# Elephant crop damage and electric fence construction in the Maputo Elephant Reserve, Mozambique

*Fred de Boer and Cornelio Ntumi*

Departamento de Ciências Biológicas, Universidade Eduardo Mondlane, C.P. 257, Maputo, Mozambique

corresponding address:
Fred de Boer, Bureau Buitenland, RuG, Postbus 72, 9700 AB Groningen, The Netherlands
fax: +31 50 363 7100; e-mail: fred_pat@hotmail.com

## Abstract

An electric fence is at present being constructed around the Maputo Elephant Reserve, Mozambique, to protect farmers from elephant raids. Elephants cause crop damage estimated at 8800 $yr^{-1}$, or USD 8800 elephant$^{-1}$. Elephants preferred maize, melons and beans, and their raid frequency increased during harvest seasons. The proportion of elephant crop damage was higher on more productive fields than the less productive ones. In the most affected areas, 90% of the farmers reported elephant crop damage and 26% of the crops was lost to elephants. The total damaged area was estimated at 10% of 983 ha of cultivated fields. The farmers, who felt that traditional methods of frightening elephants were not effective, chose the option of constructing an electric fence. The construction and maintenance of the 38-km electric fence is estimated at USD 41,100 per year. At present, annual fence construction costs are much higher than the costs of crop damage. However, eventually the fence should not only lead to a decrease in crop damage by elephants but also contribute to better control of poaching and of access by people to the park.

## Résumé

On est en train de construire une clôture électrique tout autour de la Réserve à éléphants de Maputo, au Mozambique, pour protéger les fermes contre les éléphants. Les éléphants causent chaque année aux récoltes des dommages estimés à USD 8800, ce qui fait USD 50 par éléphant. Les éléphants préfèrent le maïs, les melons et les haricots, et la fréquence de leurs incursions augmentait quand venait la saison des récoltes. La proportion des dommages dus aux éléphants était plus élevée dans les champs plus productifs que dans les moins productifs. Dans les zones les plus touchées, 90% des fermiers faisaient état de récoltes endommagées par les éléphants, et 26% des récoltes étaient perdus à cause d'eux. La superficie endommagée totale était estimée à 10% des 983 hectares cultivés. Les fermiers, qui ont estimé que les méthodes traditionnelles pour effrayer les éléphants n'étaient plus efficaces, ont opté pour la construction d'une clôture électrique. La construction et l'entretien des 38 km de clôture électrique sont estimés à quelque USD 41 100 par an. Pour le moment, la construction coûte beaucoup plus cher que les dommages causés aux récoltes. Toutefois, la clôture ne devrait pas seulement entraîner une diminution des dommages dus aux éléphants, mais aussi contribuer à un meilleur contrôle du braconnage et des personnes qui pénètrent dans le parc.

## Introduction

The fragmentation of habitats and escalating human population growth contribute to frequent elephant (*Loxodonta africana* Blumenbach) raids on cultivated fields (Dey 1991; Hoare 1995; Tchamba et al. 1995; Campbell et al. 1996; Kiiru 1996; Lahm 1996). The local authorities seek solutions such as shocking or shooting the elephants, compensating the farmers monetarily, and constructing electric fences (Hoare 1995; Thouless and Sakwa 1995; Lahm 1996; Osborn unpubl.). These measures have not always been totally successful. Shooting does not deter elephants from raiding fields (Bell 1986 cited in Mkanda 1994; Hoare 1995; Lahm 1996; Osborn unpubl.), people and animals break down the electric fences (Deodatus and Lipiya unpubl.;

Thouless and Sakwa 1995), and compensation does not decrease the conflicts between humans and elephants. Local communities living around protected areas often bear the costs of living with wildlife (Sukumar 1990; Swanson and Barbier 1992; Skonhoft 1995; de Boer and Baquete 1998), sometimes without benefiting from this coexistence (Kiss 1990; Lewis et al. 1990; Happold 1995; Rihoy 1995; Heinen 1996). People sometimes leave the area if elephant crop raids become severe (Ostrosky unpubl.; Lahm 1996; Naughton-Treves 1997). This can lead to increased conflict between local people and park authorities.

