

A proposal for a transnational forest network area for elephants in Côte d'Ivoire and Ghana

Marc P. E. Parren, Bertken M. de Leede and Frans Bongers

Abstract Forest elephants *Loxodonta africana cyclotis* in Ghana and eastern Côte d'Ivoire live in small isolated populations and number fewer than 1,000 individuals in total. To ensure the long-term survival of these elephants the present forest reserves need to be linked into a network by forest corridors. The potential of such corridors is demonstrated by the active use by elephants in Ghana of forest 'shelterbelts', created in the 1930s. Using information from recent surveys of elephants and vegetation status, and from published information, we propose three possible wildlife corridors in the border

region between Côte d'Ivoire and Ghana, establishment of which would lead to a transnational forest network area in the Bia and Bossematié areas. Establishing a forest network for forest elephants would require political will, transnational cooperation among forest and wildlife managers, and participation of the local people.

Keywords Côte d'Ivoire, forest elephant, fragmentation, Ghana, *Loxodonta africana cyclotis*, shelterbelts, West Africa, wildlife corridors.

Introduction

In West Africa c. 25% of the plant species and 20% of the vertebrate species in closed forest environments are endemic (Myers *et al.*, 2000), but these environments are also some of the most deforested areas in the tropics. Of the original moist forest zone of 31.3 million ha that stretched from Guinea to Ghana at the beginning of the 19th century, only 8.7 million ha remain (Parren & de Graaf, 1995). Some animal species in the region may have been extirpated (Oates *et al.*, 2000) and others may go extinct in the coming decades (Holbech, 1998; Caspary, 1999).

The African Elephant Database of the African Elephant Specialist Group (Barnes *et al.*, 1999) estimated that the total number of forest elephants *Loxodonta africana cyclotis* in West Africa in 1998 was c. 3,000. These elephants live mostly in patches of forest in a matrix of cultivated land, except for those in extensive forests in eastern Liberia (Parren & de Graaf, 1995; Appleton, 1997). The elephants of the Côte d'Ivoire–Ghana border area (Fig. 1), the total population of which numbered 685–855 in the late 1980s (Table 1), are contained by the savannahs of the Dahomey Gap to the east and by the so called

V-Baoulé, a savannah zone that penetrates into the moist forest zone, in Côte d'Ivoire to the west.

The effective number of mature individuals required to ensure the long-term survival of a population has been estimated at 1,000–5,000, existing preferably as interbreeding sub-populations (Vucetich & Waite, 1998). However, the counterbalance of low local population levels by movement of animals over large areas is often no longer possible. Two options can be used to overcome this problem: reinforcement of populations with individuals from elsewhere, or the creation of corridors to aid movement, thus enlarging effective population sizes (Beier & Noss, 1998). Movement of elephants between forest fragments in the Côte d'Ivoire–Ghana border area would require the linking of the elephants' present ranges with forest corridors, where a corridor is a linear feature of vegetation connecting at least two isolated habitat fragments that were once connected (Saunders & Hobbs, 1991). 'Shelterbelts', strips of forests often not more than 1.5 km wide and up to 20 km long (Foggie, 1949), established in the mid 1930s in Ghana, provide examples of potential corridor design.

In this paper we describe the current status of forest elephant populations in Ghana and eastern Côte d'Ivoire, based on both field surveys and published information, and present a proposal for a 'trans-boundary Bia-Bossematié network area', a network of forest areas connected with corridors across the border between Côte d'Ivoire and Ghana. We discuss the required characteristics of a corridor for forest elephants, and describe potential corridor locations and the costs of corridor creation.

Marc P. E. Parren (Corresponding author), **Bertken de Leede** and **Frans Bongers** Forest Ecology and Forest Management Group, Department of Environmental Sciences, Wageningen University, P.O. Box 342, 6700 AH Wageningen, The Netherlands. E-mail: marc.parren@btbo.bosb.wau.nl

Received 18 December 2000. Revision requested 27 April 2001.
Accepted 9 April 2002.

