1900) in the heavily exploited Bossematié Forest Reserve in south-eastern Ivory Coast. From August 1993 to April 1994, we estimated the distribution of elephants by dung counts on transects and documented their habitat use by trail mapping. Elephant dung density increased with the distance to the forest border and to the nearest village. During the study, the elephants used only 60% of the forest regularly. They avoided the rest because of forestry operations and human presence. Forest roads, in light but regular use, had no influence on the elephants' spatial distribution. Elephants avoided coffee and cocoa plantations in all seasons. During the dry season, elephants walked more often through forest parts with greater tree canopy cover than during the wet season, when they avoided valley bottoms. The main influence on the spatial distribution of elephants in the study area was human presence, followed by habitat structure.

Résumé

Nous avons étudié l'influence de la présence humaine et de la structure d'habitat sur la répartition et l'utilisation d'habitat des éléphants de forêt (*Loxodonta africana cyclotis* Matschie, 1900) dans la Forêt Classée de Bossematié (sud-est de la Côte d'Ivoire) qui fut fortement exploitée. De août 1993 à avril 1995, nous avons estimé la répartition des éléphants par des comptages de crottes sur transects et décrit leur utilisation d'habitat par la cartographie de leurs traces. La densité des crottes d'éléphants a augmenté avec la distance de la lisière de la forêt et du plus proche village. Au cours de l'étude les éléphants ont utilisé régulièrement seulement 60% de la forêt. Les éléphants ont évité le reste de la forêt à cause d'opérations forestières et de la présence d'hommes. Les routes forestières en usage léger mais constant n'avaient aucune influence sur la distribution spatiale des éléphants. Durant toutes les saisons, les éléphants ont évité les plantations de café et de cacao. Pendant la saison sèche, les éléphants de forêt ont marché plus souvent dans les parties de forêt avec une canopée plus fermée que pendant la saison des pluies où ils ont aussi évité les vallées. Dans le site de recherche, l'influence principale sur la répartition spatiale des éléphants était la présence humaine suivie par la structure d'habitat.

Introduction

Following poaching and habitat loss, the number of forest elephants in West Africa has declined dramatically during the last decades (Barnes 1999). In 1988/1989, Merz and Hoppe-Dominik (1991) estimated that 200 elephants lived in south-eastern Ivory Coast. In 1993, only about 55 remained (W.E. Waitkuwait, Y. Guiro, J. Theuerkauf, H. Ellenberg, unpubl. data, 1993): roughly 20 in the Songan-Tamin-Mabi-Yaja Forest Reserve complex (1700 km+), 5 in the Béki Forest Reserve (150 km+), and 30 in the Bossematié Forest Reserve (220 km+). For the last of the forest elephants in south-eastern Ivory Coast to survive, it was necessary to implement measures to prevent further poaching and to protect large forest tracts that meet the habitat needs of the animals. To contribute towards establishing conservation priorities for elephants in south-eastern Ivory Coast, we investigated the influence of human presence and forestry operations on the distribution and habitat use of the elephants in the Bossematié Forest Reserve. The study was part of a long-term biomonitoring programme included in a rehabilitation project for the reserve. The project was created to develop methods for the restoration and sustainable use of all formerly overexploited forest reserves in south-eastern Ivory Coast.

Barnes et al. (1991) and Hall et al. (1997) showed that in central Africa elephant densities are directly related to distance from human settlements or roads. We therefore investigated if human presence affected the distribution of the elephants in and around our study area. Elephants that live in large forest complexes prefer habitats with an open canopy and dense herbaceous tangle (see Barnes et al. 1991, Prins and Reitsma 1989, Struhsaker et al. 1996). However, timber extraction had been heavy in our study area (Wöll 1992), and the canopy was much more open than that in the forest complexes where the above-mentioned studies had been conducted. The study area had a low density of fruit trees, an important food source for forest elephants in West Africa (Alexandre 1978, Short 1981, White et al. 1993, Theuerkauf et al. 2000b). The objectives of this study were to determine 1) the influence of roads, villages, the forest border and forestry operations on the distribution of elephants and 2) the habitat types that elephants select. The results were necessary to design management measures aimed at improving the survival chances of the elephants.