Electric fencing is a possible long-term solution for decreasing crop damage (Hoare 1995; Thouless and Sakwa 1995). An electric fence constructed in the Maputo Elephant Reserve (MER), Mozambique, is primarily aimed at reducing the frequent elephant raids in the surrounding agricultural area (de Boer and Baquete 1998). In this paper we compare the cost of crop losses with that of constructing an electric fence.

## Materials and methods

### *Study area*

The MER is in south Mozambique (fig. 1). It was established in 1932, although its current boundaries were redefined in 1960. It is not fenced. The average annual rainfall is 690–1000 mm; the average temperature 20–26° (DNFFB unpubl.). The soils are mainly sandy. The six vegetation types are dune, mangrove, riverine, forest, woodland, and grass plains (Tello 1973; de Boer et al. 2000). A population of about 180 elephants (I.White, pers. comm. 1998) is found in the area. Other herbivores that live in the MER are hippos *(Hippopotamus amphibius)*, red duiker *(Cephalophus natalensis)*, common duiker *(Sylvicapra grimmia)*, reedbuck (*Redunca arundinum)*, and suni *(Neotragus moschatus).* Poaching in the last decades has reduced the animal population considerably. The elephants are distributed relatively close to the human settlements, and they hide in the dense forest patches (de Boer et al. 2000). They are mainly responsible for crop damage in the area. These incidents influence the attitude of the local population negatively (de Boer and Baquete 1998). Elephants do not cross the Maputo River, where the majority of the agricultural fields are found. Therefore, crop damage is reported only between Salamanga and Massuane, on the eastern side of the Maputo River and the western side of the Futi River (fig. 1).

The electric fence (fig. 1) was constructed by Blanchard Mozambique Enterprises, a private enterprise that obtained a long-term lease for the MER. The Maputo River, acting as a natural boundary for the park, forms part of a deflecting fence system (Hoare 1995). The agency intended to develop the area for tourism, but its lease was not continued after 2000. However, its plans are still valid and are being used here as an example for similar initiatives.

### *Study method*

Elephant crop raiding was studied using data sheets that were distributed to 12 informants living in different villages: Bela Vista, Lagoa Piti, Chia, Zitundo, Mvukunza, Salamanga, Fábrica de Cal, Futi River (which was divided into four areas) and Massuane (fig.1). The study was carried out over 13 months, from January 1996 to January 1997. The informants asked the villagers to report to them any incidents of crop raids by elephants in the area. The mean monthly raid frequency was calculated from the monthly percentage of days when crop raids occurred in each village. The average number of raids was calculated using data from all 12 villages.

In January 1996, just before the harvest, 100 people from each village were asked to attend a general meeting. They had no prior knowledge of the subject to be discussed. At Lagoa Piti only 19 people were present. These people were asked once if they had experienced elephant crop damage to their agricultural fields in the past 30 days. We visited and accessed the crop damage on the fields that were accessible of all the people who responded positively to this question. Crop type was determined, total field area measured, and the destroyed and non-affected areas in the fields assessed using the method described in Mettrick (1993). Elephant damage was distinguished from hippo damage by identifying footprints. The people were asked about the methods they used to deter elephants and the specific effectiveness of each method. They were also asked to mention alternative measures for reducing elephant raids. It was assumed that the total cultivated area of farmers who suffered crop damage by elephants and those who did not report crop damage was equal. Total crop damage was calculated from the combined results of questionnaires, field measurements and data on the existing total number of families in the area and agricultural fields. Crop losses (replacement costs) were estimated in US dollars, using local market prices.