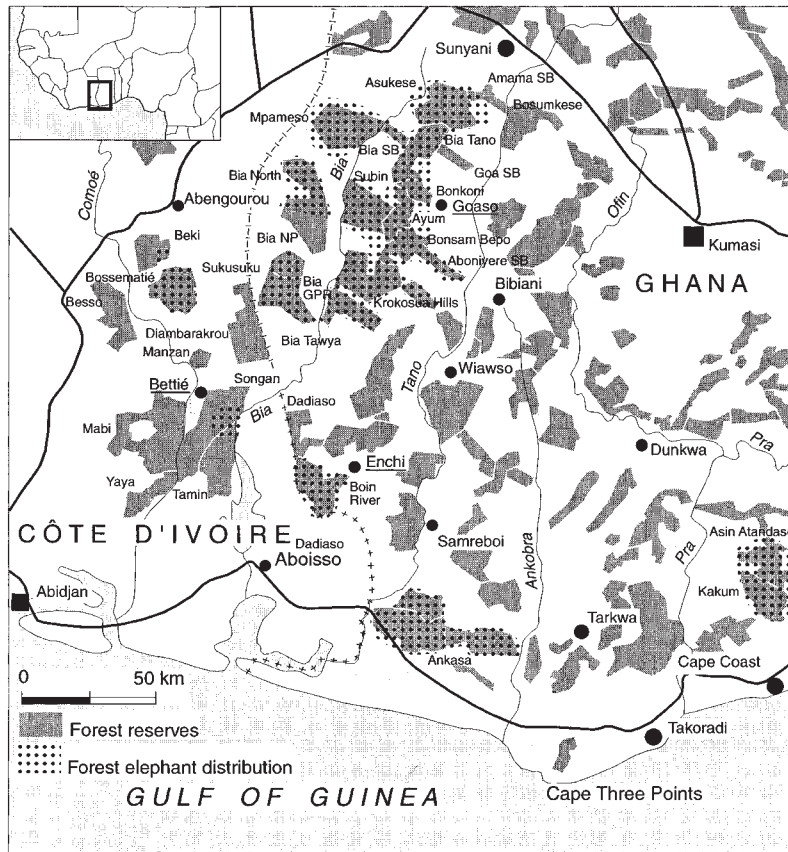


Fig. 1 Existing forest reserves (Forêt Classée in Côte d'Ivoire, and Forest Reserves, National Parks (NP), Game Production Reserves (GPR) and Shelterbelts (SB) in Ghana), and the known distribution of the forest elephant in eastern Côte d'Ivoire and Ghana. Only forest reserves mentioned in the text are labelled. The inset indicates the location of the area in West Africa.

Table 1 Estimated numbers of forest elephants in eastern Côte d'Ivoire and Ghana. Numbers from the 1970s to 1995 are based on Dickinson (1990)¹, Dudley *et al.* (1992)², Martin (1982)³, Merz & Hoppe-Dominik (1991)⁴, and Theuerkauf (1994)⁵. Post-1995 data for Ghana are based mainly on the August 1998 data of the African Elephant Database (Barnes *et al.*, 1999)⁶, and also on Heffernan & Graham (2000)⁷. Post-1995 data for Côte d'Ivoire are based on Waitkuwait (1998)⁸, and other information as explained in the text.

Country	Area	Numbers pre-1995	Numbers post-1995
Ghana	Bia	200–250 ³	100–150 ^{6,7}
	Goaso	200–250 ¹	200–500 ⁶
	Kakum	100–150 ²	100–150 ^{2,6}
	Ankasa	–	60 ⁶
	Boin River	3 ¹	3 ¹
Côte d'Ivoire	Bossematié	35–55 ⁵	60–80 ⁸
	Bettié	150 ⁴	20–30
Totals		685–855	540–970

Methods

Ground surveys were conducted to verify present forest elephant home ranges, to assess the condition of the vegetation at potential corridor sites, and to explore attitudes towards potential corridors amongst the local population and relevant authorities. The following aspects

were taken into account when considering the feasibility of corridors: distance and width of the proposed corridor, population pressure (number of nearby villages and their distribution), presence of rivers or streams, remaining forest cover, and the attitude of farmers towards tree planting for the creation of corridors.

Surveys were conducted in and around four potential corridor areas: the Bettié and Bossematié areas of Côte d'Ivoire, and the Bia and Goaso areas of Ghana. In Côte d'Ivoire surveys were carried out during January–March 1994 in (1) Forêt Classée (FC) Songan, (2) FC Manzan, (3) FC Diambarakrou, (4) in the area between the southern border of FC Bossematié and the Comoé River, (5) between FC Béki and FC Bossematié, (6) in the area between FC Songan and its border with FC Mabi, and (7) along the Bia River from FC Songan to the Ghanaian border. In total 73 km of transects outside forest reserves and 32.5 km of transects inside forest reserves were assessed for vegetation cover and elephant presence. A step counter was used to measure the distance walked in each vegetation and land use type, and whilst walking a tape recorder was used to note observations. Step length was determined as 0.75 m by counting steps five times on a known 1 km track. Elephant presence was noted in the forms of droppings, trails, wallow sites, footprints, and skeleton parts, and also by informal

interviews with seven foresters at the regional forest office at Abengourou, and 15 farmers in each of 12 villages. At FC Diambarakrou and along the transect walked towards FC Bossematié three villages were visited, around FC Bossematié three villages, at FC Manzan one village, and around FC Songan and the transect up to the border with Ghana five villages were visited.

In Ghana we visited all forest reserves around Goaso and Bia, and 23 surrounding villages, during February–May 1994. Seven local Wildlife Division staff, eight Forest Services Division staff and 15 farmers in each of the villages were interviewed. We investigated the extent of elephant damage to farms by analysing crop raiding reports for 13 forest reserves at the Wildlife Division in Goaso over 1976–1993.

Following the surveys the locations of potential corridors were determined with the additional aid of maps drawn from aerial photographs (taken in 1976 and

1993), SPOT images (taken in 1988), and aerial photographs (taken in 1991) for Côte d'Ivoire, and on maps drawn from aerial photographs (taken in 1973) and Landsat TM images (taken in 1989) for Ghana.