Study area

The Bossematié Forest Reserve (Forêt Classée de Bossematié) is a moist, semi-deciduous rain forest in the lowland zone of south-eastern Ivory Coast (6°22' to 6°33' N, 3°24' to 3°35' W). The annual distribution of rainfall is bimodal with peaks in September–October and April–July; August and December–February are dry. Mean annual rainfall for 1961–1990 was 1330 mm but varied significantly from year to year (Schroth unpubl.). The 220-km+ forest block is surrounded by fallow land as well as cocoa, banana and coffee plantations. Human density outside the forest is about 25 inhabitants per km^2 in the north and west of the study area and about 50 inhabitants per km^2 in the south and east (Kientz unpubl.). There are no settlements in the forest itself. Cars, bicycles and pedestrians pass regularly but infrequently on the forest roads, which connect villages situated around the forest.

During the 30 years up to 1988, the forest had been heavily exploited for timber (Wöll 1992), resulting in a mosaic of degraded forest with few old fruit trees and many small clearings. Only 16% of the forest has a canopy cover over 30%, whereas about 8% of its surface consists of mostly illegal cocoa and coffee plantations, clustered mainly along the southern margin of the forest (Wöll 1992). During the time of this study, forestry operations (cleaning around target trees, replanting, inventorying) were concentrated in the northern part of the forest.

Elephant poaching was common in the 1980s until 1990 when the rehabilitation project for the Bossematié Forest Reserve started and elephant poachers were arrested. During this study, some 27 to 33 elephants lived in the reserve (Theuerkauf et al. 2000a) and no elephant was observed to migrate into or out of the study area.

Methods

We counted elephant droppings on permanent 2-km transects to document the distribution of elephants within the study area. Because the elephants sometimes walked along the permanent transects, we used the presence of elephant droppings in 250-m sectors to represent the relative density of elephants, which ensured that agglomerations of droppings produced by an elephant group that had walked along a transect did not distort the data. We then calculated the proportion of sectors with elephant dung on each transect.

We noted elephant droppings that we could see from the transect line and removed all droppings after counting to ensure an independent sample for the next count. From November 1993 to February 1994, we counted on 8 transects monthly. Before the November count, we had removed droppings in October. In March 1994, we cleared and included in the April counts a further 8 transects. To assess human influence on the distribution of the forest elephants, we compared by regression analyses the percentage of transect sectors with elephant dung with the distances between the centres of the 16 transects and the nearest road, the nearest forest border and the nearest village.

To determine how the forest elephants used the habitat, we searched for fresh elephant trails that crossed forest roads. We then followed and mapped the trail by compass and topofil (a distance-measuring instrument) with the assistance of an experienced elephant tracker. We followed the trails of 16 different elephant groups for distances between 0.8 and 15.7 km (total 82.2 km) and juxtaposed the trails we had followed to a tree canopy stratification map and a soil map.

The tree canopy stratification map of the Bossematié Forest Reserve (Sabenin and Kra unpubl.), based on aerial pictures taken in 1992 and 1993, distinguished between strata of big trees (30–40 m in height) and small trees (up to 20 m). We pooled the strata into five classes: canopy cover < 10%, 10–20%, 20–30%, > 30%, and plantations. The soil map (Gerold and Hetzel unpubl.), which was mainly based on the topography of the study area, identified Ferralsol and Plinthosol on high ground and the upper parts of slopes, Cambisol on the middle and lower parts, and Arenosol and Gleysol in valley bottoms. We distinguished between two classes: high ground (Ferralsol, Plinthosol) and valley (Cambisol, Arenosol, Gleysol).

We measured the length of each trail through the different habitat types to calculate the percentage of the habitats on the trail. To compensate for the different trail lengths, we used a weighting factor when calculating mean percentages and confidence limits. We considered the average trail length (5.1 km) as the standard sample unit. The weighting factor (sample unit) of a trail was therefore not 1 but the length of the given trail divided by the mean length of the 16 trails. We considered that elephants selected or avoided a habitat if the actual (expected) percentage of the habitat in the elephant range was below or above the confidence interval of the mean percentage that elephants used the habitat. To define the elephant range, we drew a minimum convex polygon around the elephant trails and determined the actual percentage of each habitat type in the area of the minimum convex polygon.

