# Aerial elephant count in the Shimba Hills ecosystem, Kenya

*Moses Litoroh*

Shimba Hills National Reserve, PO Box 30, Kwale, Kenya
tel: +254 127 4159
email: moseslitoroh@hotmail.com

## Abstract

A total elephant wet count was conducted by helicopter in the Shimba Hills ecosystem in August 1997. The aim of the survey was to verify the estimated mean of 412 elephants obtained through dung counts, and thus ascertain if elephants in Shimba should be culled. During this survey, 464 elephants were counted, of which 150 were in Mwaluganje, giving a density of 6 elephants per km$^2$. Results from this count were similar to those from dung counts, which it complements. This survey clearly shows earlier gross underestimation of elephant numbers in the Shimba Hills. The solution to the problem in Mwaluganje caused by the high elephant density is to reduce the density. Translocation options are strongly suggested.

## Résumé

On a réalisé un comptage total des éléphants par hélicoptère dans l'écosystème des Shimba Hills en août 1997. Le but de cette étude était de vérifier l'exactitude de l'estimation moyenne de 412 éléphants obtenue à partir du comptage des crottes afin d'être sûr qu'il ne fallait pas procéder à l'abattage d'un certain nombre d'éléphants de Shimba. Au cours de cette étude, on a dénombré 464 éléphants, dont 150 à Mwaluganje, ce qui équivaut à une densité de 6 éléphants au km$^2$. Les résultats de cette étude étaient comparables à ceux des comptages de crottes qu'ils viennent complémenter. Ils montrent clairement que les évaluations précédentes des éléphants de Shimba Hills étaient grossièrement sous-estimées. La solution du problème causé par la forte densité d'éléphants à Mwaluganje passe par une réduction de cette densité. On suggère avec insistance de penser à l'option de translocation.

## Introduction

While the history of Kenya's elephants has been reviewed in detail by Poole et al. (1992), information is insufficient on elephants at the coastal strip. Unconfirmed accounts indicate that elephants were present in the Shimba Hills in the early 1900s (Poole et al. 1992), although they had been overexploited for the ivory trade between 1840 and 1890 (Spinage 1973).

Traditionally, elephants moved throughout Kwale District, migrating regularly from the Shimba Hills area to Mkomazi Game Reserve in northern Tanzania and Tsavo National Park, 40 km to the south-west and 60 km to the north-west, respectively (Stewart and Stewart 1963; Risley 1966; Ross 1981; Poole et al. 1992). Makin (1968) concluded that a game corridor should be established between Shimba Hills across the Ramisi River and west of Mt Jombo into Tanzania. Controlled shooting of elephants by the Game Department contributed significantly to migration decline. Also interfering with their migratory routes was the establishment of the Shimba Hills settlement scheme and the cultivation it brought. The recent construction of an electric fence has firmly curtailed the natural migration pattern.

Heavy elephant poaching occurred along some parts of the migration routes (Stewart and Stewart 1963; Risley 1966). Shimba elephants were also hunted for their ivory in the surrounding area. According to Game Department records, in September 1934 Pat Ayre, a professional hunter, killed 12 elephants near Mrima Hill (fig. 1) on control. Deliberate government action to eliminate them to settle people caused further elephant mortality. In 1961/62, for instance, the Game Department shot 250 elephants on control.