Results

The only confirmed elephant population in the Bettié area of Côte d'Ivoire is that in FC Songan; based on the number of elephant trails and droppings we estimate that the population numbers 20–30 individuals (Tables 1 & 2). There may be a small population in the northern part of FC Tamin, but we were unable to confirm this. The degraded south-western zone of FC Songan bordering FC Mabi is mostly given over to agriculture, with only 9% forest cover (Table 3). Forty-nine percent of the area along the Bia River that separates

Table 2 Reports of elephant presence in forest reserves, reports of crop damage by elephants in areas adjacent to reserves, estimated human population pressure on the reserves, and sources of information, for Ghana and eastern Côte d'Ivoire. Reports of elephants, crop damage, and human population pressure are all from 1994 except where noted.

Area	Forest reserve ¹	Reports of elephant presence	Crop damage by elephants	Human population pressure ²	Sources
Ghana					
Bia	Bia NP	few	none	+	pers. obs.
	Bia GPR	regular	frequent	+	Opoku, 1988
	Bia North FR	few	rare	+	farmers, Forest Services Division, Elephant Control Unit crop raiding reports
	Bia Tawya FR	none	none	++	pers. obs.
	Sukusuku FR	none	none	++	pers. obs.
Goaso	FC Diambarakrou	none	none	++	pers. obs.
	Asukese FR	regular	frequent	+	farmers
	Ayum FR	regular	frequent	+	farmers, Elephant Control Unit crop raiding reports
	Bia Tano FR	regular	frequent	+	Elephant Control Unit crop raiding reports
	Bonkoni FR	regular	frequent	+	farmers, Elephant Control Unit crop raiding reports
	Bonsam Bepo FR	regular	frequent	+	farmers, Elephant Control Unit crop raiding reports
	Krokosua Hills FR	few	rare	–	Wildlife Division, 1999
	Mpameso FR	regular	frequent	+	farmers, Elephant Control Unit crop raiding reports
	Subin FR	regular	frequent	+	farmers, Elephant Control Unit crop raiding reports
	Aboniyere SB	few	rare	+	Wildlife Division, 2000, pers. obs., 2000
	Amama SB	few	none	+	farmers
	Bia SB	regular		+	farmers, Dickinson, 1990
	Goa SB	none	none	+	Dickinson, 1990
Côte d'Ivoire					
Bossematié	FC Béki	few	none	+	W.E. Waitkuwait, pers. comm., 2001
	FC Bossematié	regular	few	+	W.E. Waitkuwait, pers. comm., 2001
	FC Besso	none	none	none	W.E. Waitkuwait, pers. comm., 2001
	FC Manzan	none	none	++	pers. obs.
Bettié	FC Tamin	few(?)	none	++	W.E. Waitkuwait, pers. comm., 2001
	FC Mabi	none	none	+	Lennertz, 1993a,b; W.E. Waitkuwait, pers. comm., 2001
	FC Songan	few	none	+	W.E. Waitkuwait, pers. comm., 2001
	FC Yaya	none	none	–	W.E. Waitkuwait, pers. comm., 2001

¹FC = Forêt Classée, FR = Forest Reserve, GPR = Game Production Reserve, NP = National Park, SB = Shelterbelt.

²– = low, + = high, ++ = many illegal farms inside reserve.

Table 3 Length of transects surveyed within forest reserves and along potential sites for forest corridors outside forest reserves in Côte d'Ivoire, and the percentage land use of the surveyed areas.

Area*	Transect length (km)	Land use			
		Cash crops (%)	Food crops (%)	Fallow land (%)	Closed forest (%)
Within forest reserves					
1. FC Songan	9.8	0.0	8.0	9.0	83.0
2. FC Manzan	11.0	55.3	1.8	19.3	23.6
3. FC Diambarakrou	9.0	45.3	12.3	16.8	25.6
Outside forest reserves					
4. FC Diambarakrou–FC Bossematié	13.2	36.6	9.1	30.0	24.3
5. FC Beki–FC Bossematié	10.5	45.0	12.0	30.0	13.0
6. FC Songan–FC Mabi	9.3	83.0	4.0	4.0	9.0
7. FC Songan–Ghana	24.5	49.4	7.5	25.0	18.1

*FC = Forêt Classée.

FC Songan from the border with Ghana consists of coffee and cocoa plantations, and although only 18% of the area is forest (Table 3), there is forest cover of 200 m width along both river banks. In the Bossematié area there is a total population of 60–80 elephants in FC Béki and FC Bossematié (Tables 1 & 2). These two areas are c. 5 km apart, but the intervening area has only 13% of its forest cover remaining (Table 3). Forest cover is 24% between FC Bossematié and FC Diambarakrou (Table 2); the latter has been converted illegally into farmlands during the last 20 years.

The largest elephant population in the region is in the forests of the Goaso area in Ghana (Tables 1 & 2). From our contacts with farmers and staff of the Wildlife Division we conclude that elephants occur in all forest reserves, with the highest number of elephants in the centrally located Ayum Forest Reserve (FR). There are four 'shelterbelts' in the Goaso area: the Bia Shelterbelt (SB) that links Mpameso FR with Bia Tano FR, the Amama SB that links Asukese FR with Bosumkese FR, the Goa SB connected to Bia Tano FR, and the Aboniyere SB connected to Bonsam Bepo FR. We observed elephant trails and droppings over the entire length of the Bia SB, which is 1.5 km wide and is crossed by a road, confirming Dickinson's (1990) observations. We found evidence of elephant presence in Amama SB but only on the Asukese FR side of the shelterbelt. Elephants visit Aboniyere SB but do not move further than 4–5 km into the shelterbelt. There were no reports of elephant presence in Goa SB.