Results

The percentage of sectors with elephant dung on transects varied little between months (SD = 2%) but

Table 1. Percentages of 250-m sectors with forest elephant dung on 16 transects, each 2 km long, in the Bossematié Forest Reserve, November 1993 to April 1994

Transect	November	December	January	February	April	Mean
1	–	–	–	–	0	0
2	0	0	0	0	25	5
3	–	–	–	–	13	13
4	–	–	–	–	13	13
5	0	0	0	0	0	0
6	13	0	0	0	0	3
7	0	0	38	0	13	10
8	0	0	25	25	0	10
9	0	0	0	0	0	0
10	–	–	–	–	13	13
11	–	–	–	–	13	13
12	38	25	0	13	13	18
13	–	–	–	–	13	13
14	0	0	0	25	0	5
15	–	–	–	–	0	0
16	–	–	–	–	0	0
all	6	3	8	8	7	7

more between transects (SD = 6%), which reflected the heterogeneous distribution of elephants in the forest (table 1). The percentage of sectors with elephant dung increased with the distance from the middle of a transect to the nearest border of the forest (fig. 1a). The linear relationship was, however, not significant ($P = 0.067$), because there were no elephant droppings on transects in the northern part of the study area in which forestry work was concentrated at the time of the study. When we excluded the northern transects (1, 5 and 9) from the regression analysis, the linear relationship between the distance to the forest border and the percentage of sectors with elephant dung became significant ($P = 0.008$). In 1992, when no forestry work was under way in the northern region, the probability of observing elephant tracks at waterholes in the northern region was dependent ($P < 0.001$) on the distance to the forest border (fig. 1b).

The percentage of sectors with elephant dung also increased with increasing distance to the nearest village when we excluded the northern region ($P = 0.017$) but not when we included all transects in the analysis ($P = 0.246$). There was no linear relationship between the percentage of sectors with elephant dung and the distance to the nearest forest road ($P = 0.988$).

We grouped transects into three zones to draw a map of the forest presenting an estimate of elephant distribution (fig. 2). It appeared that in 1993 and 1994, humans reduced the area available to the elephants to 130 km+ (60% of the forest) in the core of the forest (fig. 2). We found six carcasses of elephants poached before 1990, which were all in the centre of the forest in a mean distance of 600 m from a main forest road (range 500–800 m).

In the dry season, elephants walked more than expected in areas where the canopy cover was higher than 20% and less than expected in more open forest parts (fig. 3). Forest elephants tended to use areas with a high canopy cover more often in the dry season than in the wet season. In the wet season, elephants used open forest (< 10% cover) more than expected. In both dry and wet seasons, elephants strongly avoided plantations (outside 99.8 and 98.6% confidence interval, respectively).

High ground and valleys accounted for 78% and 22% respectively of the minimum convex polygon surface. During the wet season, only 13% of the elephant trails were in valleys, which was less than expected, whereas they walked more on high ground (87%) than expected. The actual percentages of high ground and valleys were both outside the 98.3% confidence interval of the mean percentages of elephant use. During the dry season, elephants used valleys more (35%) and high ground less (66%) than expected but only at the 91.1% confidence interval level. At the peak of the dry season, elephants were observed to leave the forest on two occasions to eat banana plants.