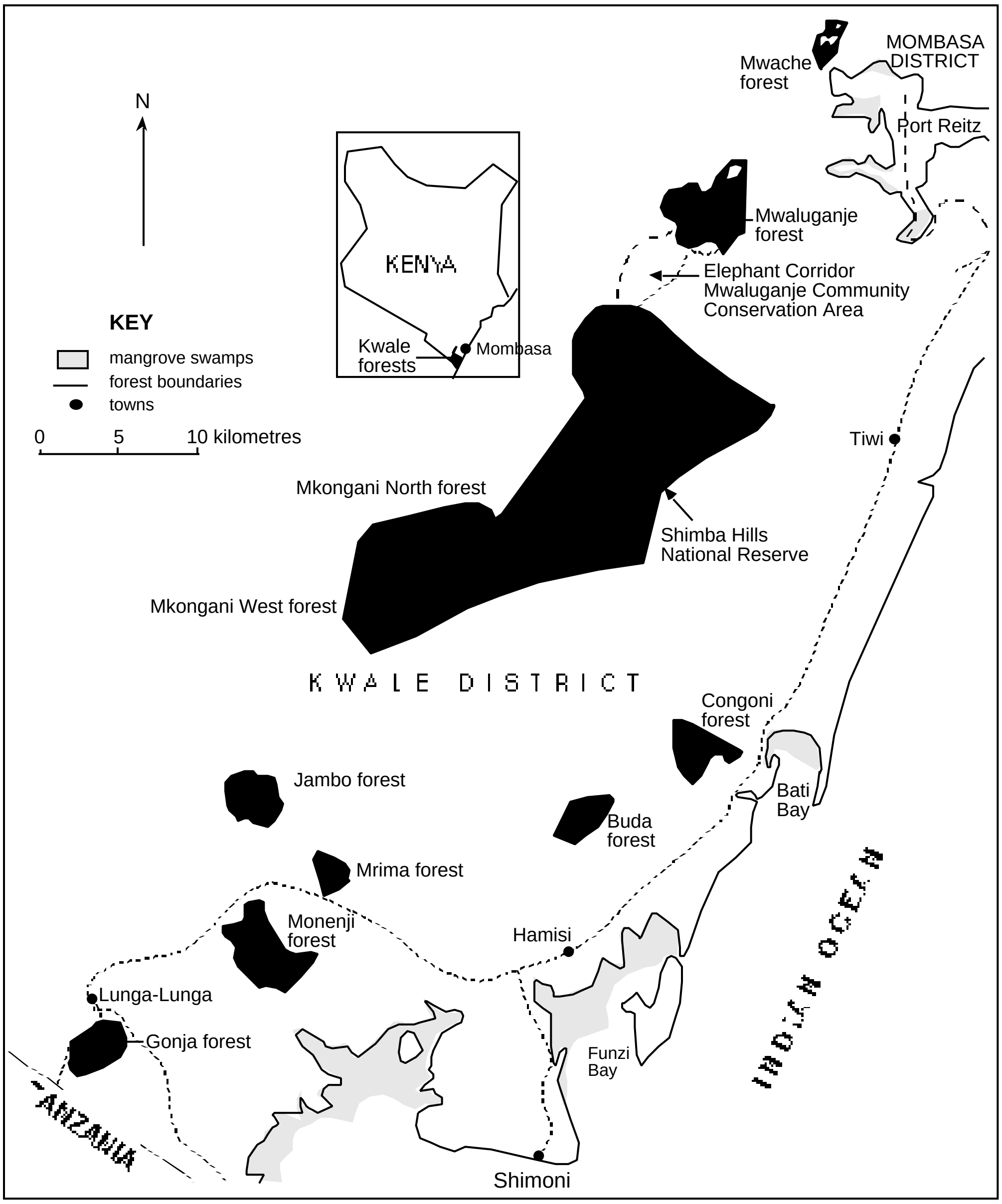


Figure 1. Location of the Shimba Hills ecosystem and Kwale forests.

### *Monitoring*

No scientific monitoring of elephants took place in the Shimba Hills before the 1970s. The available data were those recorded by Jarman (1973), estimating 2000 elephants for the entire Kwale District. These elephants were intermittently monitored by district by the Department of Resource Surveys and Remote Sensing (DRSRS) from 1977 using sample counts. Surveys the department conducted after 1993 indicate that no elephants existed in Kwale, although they were confined within Shimba. This is probably because of the dense vegetation cover. In a forest ecosystem like Shimba, making an accurate count of elephants is extremely difficult because visibility is poor.