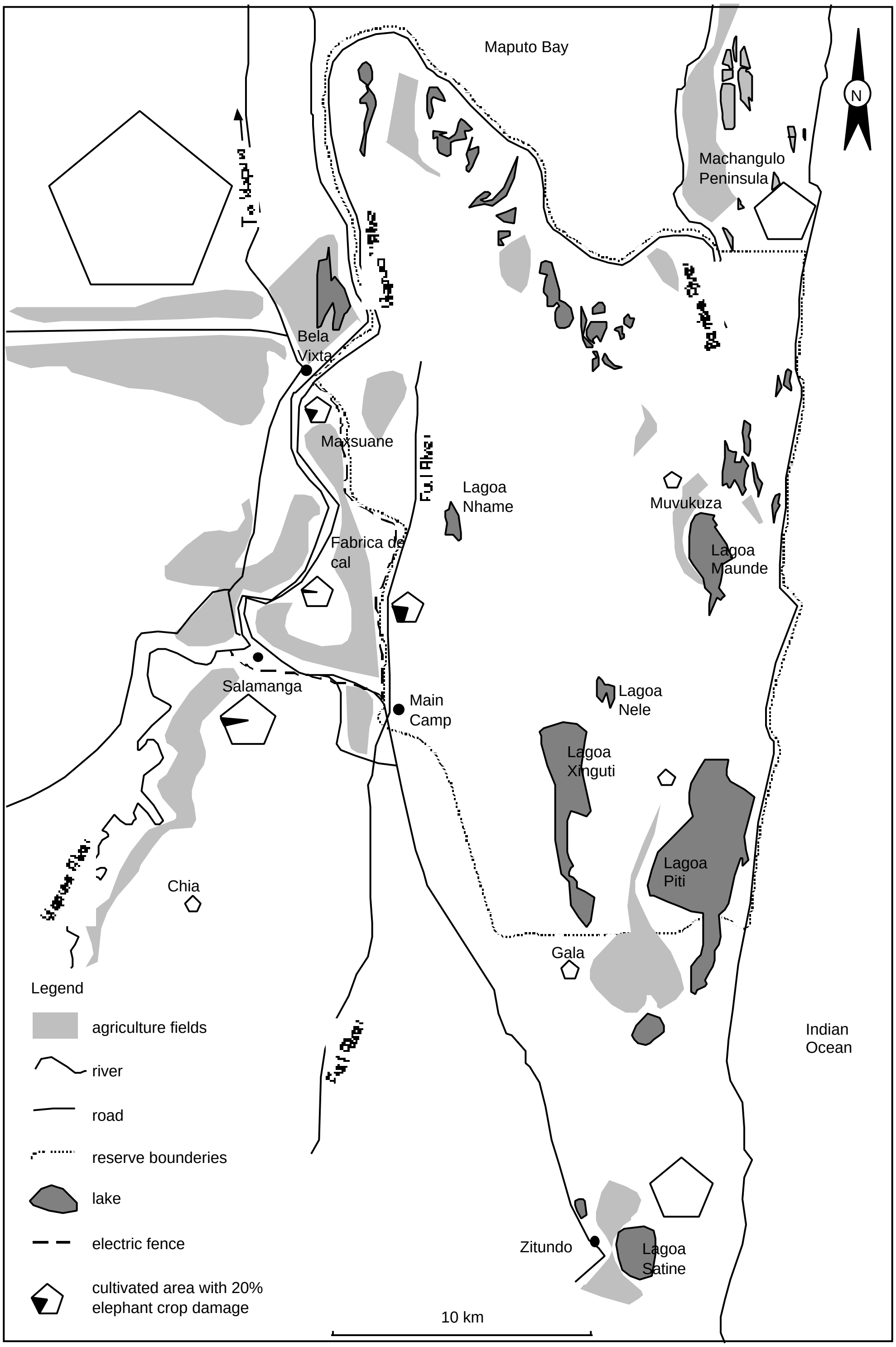


Figure 1. Location of the study area and occurrence of crop damage. The relative size of the pentagons represents the relative size of the cultivated area, with percentage of area raided by elephants indicated by the black section of the pentagon.

Compensation records provided a second data source on crop damage caused by elephants. The degree of damage to specific areas in March 1997 was estimated visually in percentage by staff from the Ministry of Agriculture, who are experienced in human–elephant conflict. The crop type was identified, and the potential expected production from each specific field was estimated. Total crop damage in kilograms was calculated by multiplying area (ha) x damage (%) x potential production (kg ha$^{-1}$). The fields of all farmers reporting crop damage were visited.