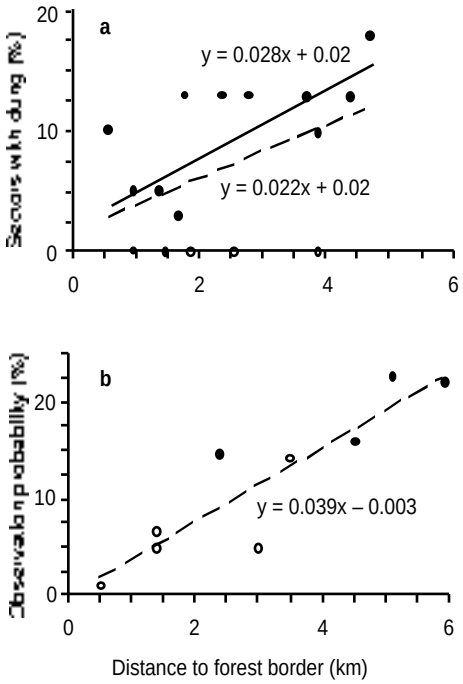

Figure 1. *a)* linear regression between the distances from the middle of a transect to the nearest forest border and the percentages of 250-m sectors with elephant dung on 16 transects in 1993/1994; *b)* linear regression between the distances from waterholes to the nearest forest border and the observation probability of elephant tracks at waterholes in 1992 (data from Mühlenberg et al. unpubl.). Dotted lines: all transects or all waterholes; continuous line: excludes transects of the northern region (1, 5 and 9). Transects and waterholes of the northern region are shown as open circles, those of other regions as closed circles.

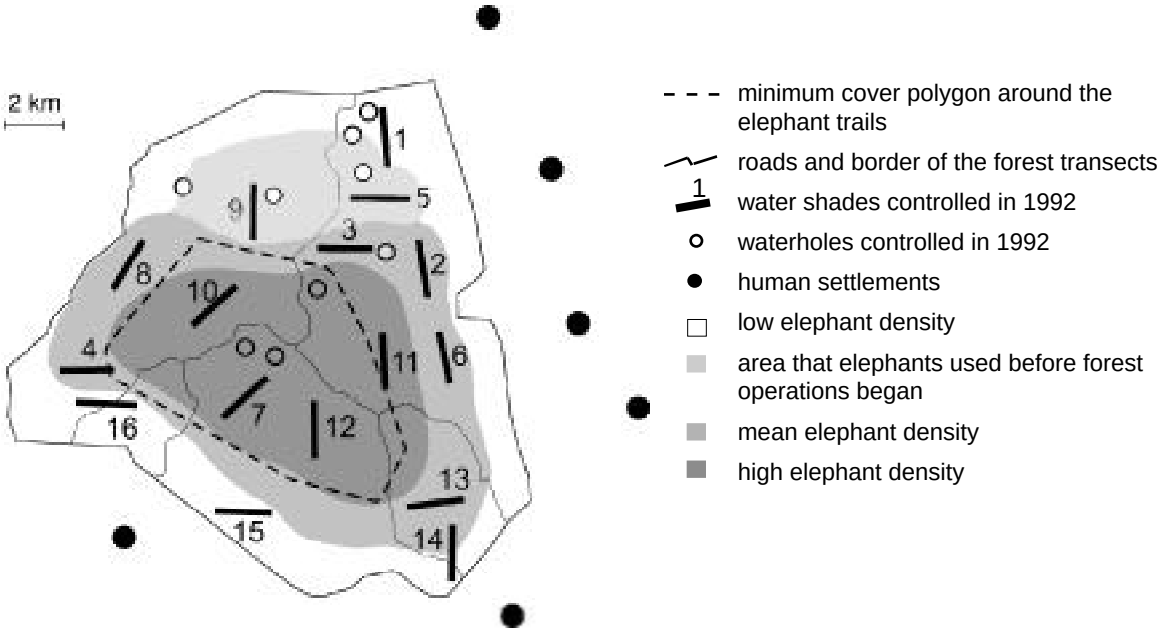

Figure 2. Estimated distribution of forest elephants in 1993/1994 in the Bossematié Forest Reserve and location of human settlements in its surroundings.

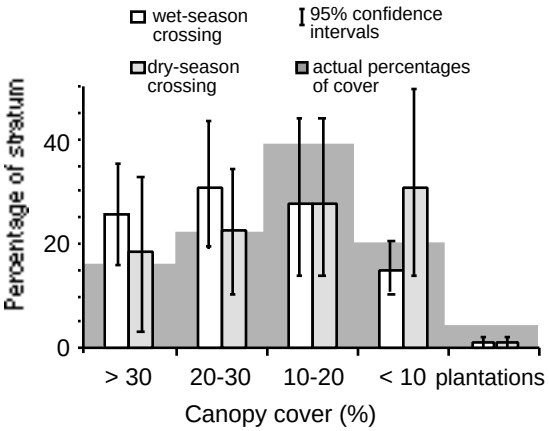

Figure 3. Canopy cover classes crossed by forest elephants compared with the actual percentages present in the used area (minimum convex polygon in fig. 2). The 95% confidence intervals of elephant use indicate avoidance or preference when they are below or above actual percentages.