Dung count therefore appears to be the most practical method for calculating elephant numbers (Barnes and Jensen 1987). Although this method has inherent statistical uncertainty, it can give precise and accurate results, depending on how the data are analysed.

Using dung counts, studies in Shimba by Reuling et al. (1992) and Mwathe (1995) gave mean estimates of 412 ± 165 and 453 ± 181 elephants, respectively. In June 1995, 232 elephants were counted by using the total count technique with a high-fixed-wing aircraft (Kiiru 1995). Unlike the DRSRS surveys, which took in the whole district, these surveys focused primarily on the Shimba Hills ecosystem.

It is generally agreed that elephant numbers in the forest have increased since the 1950s. This is probably as a result of range compression brought about by agricultural development, and poaching pressure in the 1970s and 1980s (Poole et al. 1992), which caused ele-phants to move into the forest from the surrounding areas. The thick forest cover coupled with an elephant-tolerant attitude of the local people provided protection for elephants, enabling them to survive the poaching years.

### Vegetation damage by elephants

Vegetation damage by elephants in the Shimba Hills ecosystem has reached critical levels in localized areas. The damage ranges from inhibiting regeneration through browsing in areas like Longomwagandi (Höft and Höft 1995) to causing death of mature trees through debarking and toppling them in Mwaluganje Forest (pers. obs.). Now that the reserve is nearly fully ringed with an electric fence, the destruction of biodiversity is likely to increase to crisis levels. This has caused concern for the Kenya Wildlife Service (KWS) and other conservation bodies, both locally and internationally. Previous studies in the Shimba Hills (for example, Schmidt 1991, 1992; Robertson and Luke 1993; Davis and Bennum 1993; Höft and Höft 1995) have expressed similar concerns. Results from these studies express the need to manage elephant intervention urgently to protect biodiversity. Additionally, in 1993 KWS initiated a study of the interaction between elephants and their habitat to investigate the impact of elephants on biodiversity. The objective was to help formulate management strategies suitable for maintaining a viable elephant population. Preliminary results from this study (Mwathe 1995) indicate that vegetation parameters such as tree height, tree density, mean stem diameter and forest openness were negatively correlated with elephant density.

What is at stake if the present level of elephant density is not reduced? Shimba Hills is probably the richest among the coastal forests for plant species (Davies and Bennum 1993). According to these authors, Shimba and Arabuko-Sokoke to the north account for most of the coastal forest biodiversity in Kenya. About 15% of the Shimba Hills plants are coastal endemics (Schmidt 1991), and 19 of the 159 rare tree species known for Kenya occur in Shimba (Beentje 1988). This makes Shimba Hills an important area for conserving the country's plant biodiversity. It is also a significant water catchment area, from which fresh water is supplied to Kwale and Mombasa towns and to the international tourist hotels along the south coast. This water catchment area must be protected through sound management initiatives for the benefit of coastal people. All these functions are at stake if the present level of ele-phant density is not reduced. At Mwaluganje Elephant Sanctuary there is additional conflict between developing tourism and conserving biodiversity. The challenge for KWS is to find the balance between the two.

### Survey justification

In search of a solution to the elephant problem at Shimba, KWS convened a workshop at Tiwi in Kwale District in March 1997. The participants were drawn from KWS, local and international NGOs, conservationists, universities, community leaders and research organizations. The workshop resolved that elephant density must be reduced. Although it recommended culling as the immediate and short-term intervention management option, this option became the subject of much debate. The controversy intensified when results from a modelling exercise (Kamanga 1997) were presented, proposing culling 200 elephants to save biodiversity. This study was based on data by Mwathe (1995). However, some participants felt that since there is statistical uncertainty in dung counts, Mwathe's results, and therefore Kamanga's, should be treated with caution.