### Fence construction

The fence is supposed to protect agricultural fields between Salamanga and Massuane, along the Futi River (see fig. 1). It was made of three-strand electric wire mounted on a game fence 2.5 m high and powered with solar energy. The fence is 38 km long and cost USD 228,000, which is USD 6000 for each kilometre of construction (E. Gouws, pers. comm. 1998). We assumed that the investment was financed from a loan, and that the loan would be repaid by the investor at an interest rate of 5% over 20 years of equal annual instalments. The annual maintenance costs are estimated at 10% of the initial investment. The annual costs of fence construction cover the fixed annual repayment of the loan including interest of USD 18,300 (calculated following Emmanuel et al. 1990), and maintenance costs of USD 22,800, totalling USD 41,100 per year.

## Results

### Crop damage assessment

Crop damage is not evenly distributed in the area (fig. 1). In Massuane, 90% of the household were affected, which is the highest percentage of crop raiding (table 1). The mean area of agricultural fields on which elephant damage was reported was 38% of the total field area. Among the farmers who reported elephant damage, 17% lost more than half their cultivated area. Extrapolating the percentage of respondents with crop damage and the average damaged area per field, we estimated 100 ha to have been destroyed by elephants in the 30 days before the questionnaire was administered. This area represents 10% of the total area cultivated in Salamanga, Fábrica de Cal, Massuane and alongside Futi River. The area around the river was most affected, with a quarter of the total destroyed by elephants. Productivity of the fields was estimated at 402 kg ha$^{-1}$, of which 375 kg was maize and the

Table 1. Results of the crop-damage assessment carried out in January 1996 in four areas with elephant raids around the Maputo Elephant Reserve, Mozambique. Total field size and area destroyed by elephants are given; total crop damage is estimated

| | Area | | | | Total |
|---|---|---|---|---|---|
| | Salamanga | Fábrica de Cal | Futi | Massuane | |
| *Questionnaire data* | | | | | |
| Total questionnaires | 100 | 100 | 100 | 100 | 400 |
| People with crop damage (%) | 8 | 2 | 70 | 90 | 43 |
| *Fields with crop damage* | | | | | |
| Mean field size (ha) | 0.6 | 2.0 | 0.9 | 0.6 | 1.0 |
| Mean destroyed area (ha) | 0.3 | 0.8 | 0.4 | 0.1 | 0.4 |
| Area destroyed (%) | 50 | 38 | 41 | 22 | 38 |
| *Total area* | | | | | |
| Total cultivated area (ha) | 410 | 256 | 213 | 104 | 983 |
| Total destroyed area (ha) | 16 | 2 | 61 | 21 | 100 |
| Total area destroyed (%) | 4 | 1 | 26 | 20 | 10 |
| Estimated average potential production (kg ha$^{-1}$) | 402 | 402 | 402 | 402 | 402 |
| Total production loss (kg) | 6,430 | 800 | 24,520 | 8,440 | 40,200 |
| Total production loss (USD) | 1,008 | 126 | 3,843 | 1,323 | 6,300 |

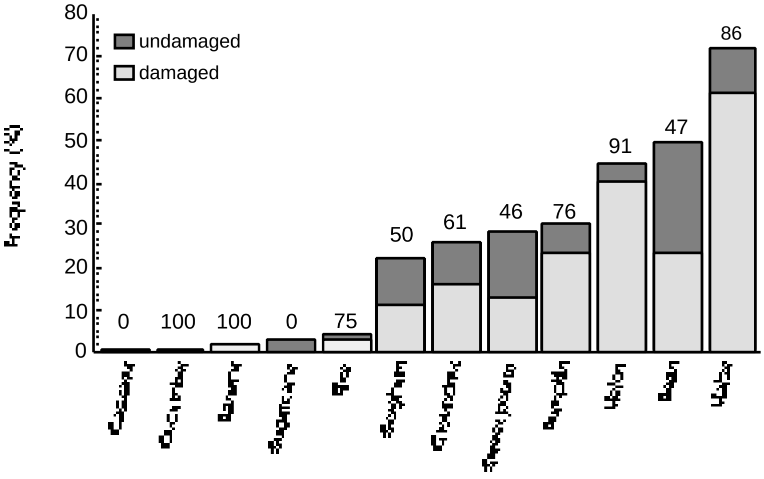


Figure 3. Cumulative frequency of agricultural fields with and without elephant crop damage. The values given above the bars are the percentages of agricultural fields in which the specific crop was raided by elephants and are a relative measurement of preference.

remaining 27 kg associated crops (cassava, bean, sweet potato and other vegetables). This production was equivalent to USD 63 ha$^{-1}$, of which 81% was maize. A total loss of production caused by elephants of 40,190 kg was estimated during the previous 30 days, equivalent to USD 6300 (table 1).