Discussion

In Central Africa, where elephants range over large forests, their density is directly related to the distance from human settlements or major roads, according to Barnes et al. (1991) and Hall et al. (1997). Both studies found very low elephant densities in the first 10–20 km from settlements. In south-eastern Ivory Coast, conditions are more difficult for forest elephants because of widespread deforestation and ubiquitous land exploitation, which have resulted in small and fragmented forests. In our study, elephants avoided a zone within 4 km of villages and reached their maximum density in the centre of the forest, 7–11 km from settlements. The distance to the forest border was a better measure of human influence than the distance to the nearest village because it reflected the human activity around the forest, which was not limited to villages. The forestry operations during the time of the study also influenced elephant distribution, probably because of the long-time human presence, whereas forest roads did not affect it. Roads, however, seemed to have facilitated poaching, as all elephants poached before this study were killed near roads.

Barnes et al. (1991) found a direct relationship between the density of elephant dung and the percentage of secondary forest, which implies that elephants prefer the parts of the forest with the lowest canopy cover. Elephant preference for forest parts with higher canopy cover in the Bossematié Forest Reserve contradicts these findings and suggests that

the forest has been so heavily exploited that it is now too degraded to offer optimal conditions for the elephants. In Taï National Park of Ivory Coast, Merz (unpubl.) observed higher density of elephants in secondary forest than in primary forest but also intensive use of primary forest parts because of the abundance of fruit trees in the latter. In Bia National Park of Ghana, forest elephants mainly select open areas but eat the bark and fruits of trees in areas with high canopy cover (Short 1981). We suggest that our elephants selected forest parts that had a higher canopy cover to obtain fruits from the remaining mature trees. Furthermore, elephants selected shade-tolerant species (Theuerkauf et al. 2000b), which were rare after the heavy exploitation.

Vanleeuwe and Gautier-Hion (1998) found that the foraging paths of elephants were mostly in forest parts with a canopy cover of 80%, as this provided the elephants with herbaceous plants and fruits. As in our study, those elephants avoided dense forest parts with an open canopy. The elephants they studied, however, fed regularly in clearings. During our fieldwork, we noticed no preference for clearings, which in the study area are usually covered by the introduced neotropical Asteraceae *Chromolaena odorata*, an invasive plant without importance in the elephants' diet. Elephants in our study area also avoided plantations, which were mainly cocoa and coffee and provided them with little food.

It is likely that the selection of open or closed parts of a forest is also influenced by weather. In the dry season, the preference was for closed canopy, perhaps because exposure to the sun would increase water loss. The elephants' avoidance of valleys in the wet season may be a result of the poorer soils (Gerold and Hetzel unpubl.), which could bear vegetation of lower nutritional value than that found on high ground. In the dry season when water is scarce on high ground and soils in valleys remained moister than on high ground, elephants used valleys more frequently. Although the habitat use of elephants changed with the seasons, this did not affect the distribution of elephants in the forest. Waterholes are numerous in the study area and elephants use them often in the dry season (Theuerkauf and Ellenberg 2000). Fruits of different trees (for example, *Desplatsia chrysochlamys*) as well as crop plants (for example, banana) supplement the water requirements of elephants during the driest months (January to March).

We conclude that the heavy timber exploitation and plantation of coffee and cocoa have lowered the habitat quality of the Bossematié Forest Reserve for the elephants. We have suggested that the optimal habitat structure for forest elephants may be found in forests with a canopy cover denser than in our study area. We therefore provided a list of 25 food plants of particular importance to the elephants. This list was included in the management plan for the Bossematié Forest Reserve and the species now stand under protection during forestry operations. Large-scale forestry operations also negatively affected the distribution of elephants. Forest exploitation should therefore be limited to small areas and short periods to prevent elephants from avoiding the areas altogether. However, forestry activity deterred poachers and thus also had a positive effect, which led to the high recruitment of the elephant population observed every year since the protection of the Bossematié Forest Reserve (W.E. Waitkuwait, unpubl. data, 1998).

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References

Alexandre, D.Y. (1978) Le rôle disséminateur des éléphants en forêt de Taï, Côte d'Ivoire. *Terre et Vie* 32, 47–72.