In view of this controversy and uncertainty, the Eden Trust and the Mwaluganje/Golini Community Conservation Company volunteered to raise funds for another elephant count if KWS would authorize it, to determine a more accurate number before taking any culling decision. The survey went ahead with KWS facilitating and coordinating it. Its purpose was to count all elephants and determine their distribution in the Shimba Hills ecosystem, test the efficacy of a helicopter count and compare the results of the helicopter count with those of the dung count.

## Study area

The Shimba Hills ecosystem comprises the Shimba Hills National Reserve, Mkongani West and North Forest Reserves, the elephant corridor area and the Mwaluganje Forest Reserve (fig. 1). It is situated in Kwale District (south-eastern Kenya), stretching from 39°17' to 39°30' east and from 4°09' to 4°21' south. The climate is humid semi-hot equatorial (FAO/ UNESCO 1977), with a mean annual temperature of 24.2 °C (Braun 1977). The Shimba Hills has two rain seasons, the 'long rains' from mid-March to the end of June and the 'short rains' in October and November. Jatzold and Schmidt (1983) have reported a mean annual rainfall of 1150 mm. Mist and fog contribute considerably to the total amount of precipitation.

The Shimba Hills Forest Reserve was first gazetted in 1903. Its size was increased to 21,740 ha in 1956. In 1967 the Shimba Hills National Reserve (19,250 ha) was gazetted and superimposed on the bulk of the Shimba Hills Forest Reserve. By this gazettement it became the responsibility of the Wildlife Conservation and Management Department, the predecessor of KWS, and the Forest Department to manage the reserve jointly. Mkongani West (1366 ha) and Mkongani North (1113 ha) Forest Reserves were not gazetted as national reserves. Mwaluganje Forest Reserve (1715 ha) lies approximately 5 km north of the Shimba Hills National Reserve.

The Shimba Hills rise abruptly from the coastal plain to form a table plateau, which is surrounded by an escarpment rising from about 120 m on the coastal plain to 300 m for most of the plateau. The plateau is generally flat but rises to 450 m at Marere and Pengo Hills. This plateau encourages precipitation from water-laden clouds blowing in from the Indian Ocean. The water flow during both wettest and driest months is stabilized by the forest.

The Kenya Soil Survey (1978) described the soils of Shimba as deeply weathered. They are made up of sediments derived from Shimba grits and Mazeras sandstone, which yield coarse-grained ferralitic soils. A cover of medium-grained Magarini sands deposited on top of Shimba grits in the centre of the reserve yields soils with a higher cation exchange capacity, base saturation and larger water storage capacity in some areas like Longomwagandi.

The vegetation of Shimba Hills has been described in detail by Schmidt (1991). Generally, it consists of a mosaic of tropical, seasonal evergreen rain forest,

Moses Litoroh, KWS

In a forest ecosystem like Shimba, making an accurate count of elephants is extremely difficult because visibility is poor.

woodland (eight forest types) and fire-induced grassland. An analysis of 1991 aerial photographs of the Shimba Hills/Mkongani reserves suggests that 48% is forest formations, 36% scrub formation and 13% grasslands. In Mwalunganje, 23% is forest and woodland and 76% thicket and scrub.

Such combinations of habitat undoubtedly provide for a varied fauna: 295 butterfly species (35% of Kenya's species), of which 13 are rare, 24 are forest dependent, 2 are endemic; 35 mammal species, which include elephant, giraffe, yellow baboon, Angolan colobus and Sykes monkeys, Grimm's duiker, bushbuck, ring-backed waterbuck, warthog, buffalo, leopard, spotted and striped hyena (plus small mammals such as bats, rats and mice). Shimba is known for its threatened population of the sable antelope, which is endemic to the reserve. One hundred eleven forest bird species have been recorded, 20 of which are coastal birds (Davis and Bennum 1993).