We found no signs of elephants in Bia National Park (NP), but their presence was confirmed on the eastern side of the Bia Game Production Reserve (GPR) by their regular visits to farms (Table 2). In Bia North FR a small population, probably limited to one herd, lives in the

central part of the reserve; farmers along the northern and eastern side of the reserve reported sightings of elephants in the early 1990s. Land pressure at the edge of these reserves is high and farmers are not sympathetic towards the creation of more forest. The only possibilities for the creation of corridors in this area are along the Bia River from Subin FR towards Bia GPR, but the whole length of the Bia River bank in this area is deforested and used for agriculture, and there are many villages. Further downstream along the Bia River towards the border with Côte d'Ivoire there are similar amounts of deforestation, but in some villages people were aware that environmental degradation taking place was affecting their livelihoods, and were in favour of restoring vegetation along the riverbanks.

No crop raiding reports were available in Côte d'Ivoire, probably because of low elephant densities in the reserves. In Ghana crop raiding reports show that elephant disturbance occurs during the dry season (November–March) when the elephants are searching for water, but is most frequent early in the rainy season (April–June) before the peak fruiting of trees, when food is still scarce. Of the 13 forested areas with crop raiding reports, four are shelterbelts (mean area 32 km²) and nine are forest reserves (mean area 215 km²). Most crop raiding reports came from farmers around Bia Tano FR and Subin FR, with 91 and 88 crop raiding events respectively. Low numbers of reports for Bia North FR and Krokosua Hills FR may be underestimates; farmers from these more remote areas do not always report damage because of the relatively great distance to the Wildlife Division office in Goaso. Excluding these two reserves, the mean annual number of crop raids (1976–1993) made by elephants from forest reserves and from shelterbelts were 1.8–6.1 and 0.1–0.6, respectively.

Discussion

Current status of elephants

Some of the currently available estimates of the number of forest elephants in Ghana and eastern Côte d'Ivoire are based on censuses made in the 1970s and 1980s, and are therefore not reliable as estimates of current numbers. Although during the 20th century the Ghanaian elephant population doubled every 25 years (Barnes, 1999), culling following crop damage was common up to the late 1980s (Opoku, 1988), suggesting that the density limits for the coexistence of human and elephant populations had been reached (*cf.* Hoare & du Toit, 1999). In Côte d'Ivoire human-elephant conflict is aggravated by the fact that most forest reserves are used to some extent by farmers (Table 2). Logging took place in all current elephant home ranges in both Côte d'Ivoire and Ghana from the early 1970s until the 1990s, and the Bia and Bettié elephant populations were affected by hunting at the end of the twentieth century (K. Moses Sam & W.E. Waitkuwait, pers. comm.). We estimate that the total population of elephants in this region is now 540–970 individuals (Table 1).

The elephant population in the Bettié area decreased from 150 in 1989 (Merz & Hoppe-Dominik, 1991) to 20–30 six years later (this study) most probably as the result of poaching. FC Béki is badly degraded and the only closed forest formations are confined to the south-east corner where, according to local people, the last 5–6 elephants survive (W.E. Waitkuwait & J. Theuerkauf, pers. comm.). The forest of FC Bossematié is in a better condition, with *c.* 60–80 elephants (Waitkuwait, 1998). In the Goaso area (Table 3) elephant numbers and crop raiding reports are relatively high in all forest reserves. Barnes *et al.* (1999) estimated the Goaso population to be 200–500 in 1998, although as the elephants there are hunted (M. Abedi Lartey, pers. comm.) the lower estimate is probably more accurate. In the 1970s elephants were found in Bia NP, Bia GPR, Bia Tawya FR, Sucusuku FR and FC Diambarakrou (Short, 1981; Martin, 1982). The proposed Sucusuku FR and Bia Tawya FR, between Bia NP and GPR and the border with Côte d'Ivoire, have been converted illegally into farmlands during the last 20 years and thus the available elephant habitat has been reduced to Bia NP and GPR, a total area of 306 km². The Bia population was recently estimated at 138 individuals (Heffernan & Graham, 2000).

Characteristics of a successful elephant corridor

Corridors should be designed to attract forest elephants into them, and important characteristics to take into consideration are the presence of food plants, availability

of water, and the size and structure of the corridors. Forest elephants feed opportunistically on the fleshy fruits of favoured tree species when these are available, which is mostly in the dry season (Taylor, 1960; De la Mensbrugge, 1966; Alexandre, 1980), and rely upon less nutritious foods at other times. In this region the forest tree species favoured by elephants are *Parinari excelsa*, *Balanites wilsoniana*, *Duboscia viridiflora*, *Panda oleosa*, *Sacoglottis gabonensis* and *Tieghemella heckelii* (Sachtler, 1968; Martin, 1991; Hawthorne & Parren, 2000).