Figure 2 gives the mean monthly elephant raid frequency over the year and the development stage of the main crops.The raids show a bimodal pattern corresponding to the two peak production periods of maize and cassava. Elephant crop raids are less frequent in periods when crops are still immature. The elephants' preference for certain crop species was analysed by comparing the crop species on an agricultural field with the crop species that were actually eaten by elephants (fig. 3). The highest number of raids was reported for fields with maize, melon and bean, but the elephants preferred maize and melon to bean. The elephants also consumed pumpkin, rice, banana and cucumber. However, the total area cultivated with rice, banana or cucumber was very low.

The second data source of information on crop damage incidents was the records used to compensate for crop damage in March 1997 (table 2). Damage was less in 1997 than in 1996; the mean damaged area was 0.024 ha per field, on which 58% of the crops was estimated to have been damaged. Total damaged area was 4.5 ha, and total crop loss was estimated at 12,530 kg, or 31% of the 1996 estimates. This crop damage is equivalent to USD 2500. Elephant damage was not evenly distributed over the fields (fig. 4). The more productive fields had a relatively higher percentage of elephant damage, while on the less productive fields, elephant damage was 40% or less. A positive significant correlation confirmed this relationship between field production and elephant damage ($r = 0.341$, $t = 4.00$, $n = 185$, $P < 0.0001$).

Landowners ($n = 79$) were asked what methods they used for deterring elephants. All respondents (100%) replied that they drummed on tins and pots to frighten them off, but only 52% of the people affirmed that this method was effective. About half of the people (55%) also used clothes and rags tied to poles and trees to frighten off elephants, but this was generally found to be the least efficient method, with only 15% of the people confirming success. The only method consid-

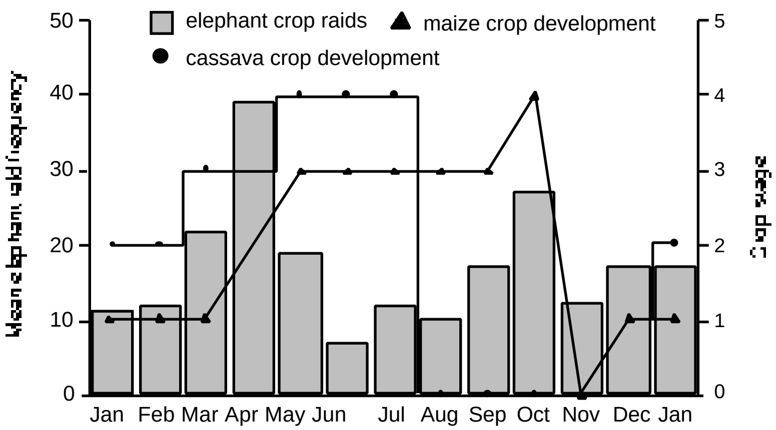


Figure 2. The frequency of elephant crop raids from January 1996 to January 1997 in relation to crop development. Crop stage is classified in five categories from 1 (seedlings) to 5 (harvest).

Table 2. Crop damage caused by elephants in March 1997 around the Maputo Elephant Reserve

| Variable | Value |
|---|---|
| Households with crop damage | 185 no. |
| Damaged fields with maize | 97% |
| Damaged fields with bean | 73% |
| Average destroyed area | 0.024 ha |
| Total destroyed area | 4.5 ha |
| Estimated average potential production | 201 kg $ha^{-1}$ |
| Average loss | 58% |
| Total production loss | 12,530 kg |
| Total production loss | USD 2490 |

Data as determined by the Blanchard Mozambique Enterprises and the Mozambique Foundation