## Method

The count was carried out in August 1997. The stand-ard technique of total aerial count was used. This technique aimed to systematically cover the entire surface of the defined census zone and to record every species of animals being counted and its geographical location. The pilot and observers were instructed according to the protocol described by Norton-Griffiths (1978) and improved upon by Douglas-Hamilton et al. (1994) and Douglas-Hamilton (1996). A six-seat Hughes 500 Jet Ranger helicopter, with doors removed to improve visibility, was used. The special advantage of the helicopter was that it could hover over big elephant groups and split them, allowing the observers to count accurately.

### *Census zone and counting blocks*

As the study area was only 250 km$^2$, it would ordinarily have been treated as one counting block. However, because of its shape and the strong monsoon winds from the Indian Ocean, it was decided to divide the census zone into four blocks (fig. 2), numbered 1 to 4. These blocks were demarcated using a GPS (global positioning system) and easily recognizable boundaries from an electric fence and human settlements around the study area. Flight blocks were marked on 1:50,000 maps with universal transverse mercator (UTM) coordinates superimposed on them to facilitate navigation with the GPS.

The whole survey was done in one day. Approximately 250 km$^2$ were covered in 5.56 h of count time, giving a searching rate of about 45 km$^2$ per hour. This searching rate gives data quality of category 1 (best quality) as described in the *African Elephant Database* (Said et al. 1995).

### *Flight paths*

The flight paths were determined by the pilot using the GPS and flown north–south because of strong winds. The transects were spaced at 500-m intervals

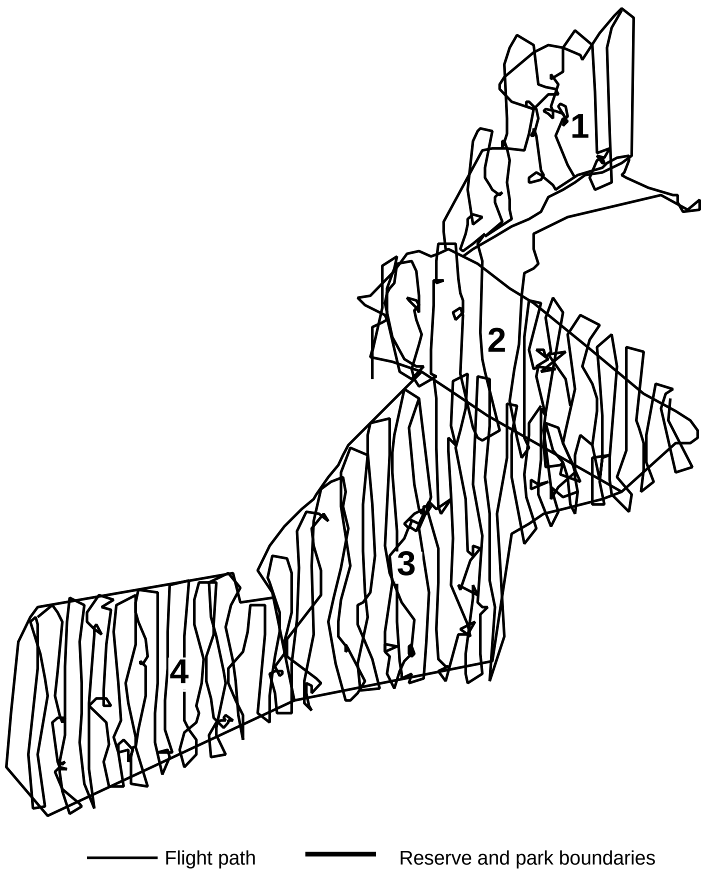


Figure 2. Counting blocks 1 to 4 and flight lines of helicopter 5Y-TOR.

but opened up to 1 km in areas where vegetation was not thick. Figure 2 shows the flight paths and relative intensity of the coverage, as recorded by GPS. Small circles in the flight paths indicate where the aircraft circled while elephants were counted.