In Ghana elephants migrate from Bia GPR in the late wet season/early dry season, when the peak fruiting of *T. heckelii* comes to an end, to Bia NP for the massive fruiting of *P. excelsa* in the dry season (Martin, 1982; Short, 1983). White (1994) noticed a similar phenomenon involving *S. gabonensis* in Gabon. Dudley *et al.* (1992) linked a sharp reduction in crop depredation to the fruiting of *T. heckelii* in the Kakum-Asin Atandaso area of Ghana. Planting *T. heckelii*, *S. gabonensis* and other favoured fruit trees in corridors (Alexandre, 1978; Merz, 1981; Short, 1981; Lieberman *et al.*, 1987; Hawthorne & Parren, 2000), and enriching forests close to the entrance of corridors, could attract elephants into the corridors.

In the dry season the water provided by fruits may be insufficient and elephants come out of the forest in search of water. Artificial waterholes could be created in forest elephant reserves to ensure they stay within the reserve boundaries, as has already been successfully done in FC Bossematié (Waitkuwait, 1992). Corridors along river banks would have the advantage of providing readily available drinking water.

The use of shelterbelts by elephants in the Goaso area indicates that linear forest corridors have the potential to be used as passage by elephants. An examination of five forest elephant corridors of varying width (0.5–3 km) and length (3–13 km) in India indicated that even a corridor of 0.5 km width may be utilized by elephants (Johnsingh & Christy Williams, 1999).

Proposed corridors: a transnational forest network area

Based on elephant population sizes, the condition of the remaining forest, and attitudes of local people, the elephant populations that could most successfully be connected by forest corridors (Fig. 2) are: (A) the populations of the Bia area with those of the Bettié area by a corridor along the Bia River, including the Boin River FR population, (B) the populations of the Bia area with the Bettié area via FC Diambarakrou, and (C) the population in FC Songan of the Bettié area with suitable habitat in FC Mabi (Fig. 3). This proposed transnational forest network area encompasses all known elephant populations in Côte d'Ivoire at its border with Ghana, but only the Bia and Goaso populations in Ghana, as the

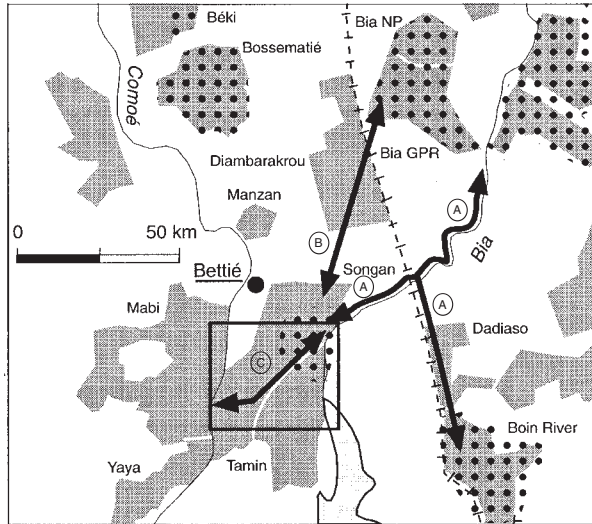


Fig. 2 Proposed transnational forest network area in the Bia-Bossematié region of eastern Côte d'Ivoire and Ghana. This proposed network is composed of existing forest reserves, national parks, and game production reserves, and the proposed corridors, which are indicated as arrows: (A) the Bia River corridor, (B) the Diambarakrou corridor, (C) the Songan-Mabi corridor. The rectangle indicates the location of Fig. 3, and the legend is otherwise as Fig. 1.

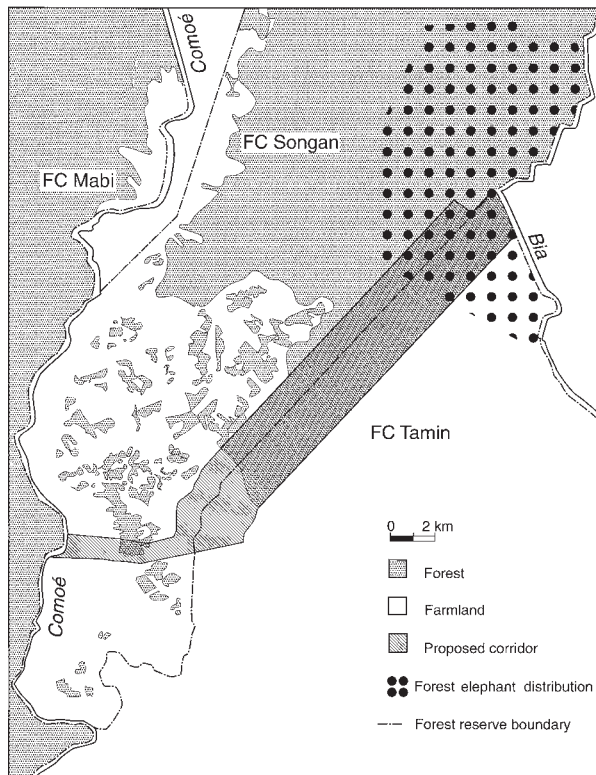


Fig. 3 Present land use in the area of the proposed Songan-Mabi corridor (see Fig. 2 for location).

Ankasa and Kakum populations in Ghana are separated from the nearest populations by *c.* 100 km (Fig. 1).