Barnes, R.F.W. (1999) Is there a future for elephants in West Africa? *Mammal Review* 29, 175–199.

Barnes, R.F.W., Barnes, K.L., Alers, M.P.T., and Blom, A. (1991) Man determines the distribution of elephants in the rain forests of northeastern Gabon. *African Journal of Ecology* 29, 54–63.

Gerold, G., and Hetzel, F. (unpubl.) Bodenkarte des Forêt Classée de la Bossematié. 1993 map. University of Göttingen.

Hall, J.S., Inogwabini, B.I., Williamson, E.A., Omari, I., Sikubwabo, C., and White, L.J.T. (1997) A survey of elephants (*Loxodonta africana*) in the Kahuzi-Biega National Park lowland sector and adjacent forest in eastern Zaire. *African Journal of Ecology* 35, 213–223.

Kientz, A. (unpubl.) Participation de la population riveraine à la protection de la Forêt Classée de Bossematié. 1993 report. Deutsche Gesellschaft für Technische Zusammenarbeit.

Merz, G. (unpubl.) Untersuchungen über Lebensraum und Verhalten des afrikanischen Waldelefanten im Taï-Nationalpark der Republik Elfenbeinküste unter dem Einfluß der regionalen Entwicklung. PhD thesis, 1982. University of Heidelberg.

Merz, G., and Hoppe-Dominik, B. (1991) Distribution and status of the forest elephant in the Ivory Coast, West Africa. *Pachyderm* 14, 22–24.

Mühlenberg, M., Slowik, J., and Waitkuwait, W.E. (unpubl.) Waldrehabilitierung in der Ostregion der Côte d'Ivoire. Bericht über die ökologischen Begleitmaßnahmen in der Projektphase 1991–1993. 1993 report. Deutsche Gesellschaft für Technische Zusammenarbeit.

Prins, H.H.T., and Reitsma, J.M. (1989) Mammalian biomass in an African equatorial forest. *Journal of Animal Ecology* 58, 851–861.

Sabenin, Y., and Kra, Y. (unpubl.) Etude expérimentale de la stratification dans la Forêt Bossematié. 1993 map. IGCI/IGT.

Schroth, G. (unpubl.) Rapport de mission pour le projet Stabilisation des systèmes de production agricole dans la région d'Abengourou. 1992 report. Deutsche Gesellschaft für Technische Zusammenarbeit.

Short, J. (1981) Diet and feeding behaviour of the forest elephant. *Mammalia* 45, 177–185.

Struhsaker, T.T., Lwanga, J.S., and Kasenene, J.M. (1996) Elephants, selective logging and forest regeneration in the Kibale Forest, Uganda. *Journal of Tropical Ecology* 12, 45–64.

Theuerkauf, J., and Ellenberg, H. (2000) Movements and defecation of forest elephants in the moist semi-deciduous Bossematié Forest Reserve, Ivory Coast. *African Journal of Ecology* 38, 258–261.

Theuerkauf, J., Ellenberg, H., and Guiro, Y. (2000a) Group structure of forest elephants in the Bossematié Forest Reserve, Ivory Coast. *African Journal of Ecology* 38, 262–264.

Theuerkauf, J., Waitkuwait, W.E., Guiro, Y., Ellenberg, H., and Porembski, S. (2000b) Diet of forest elephants and their role in seed dispersal in the Bossematié Forest Reserve, Ivory Coast. *Mammalia* 64, 447–459.

Vanleeuwe, H., and Gautier-Hion, A. (1998) Forest elephant paths and movements at the Odzala National Park, Congo: the role of clearings and Marantaceae forests. *African Journal of Ecology* 36, 174–182.

White, L.J.T., Tutin, C.E.G., and Fernandez, M. (1993) Group composition and diet of forest elephants, *Loxodonta africana cyclotis* Matschie 1900, in the Lopé Reserve, Gabon. *African Journal of Ecology* 31, 181–199.

Wöll, H.-J. (1992) Le projet Rehabilitation de la Forêt Classée de Bossematié, Côte d'Ivoire, région d'Abengourou. *Tropenbos Series* 1**,** 163–179.