Table 1. Summary of elephant counts in the study area, 1997

| Location | Counted (no.) | Area ($km^2$) | Minimum elephant density ($km^2$) |
|---|---|---|---|
| Mwaluganje | 150 | 25 | 6.0 |
| Shimba Hills Nature Reserve and forest reserves | 314 | 217 | 1.4 |
| Shimba ecosystem | 464 | 250 | 1.9 |

### *Recording data*

The front-seat observer (FSO) ensured that the data were recorded on a data sheet. Each observation was recorded in the GPS as a 'waypoint', and the waypoint simultaneously recorded on a data sheet. The rear-seat observers (RSOs) were responsible for spotting and counting. If RSOs spotted an animal, they called out to the pilot and the FSO, indicating if a diversion was needed to obtain a proper count. Every crew member and the pilot participated in the count. If the pilot circled, he ensured that the flight resumed on the transect at the point where the flight had broken off.

## Results

A total of 464 elephants (table 1) were counted in the study area. These include 452 elephants, which can be summed up from the GPS waypoints (fig. 4) plus 12 extra elephants that were not recorded in the GPS (see Discussion).

Mwaluganje elephant sanctuary had 150 elephants, while the rest were counted in the reserve. It was relatively easy to count elephants accurately in more open areas. However, in some instances elephants were spotted but their numbers could not be determined because of the thick vegetation. Hence the 150 is minimum.

Elephants were found in all habitat types, with large numbers in Mwaluganje, at Marere and along the southern border, where heavy crop-raiding had been reported a week before the survey. Figure 3 shows their distribution and concentrations.

A qualitative observation made on elephant sex groupings revealed that the Mwaluganje forest area had many cow–calf groups, and only a few were associated with a few bulls. The corridor area had a number of groupings of bulls but few cow–calf groups. Marere area had many cow–calf groups and few bull groups, contrary to previous indications.

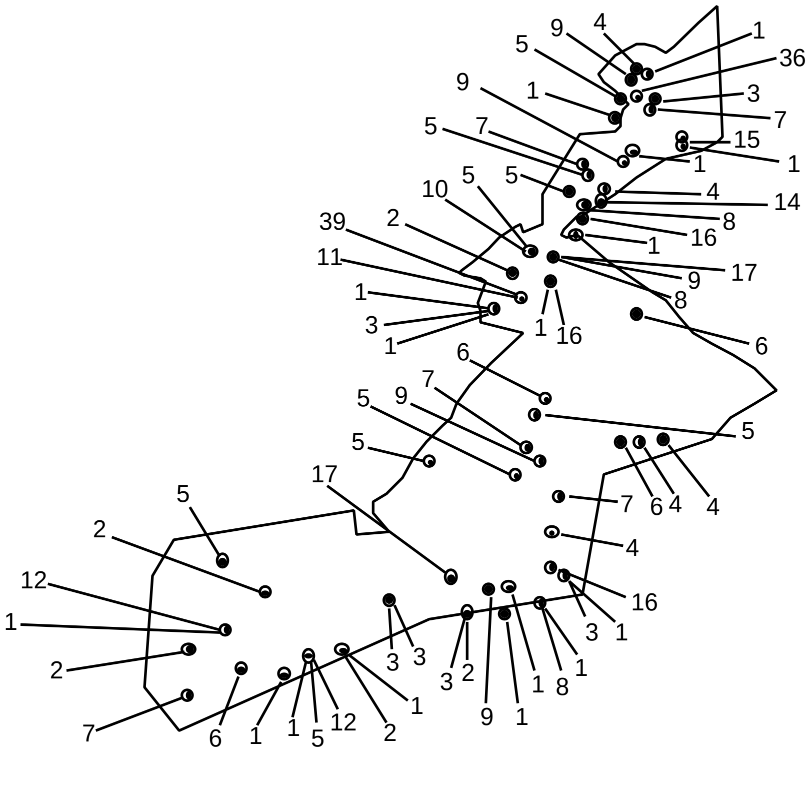


Figure 3. Elephant distribution.