To connect Bia GPR with Dadiaso FR, both in Ghana, with FC Songan in Côte d'Ivoire, a 'boundary-corridor continuum' (*cf.* Puth & Wilson, 2001) would need to be created along *c.* 50 km of the Bia River (the Bia River corridor, Fig. 2). The northern edge of Dadiaso FR, one of the best preserved forests in Ghana (Hawthorne, 1996), is located where the Bia River crosses the border with Côte d'Ivoire. It is connected to the Boin River FR, which contains a small population of elephants (Dickinson, 1990). A corridor along the Bia River would connect the elephant populations of Bia NP, Boin River RF, and FC Songan. At the same time it would link the Bia population with that of the Goaso area. The Bia River forms a barrier between the populations of Bia GPR and Kokosua Hills FR, but Wildlife Division staff in Asempanaye have reported that elephants do wade across.

Restoration of FC Diambarakrou in Côte d'Ivoire, a forest that is almost connected to the western tip of Bia GPR in Ghana, would facilitate the establishment of a corridor between FC Songan and Bia GPR (the Diambarakrou corridor, Fig. 2). Although the distance is *c.* 50 km, more than half of this lies within the reserved forest area of FC Diambarakrou, and the corridor could follow a stream that flows from FC Diambarakrou to FC Songan, where the human settlement is sparse (S. Bamba & M.N.P. Gbanzai, *pers. comm.*). The Ivorian forest service, Société de Développement des Forêts (SODEFOR), has a good relationship with the local population at the site of this proposed corridor (M.N.P. Gbanzai, *pers. comm.*).

To ensure the survival of the elephant population in FC Songan, the elephants need access to FC Mabi in order to enlarge their potential range area from 35,000 ha to *c.* 135,000 ha (Fig. 3). This proposed corridor (the Songan-Mabi corridor, Fig. 2) leads from the present elephant range to the south-western corner of the FC Songan. The whole length of the proposed corridor is through reserved area, and is adjacent to the southern, best preserved part of FC Mabi. The Ivorian forest service integrated this proposed corridor idea in their most recent management plan for FC Songan (SODEFOR, 1999). The required area was estimated to be 2,119 ha, of which more than half consisted of illegal small-scale plantations. FC Mabi and FC Yaya should be included into this network, as the area has suitable elephant habitat and only 10% agricultural encroachment (Lennertz, 1993a, b).

The following conditions would need to be met for the proposed forest network area to be successful: (1) The three proposed corridors would need to be at least 0.5 km, but preferably 1.5 km, wide. (2) The corridors would need to have sufficient numbers of the forest elephants' preferred food trees, and logging of

these species would have to be banned within corridors. (3) Artificial waterholes would need to be provided where necessary. (4) Illegal agricultural activities within existing forest reserves would need to be halted, although small-scale collection of non-timber forest products during certain periods could be an important incentive for participation of the local population. (5) Hunting within all protected areas would need to be regulated in cooperation with the local population, but hunting of large game such as elephants and primates must be completely banned.

Farmers would have to be compensated for loss of land required for the construction of corridors. Cocoa plantations in the Abengourou region in Côte d'Ivoire yield on average 610 kg ha⁻¹ at a trade price of 240 FCFA kg⁻¹ (Anon., 1992, 1993; Ballo, 1992), and coffee yields on average 1,500 kg ha⁻¹ at a trade price of 100 FCFA kg⁻¹ (A. Agbatou, pers. comm.). Both would produce an annual gross profit of about 300 US\$ ha⁻¹ (100 FCFA = 0.20 US\$). Compensation would need to cover at least three production years since cocoa produces a crop only at three years of age. This would mean compensation of 900 US\$ ha⁻¹. As cash crop plantations cover approximately half of the proposed corridors the cost would be a minimum of c. 50,000 US\$ km⁻² of corridor. The costs of reforestation would have to be added to this.

Conclusions

The existing use of 1.5 km-wide shelterbelts, from which crop-raiding incidents are infrequent, by elephants in Ghana demonstrates that corridors could be successfully used to connect existing National Parks and Forest Reserves into a transnational forest network area. Corridors along streams and rivers would probably be the most useful and successful as such landscape features have a disproportionately large influence on landscape functions (Puth & Wilson, 2001), and would not require the creation of artificial water pools. In Côte d'Ivoire the Bia River has an almost intact 200 m wide forest zone along its banks that could be enlarged to a width of 500 m, but a similar forest belt would need to be restored along the Bia River on the Ghanaian side of the border in order to complete the Bia River corridor. Although current transnational cooperation is not intensive, the current wildlife policy of Ghana does include proposals for transnational forest corridors (Anon., 2001). Such corridors would require both political will and agreements on law enforcement across the border. Even though the cost of creating corridors is high, they can provide ecosystem services in addition to facilitating the movement of elephants. As farmers along the Bia River have suggested to us, corridors can be beneficial

for both water levels and water quality, and can produce useful non-timber forest products. The latter could form the key to local participation in forest restoration and wildlife monitoring, and guarantee the functioning of forest corridors for both elephants and other wildlife.