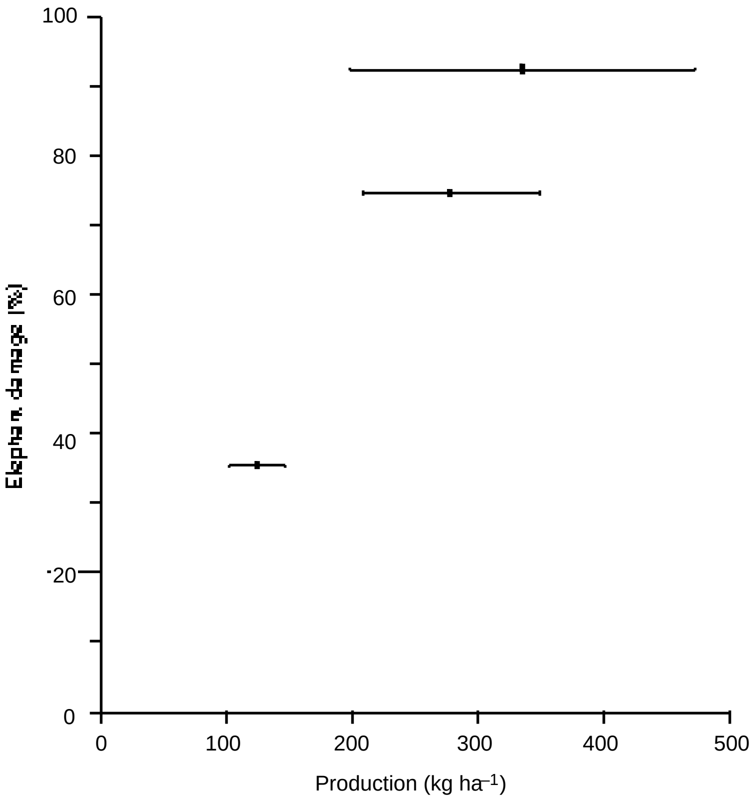


Figure 4. The percentage of elephant crop damage found on an agricultural field in relation to the estimated potential production of that field (data from Blanchard Mozambique Enterprises and the Mozambique Foundation).

ered 100% successful was for game wardens to fire shots. However, only 22% of the respondents said that this way of frightening off elephants was used on their fields. Farmers suggested the following as measures for dealing with elephant crop raids: installation of an electric fence (81% of respondents), compensation payments (46%), regular patrols by game wardens (23%), and the shooting of problem elephants (9%).

## Discussion

Elephants, although generalist feeders, prefer certain crops. The food preferences that both Deodatus and Sefu (unpubl.) and Lahm (1996) have reported are similar. No relation could be found between the percentage of crop damage and the total area under cultivation, as documented by Sukumar (1990) (see fig. 1). Instead, damage seems related to proximity to the MER boundary and hence the presence of forest patches that can be used for shelter. A similar situation where crop damage was higher near park bounderies and in the vicinity of forest patches was described for Uganda (Naughton-Treves 1997, 1998). Elephants raid the fields and damage the growing crops mainly at night (Sukumar 1990; Hoare 1995; Lahm 1996). Raids that occur outside the gowing season might be related to the browsing of trees in communal areas (Sukumar 1990; Naughton-Treves 1997; Osborn unpubl.).

Elephants clearly prefer the more productive fields to the less productive ones. Figure 4 shows that elephants stay longer and consume more from more productive fields. Equal amounts of forage could be left on the more productive as well as the less productive fields after a raid. This corresponds with the marginal value theorem (Charnov 1976), which assumes that an animal will leave a patch when the grazing intake averages that overall mean of all patches combined. This means that animals stay longer in patches of higher quality (Jiang and Hudson 1993; Wildhaber et al. 1994). However, more data are needed to test this hypothesis.

The crop damage estimates were USD 6300 for 1996 and USD 2500 for 1997. Differences in these estimates can be explained by the different methods used for the estimations as well as by the different years of study. The mean damage of the two estimates is USD 4400. However, this figure is certainly an underestimation, as it is based on two one-month field studies. The damage that occurred outside the sampling period was not taken into account in either study. Therefore, it needs to be multiplied by a factor of two at least because of ongoing agricultural activities and crop raids by elephants throughout the year (see fig.2). The total annual cost, therefore, increases to USD 8800.

Paying compensation may, in the long run, encourage farmers to cultivate in areas with a high record of elephant crop damage, because compensation payments exclude production risks. According to Hoare (1995) compensation schemes are not successful. The total annual costs are not evenly spread among the human population, and some farmers experience considerably more loss from elephant raids than others (see also Naughton-Treves 1997).