## Discussion

This aerial census counted 464 elephants in the study area, complementing the dung count surveys. This figure is similar to the mean estimates of 412 and 429 elephants from dung counts by Mwathe (1995) and Reuling et al. (1992), respectively, but twice the number counted by Kiiru (1995). The difference in elephant numbers between this study and that of Kiiru (1995) clearly cannot be due to natural recruitment because of the short time interval. Neither can it be explained in terms of immigration because there is no evidence to suggest that elephant migration to Tsavo and Mkomazi still exists. This difference probably lies in the different techniques used. Although both surveys were total aerial counts during the wet season, Kiiru (1995) used a Husky with transects spaced at 1-km intervals while the present study used a chopper flying on 500-m transect interval. This had the effect of increasing the scanning intensity. Additionally, a helicopter had the special advantage of being able to hover over big elephant groups and split them up, allowing observers to make accurate counts. The present study shows that it is possible to count elephants and obtain a reliable minimum number in the Shimba Hills using a helicopter, and future surveys, done seasonally, should involve the use of one.

In a total aerial survey, the most important source of bias is observer efficiency and the failure of observers to see all the animals in their counting blocks (Caughley and Goddard 1972). In this study, the significant bias was due to dense vegetation. Shimba Hills is essentially a forest ecosystem, unlike savannahs where elephant aerial surveys are popular. A thick forest impairs visibility. An example of poor visibility was observed when an area had been flown twice without spotting any elephants, but on the third flight to refuel, 12 elephants emerging from the forest were sighted in a glade. In addition, elephants were sighted in the forest during the survey but could not be counted because of poor visibility. As a result, a few elephants were uncounted.

The second bias resulted from the inexperience of some crew members who were surveying for the first time. In view of the above biases, the number of elephants from this survey should be treated only as minimum. The true mean estimate, based on dung counts (Litoroh et al. 2001) is 575 elephants.

Elephants were distributed all over the reserve including in the southern part where it was thought that elephants do not occur. The highest concentrations were around Marere and Mwaluganje areas. Kiiru (1995) recorded a similar distribution pattern. She found that elephants clearly prefer thickets and scrub. Such habitat with glades occurs at Marere and in the corridor, probably accounting for the high numbers of elephants occurring there. However, this distribution pattern probably does not reflect the true situation because ground surveys by Mwathe (1995) and Litoroh (in prep.) have recorded high elephant dung densities in high canopy forest where no elephants were spotted. Marere and the corridor area have low vegetation cover, which allows easy spotting and counting of elephants. Clearly, this survey alone does not tell the whole story about elephant distribution in the Shimba ecosystem. To form a true picture, we must consider dung counts, which cover areas of dense vegetation.

Kiiru (1995) postulated that Shimba elephants will number about 400 animals (1.7 elephants per km$^2$) in the next 10 years, by which time vegetation damage will have become critical. However, Mwathe (1995) contradicted this and said that elephants at an estimated mean density of 1.6 per km$^2$ were already causing considerable damage. He showed that tree height and density were negatively correlated with high elephant densities. Coetzee et al. (1979) studying elephants in Kruger National Park obtained an elephant density of 0.4 km$^2$ while Pellew (1983) found a bull elephant density of 0.2 km$^2$ in the Seronera area of Serengeti National Park. Both studies showed that even at such low densities, elephants were causing considerable damage. In the current study, the minimum overall elephant density for Shimba Hills is 1.9 elephants per km$^2$; the density in Mwaluganje was 6, which is probably one of the highest elephant densities ever recorded. The impact of such high elephant densities on vegetation cannot be overemphasized, as can be seen in the Mwaluganje Forest Reserve.

To maintain an ecological balance, the elephant density must be reduced. Translocation should be considered. In good terrain and open country, KWS commonly uses translocation to manage wildlife populations. Shimba Hills and Mwaluganje, however, present special difficulties because the terrain is rough and the vegetation relatively thick. Nevertheless, and based on the outcome of the Tiwi workshop, KWS should take a bold step and translocate elephants to reduce the population density. A density of 0.5 ele-phants/km$^2$ is probably suitable for the Shimba Hills ecosystem at the moment. To achieve this and have an effect, 200 el ephants should be removed. Additionally, elephant immunocontraception should be considered as a means to stabilize the remaining population.