Acknowledgements

We would like to thank the Lucie Burgers Foundation and The Netherlands Foundation for International Nature Protection for financial support. We are grateful to the Ghana Forest Services Division, especially the late J. François and Yeboah, and the Ghana Wildlife Division, in particular G.A. Punguse, L. Agyene, M. Adu-Nsiah, K. Moses Sam and J. Grainger and their team at Goaso, for supporting the fieldwork. In Côte d'Ivoire we are grateful for the fieldwork executed by Caspar Versteegden with the assistance and permission of SODEFOR, and H.J. Wöll, S. Bamba, B. Birchenhäger, M.N.P. Gbanzaï, J. Theuerkauf and W.E. Waitkuwait of the GTZ project in Côte d'Ivoire. Three reviewers provided useful comments. This paper is a contribution of the ECOSYN project funded by DG VIII of the EC grant # B7-5041/95.02/VIII.

References

- Alexandre, D.Y. (1978) Le rôle disseminateur des éléphants en forêt de Taï, Côte d'Ivoire. *La Terre et la Vie*, **32**, 47–72.
- Alexandre, D.Y. (1980) Caractère saisonnier de la fructification dans une forêt hygrophile de Côte d'Ivoire. *La Terre et la Vie*, **34**, 335–350.
- Anon. (1992) *Rapports de programmes régionaux*. SATMACI, Direction Regionale de Est, Abengourou, Côte d'Ivoire.
- Anon. (1993) *Rapport d'activités Jan–Sept 1993*. SATMACI, Direction Regionale de Est, Abengourou, Côte d'Ivoire.
- Anon. (2001) *Strategy for the Conservation of Elephants in Ghana. To Ensure the Conservation of Viable Elephant Populations and their Habitats in Ghana*. Wildlife Division, Accra, Ghana.
- Appleton, M. (1997) Conservation in a conflict area. Illegal logging and the re-emergence of conservation in Liberia. *Oryx*, **31**, 153–155.
- Ballo, K. (1992) Perspectives d'un aménagement agro-sylvo-pastoral dans le Sud-Est de la Côte d'Ivoire. In *Compte rendu séminaire sur l'aménagement intégré des forêts denses humides et des zones agricoles périphériques* (eds A.P. Vooren, W. Schork, W.A. Blokhuis & A.J.C. Spijkerman), pp. 189–202. Tropenbos Series 1, La Fondation Tropenbos, Wageningen, Netherlands.
- Barnes, R.F.W. (1999) Is there a future for elephants in West Africa? *Mammal Review*, **29**, 175–199.
- Barnes, R.F.W., Craig, G.C., Dublin, H.T., Overton, G., Simons, W. & Thouless, C.R. (1999) *African Elephant Database 1998*. IUCN/SSC/AfESG in collaboration with UNEP/GRID. IUCN, Gland, Switzerland.
- Beier, P. & Noss, R.F. (1998) Do habitat corridors provide connectivity? *Conservation Biology*, **12**, 1241–1252.
- Caspar, H.-U. (1999) *Wildlife Utilization in Côte d'Ivoire and West Africa – Potentials and Constraints for Development Cooperation*.