Most people (81%) favoured construction of an electric fence because traditional methods were not effective.

The negative attitude of people towards the MER has largely been influenced by loss from elephant crop damage (de Boer and Baquete 1998). Although the fence may also decrease the raid frequency of bush pigs *(Potamochoerus porcus)* and hippos from the Futi River, damage by antelopes and hippos coming from the Maputo River will continue. People complain about large, aggressive, nocturnal animals (Deodatus and Sefu unpubl.; Hill 1997; Naughton-Treves 1997). However, small rodents generally cause more crop damage than the large animals (Lahm 1996). The fence will probably decrease crop damage, but fence-breaking elephants and other crop-raiding animals will still cause problems (Thouless and Sakwa 1995).

The proposed fence will not entirely enclose the MER. A deflecting fence will be constructed in the favoured crossing area of elephants on their way from the reserve to the agricultural area. The protected area is only a small section where crop damage is highest. The MER benefits from its natural boundaries formed by the Futi River, Maputo Bay and the sea. These natural boundaries minimize the amount of fencing required, thus making the project cheaper. Costs for the area are still relatively high, however, when compared with the construction cost of fences in other countries (compare with Hoare 1995; Thouless and Sakwa 1995).

Fence construction costs will be partly compensated by the decreasing crop damage. The break-even point depends on the amount of crop damage. Presently estimated at USD 8800 per year, this figure is much less than the costs of constructing and maintaining the fence, estimated at USD 41,100 per year. Fence construction is therefore not economically viable for the present amount of crop damage. The fence, however, will also improve the protection of other animal species presently in the reserve and species that it is planned to reintroduce. The fence will also help control human activities such as cultivating and exploiting natural resources in the reserve (see de Boer and Baquete 1998). These extra benefits are not included in the calculation. The cost–benefit analysis could also be improved by including the cost of fence breaking by elephants (Thouless and Sakwa 1995) and the decrease in elephant poaching. De Boer and Ntumi (unpubl.) analyse the financial costs and benefits of an electric fence where such factors other than crop damage are taken into account.

## Acknowledgements

We are grateful to the Direcção Nacional de Florestas e Fauna Bravia, the staff of the Maputo Elephant Reserve, and Blanchard Mozambique Enterprises, who granted us permission to work in the Maputo Elephant Reserve. We also thank the Mozambique Foundation, and Ben Ngwenya and Eugene Gouws, who let us use their crop damage estimations. The manuscript was considerably improved by discussions with Herbert Prins and Rudi Drent, and by the comments of Ian Whyte, John Hearne, Richard Hoare and Kyle Tomlinson, for which we sincerely thank them. The research was carried out within the framework of the Deibi Project.

## References

Campbell, B.M., Butler, J.R.A., Mapaure, I., Vermeulen, S.J., and Mashove, P. (1996) Elephant damage and safari hunting in *Pterocarpus angolensis* woodland in northwestern Matabeleland, Zimbabwe. *African Journal of Ecology* 34, 380–388.

Charnov, E.L. (1976) Optimal foraging, the marginal value theorem. *Theoretical Population Biology* 9, 129–136.

de Boer, W.F., and Baquete, D.S. (1998) Natural resource use, crop damage and attitudes of rural people in the vicinity of the Maputo Elephant Reserve, Mozambique. *Environmental Conservation* 25, 208–218.

de Boer, W.F., and Ntumi, C.P. (unpubl.) A cost-benefit analysis of an electric fence protecting farmers from crop raiding elephants in the Maputo Elephant Reserve. 34 p.

de Boer, W.F., Ntumi, C.P., Correia, A.U., and Mafuca, J.M. (2000) Diet and distribution of elephants: the Maputo Elephant Reserve, Mozambique. *African Journal of Ecology* 38, 188–201.

Deodatus, F.D., and Lipiya, A.K. (unpubl.) Public relations and crop protection electric fencing, Kasungu National Park 1990. FAO, Lilongwe, Malawi, 1991. 19 pp.

Deodatus, F.D., and Sefu, L. (unpubl.) National survey of wildlife pests. FAO, Lilongwe, Malawi, 1992. 57 pp.