- Tropical Ecology Support Program, Deutsche Gesellschaft für Technische Zusammenarbeit GmbH, Eschborn, Germany.
- De la Mensbrughe, G. (1966) *La germination et les plantules des essences arborées de la forêt dense humide de la Côte d'Ivoire*. Publication no. 26. Centre Technique Forestier Tropical, Nogent-sur-Marne (Seine), France.
- Dickinson, B. (1990) *An Estimation of Population Density of Forest Elephant (Loxodonta africana cyclotis Matschie) in Bia Tano and Subin Forest Reserves, Brong Ahafo Region, Ghana*. Unpublished report, Game and Wildlife Department, Accra, Ghana.
- Dudley, J.P., Mensah-Ntiamoah, A.Y. & Kpelle, D.G. (1992) Forest elephants in a rainforest fragment: preliminary findings from a wildlife conservation project in southern Ghana. *African Journal of Ecology*, **30**, 116–126.
- Foggie, A. (1949) Forest reservation in the Gold Coast. *Comptes rendus de la conférence Africaine des sols (Goma, Congo Belge 1948)*. *Bulletin Agricole du Congo Belge*, **40**, 677–688.
- Hawthorne, W.D. (1996) Holes and the sums of parts in Ghanaian forest: Regeneration, scale and sustainable use. In *Studies in Guinea-Congo Rain Forest* (eds M.D. Swaine, I.J. Alexander & R. Watling), pp. 75–176. Proceedings of the Royal Society, Edinburgh, UK.
- Hawthorne, W.D. & Parren, M.P.E. (2000) How important are forest elephants to the survival of woody plant species in Upper Guinean forests? *Journal of Tropical Ecology*, **16**, 133–150.
- Heffernan, P.J. & Graham, N.A.J. (2000) *Bia Elephant Census Ghana. Report I. Elephant Census*. Unpublished report, University of Newcastle, UK.
- Hoare, R.E. & du Toit, J.T. (1999) Coexistence between people and elephants in African savannas. *Conservation Biology*, **13**, 633–639.
- Holbeck, L.H. (1998) *Bushmeat Survey*. Unpublished report, Protected Areas Development Programme, Western Region. Wildlife Division, Takoradi, Ghana.
- Johnsingh, A.J.T. & Christy Williams, A. (1999) Elephant corridors in India: lessons for other elephant range countries. *Oryx*, **33**, 210–214.
- Lennertz, R. (1993a) *Inventaire des Forêts Classées de l'Est de la Côte d'Ivoire. FC Mabi. Rapport IFCE No. 7, SODEFOR/KfW/GTZ, Abengourou, Côte d'Ivoire*.
- Lennertz, R. (1993b) *Analyse des résultats. Rapport ICFE no. 8, SODEFOR/KfW/GTZ, Abengourou, Côte d'Ivoire*.
- Lieberman, D., Lieberman, M. & Martin, C. (1987) Notes on seeds in elephant dung from Bia National Park, Ghana. *Biotropica*, **19**, 365–369.
- Martin, C. (1982) *Management Plan for the Bia Wildlife Conservation Areas, Part I*. Final report, IUCN/WWF project 1251, Wildlife and National Parks Division, Ghana Forestry Commission, Accra, Ghana.
- Martin, C. (1991) *The Rainforests of West Africa. Ecology, Threats, Conservation*. Birkhäuser Verlag, Basel, Switzerland.
- Merz, G. (1981) Recherches sur la biologie de nutrition et les habitats préférés de l'éléphant de forêt, *Loxodonta africana cyclotis*, Matschie 1900. *Mammalia*, **45**, 299–312.
- Merz, G. & Hoppe-Dominik, B. (1991) Distribution and status of the forest elephant in the Ivory Coast, West Africa. *Pachyderm*, **14**, 22–24.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, **403**, 853–858.
- Oates, J.F., Abedey-Lartey, M., McGraw, W.S., Struhsaker, T.T. & Whitesides, G.H. (2000) Extinction of a West African red colobus monkey. *Conservation Biology*, **14**, 1526–1532.
- Opoku, G.K. (1988) *The elephant (Loxodonta africana cyclotis) farm raiding around the Bia National Park; incidences, causes and solutions*. BSc thesis, Institute of Renewable Natural Resources, University of Science and Technology, Kumasi, Ghana.
- Parren, M.P.E. & de Graaf, N.R. (1995) *The Quest for Natural Forest Management in Ghana, Côte d'Ivoire and Liberia*. Tropenbos Series 13. Tropenbos Foundation, Wageningen, Netherlands.
- Puth, L.M. & Wilson, K.A. (2001) Boundaries and corridors as a continuum of ecological flow control: Lessons from rivers and streams. *Conservation Biology*, **15**, 21–30.
- Sachtler, M. (1968) *General Report on National Forest Inventory in Liberia*. Technical Report No. 1, German Forestry Mission to Liberia, Bureau of Forest and Wildlife Conservation, Monrovia, Liberia.
- Saunders, D.A. & Hobbs, R.J. (1991) The role of corridors in conservation: what do we know and where do we go? In *Nature Conservation 2. The Role of Corridors* (eds D.A. Saunders & R.J. Hobbs), pp. 421–427. Surrey Beatty & Sons, Chipping Norton, Australia.
- Short, J. (1981) Diet and feeding behaviour of the forest elephant. *Mammalia*, **45**, 178–185.
- Short, J. (1983) Density and seasonal movements of forest elephant (*Loxodonta africana cyclotis*, Matschie) in Bia National Park, Ghana. *African Journal of Ecology*, **21**, 175–184.
- SODEFOR (1999) *Programme d'aménagement des forêts classées de l'est et de protection de la nature. Plan d'aménagement de la Forêt Classée de la Sogan*. Centre de Gestion d'Abengourou, SODEFOR, Abengourou, Côte d'Ivoire.
- Taylor, C.J. (1960) *Synecology and Sylviculture in Ghana*. Thomas Nelson and Sons, Edinburgh, UK.
- Vucetich, J.A. & Waite, T.A. (1998) Number of censuses required for demographic estimation of effective population size. *Conservation Biology*, **12**, 1023–1030.
- Waitkuwait, W.E. (1992) Restoration d'un écosystème forestier: contribution de l'aménagement de la faune. In *Compte rendu séminaire sur l'aménagement intégré des forêts denses humides et des zones agricoles périphériques* (eds A.P. Vooren, W. Schork, W.A. Blokhuis & A.J.C. Spijkerman), pp. 203–214. Tropenbos Series 1, La Fondation Tropenbos, Wageningen, Netherlands.
- Waitkuwait, W.E. (1998) *Aménagement écologique et suivi biologique. Leur intérêt pour l'orientation écologique de la gestion forestière*. Unpublished report, SODEFOR, Centre de Gestion Abengourou, Cellule Ecologie, Abengourou, Côte d'Ivoire.
- White, L.J.T. (1994) *Sacoglottis gabonensis* fruiting and the seasonal movements of elephants in the Lopé reserve, Gabon. *Journal of Tropical Ecology*, **10**, 121–125.

Biographical sketches

Marc Parren is a lecturer in tropical forestry at the University of Professional Education Larenstein and a researcher at Wageningen University. He studies the ecological effects of logging, and has conducted research on natural forest management in Cameroon, Equatorial Guinea, Ghana, Côte d'Ivoire and Liberia.

Bertken de Leede first worked in nature conservation as a volunteer in Ghana, since which she has worked for the Netherlands Ministry of Development Cooperation, with postings in Pakistan and Bolivia.