Dey, S.C. (1991) Depredation by wildlife in the fringe areas of North Bengal forests with special reference to elephant damage. *Indian Forester*, October, p. 901–908.

DNFFB (unpubl.) GEF transfrontier conservation areas and institution strengthening project. Direcção Nacional de Florestas e Fauna Bravia, Maputo, Mozambique, 1994. 297 pp.

Emmanuel, C., Otley, D., and Merchant, K. (1990) *Accounting for management control.* Chapman and Hall, London.

Happold, D.C.D. (1995) The interactions between humans and mammals in Africa in relation to conservation: a review. *Biodiversity and Conservation* 4, 395–414.

Heinen, J.T. (1996) Human behavior, incentives, and protected area management. *Conservation Biology* 10, 681–684.

Hill, C.M. (1997) Crop-raiding by wild vertebrates: the farmer‘s perspective in an agricultural community in western Uganda. *International Journal of Pest Management* 43, 77–84.

Hoare, R. (1995) Options for the control of elephants in conflict with people. *Pachyderm* 19, 54–63.

Jiang, Z., and Hudson, R.J. (1993) Optimal grazing of wapiti (*Cervus elephus*) on grassland: patch and feeding station departure rules. *Evolutionary Ecology* 7, 488–498.

Kiiru, W. (1996) Management options for Shimba Hills elephants after fencing of the reserve. *Pachyderm* 22, 45–46.

Kiss, A. (1990) *Living with wildlife resource management with local participation in Africa.* World Bank Technical Paper 130. World Bank, Washington.

Lahm, S.A. (1996) A nationwide survey of crop-raiding by elephants and other species in Gabon. *Pachyderm* 21, 69–77.

Lewis, D., Kaweche, G.B., and Mwenya, A. (1990) Wildlife conservation outside protected areas: lessons from an experiment in Zambia. *Conservation Biology* 4, 171–180.

Mettrick, H. (1993) *Development oriented research in agriculture.* Centre for Development Orientated Research in Agriculture, Wageningen, Netherlands.

Mkande, F.X. (1994) Conflicts between hippopotamus (*Hippopotamus amphibius* (L.)) and man in Malawi. *African Journal of Ecology* 32, 75–79.

Naughton-Treves, L. (1997) Farming the forest edge: vulnerable places and people around Kibale National Park, Uganda. *Geographical Review* 87, 27–46.

____(1998) Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conservation Biology* 12, 156–168.

Osborn, L (unpubl.) Elephants human conflicts around the Maputo Elephant Reserve, Mozambique. IUCN, Maputo, Mozambique, 1996. 8 pp.

Ostrosky E.W. (unpubl.) The elephant population of the Tembe Elephant Park, KwaZulu: management recommendations. Department of Economic Affairs, Ulundi, South Africa, 1988. 22 pp.

Rihoy, E. (1995) *The commons without the tragedy: strategies for community-based natural resources management in southern Africa.* Conference proceedings. Wildlife Technical Coordination Unit, Southern Africa Development Community, Lilongwe, Malawi.

Skonhoft, A. (1995) On the conflicts of wildlife management in Africa. *International Journal of Sustainable Development and World Ecology* 2, 267–277.

Sukumar, R. (1990) Ecology of the Asian elephant in southern India. 2: Feeding habits and crop raiding patterns. *Journal of Tropical Ecology* 6, 33–53.

Swanson, T.M., and Barbier, E.B. (eds.) (1992) *Economics for the wild.* Earthscan Publications, London.

Tchamba, M.N., Bauer, N., and Iongh, H.H. (1995) Application for VHF-radio and satellite telemetry techniques on elephants in Waza National Park, Cameroon. *African Journal of Ecology* 33, 335–346.

Tello, J.L.P.L. (1973) Reconhecimento ecológico da Reserva dos Elefantes do Maputo. *Revista de Veterinária Moçambicana* 5/6, 1–186.

Thouless, C.R., and Sakwa, J. (1995) Shocking elephants: fences and crop raiders in Laikipia District, Kenya. *Biological Conservation* 72, 99–107.

Wildhaber, M.L., Green, R.F., and Crowder, L.B. (1994) Bluegills continuously update patch giving-up times based on foraging experience. *Animal Behaviour* 47, 501–513.