It is also important that KWS puts in place an elephant management policy to avoid emotional arguments against some management decisions even when the data are sufficient to support such decisions.

## Acknowledgements

This survey would not have been possible without the sole financial support of the Eden Wildlife Trust. KWS authorized this survey and facilitated and coordinated it in collaboration with the Eden Wildlife Trust. I would like to thank Dr Ian Douglas-Hamilton, who provided assistance at the planning stage. Mr Halvor Astrup provided the helicopter, which was piloted by Captain Phil Mathews. Logistical support came from Ted Goss. Aerial observers in addition to myself were George Muriuki and Moses Omurambi, all of us from KWS. Paula Kahumbu, then a graduate student at Princeton University, Camilla Moore, a student from the University of Edinburgh, and Will Travers were observers with private interests. Claire Geddes helped with the cartography as well as downloading data to a computer from the GPS. Thank you all.

## References

Barnes, R.F.W., and Jensen, K.L. 1987. How to count elephants in the forest. *IUCN African Elephant and Rhino Specialist Group Technical Bulletin* 1:1–6.

Beentje, H.J. 1988. Atlas of the rare trees of Kenya. *Utafiti* 1(3):71–123.

Braun, H.M.H. 1977. Seasonal and monthly rainfall probability tables for the east-central, north-western and coast regions of Kenya. Misc. Paper M 13. Kenya Soil Survey, Nairobi.

Caughley, G.J., and Goddard, J. 1972. Improving the estimates from inaccurate censuses. *Journal of Wildlife Management* 36:135–140.

Coetzee, B.J., Engelbrech, A.H., Joubert, S.P.J., and Retief, P.J. 1979. Elephant impact on *Sclerocarya* trees in *Acacia nigrescens,* the tropical plains thorn veld of Kruger National Park. *Koedoe* 22:39–60.

Davis G., and Bennum, L. 1993. Biodiversity overview of Shimba Hills National Reserve, Mkongani Forest Reserve and Mwaluganje Forest Reserve. A report prepared for the Kenya Indigenous Forest Conservation Project (KIFCON). KIFCON, Nairobi.

Douglas-Hamilton, I. 1996. Counting elephants from the air: total counts. In: Kadzo Kangwana, ed., *Studying elephants.* Technical Handbook Series No 7. African Wildlife Foundation, Nairobi.

Douglas-Hamilton, I., Gachago, S., Litoroh, M.W., and Mirangi, J. 1994. Tsavo elephant count. Report. Kenya Wildlife Service, Nairobi.

FAO/UNESCO. 1977. *Soil map of the world 1:5 000 000.* vol. 6, *Africa*. UNESCO, Paris. 299 p.

Höft, R., and Höft, M. 1995. The differential effects of elephants on rain forest communities in the Shimba Hills, Kenya. *Biological Conservation* 73:67–69.

Jarman, P.J., ed. 1973. Game Department Seminar, Elephant Discussion Group. University of Nairobi, 17 September 1973. Unpublished paper.

Jatzold, R., and Schmidt, H. 1983. *Farm management handbook of Kenya,* vol. 2c, *East Kenya.* Ministry of Agriculture, Kenya, in cooperation with the German Agricultural Team of the Germany Agency for Technical Cooperation. Erhart Gmbh, Trier. 411 p.

Kamanga, C.G. 1997. *Impacts of increasing elephant densities on biodiversity in Shimba.* Consultancy report. Kenya Wildlife Services, Nairobi.

Kenya Soil Survey. 1978. *Soils of the Kwale–Mombasa–Lungalunga area.* Reconnaissance Soil Survey Report No. R3 by D.O. Michieka, B.J.A. Van der Pouw, and J.J. Vleeshauer. Ministry of Agriculture, National Agricultural Laboratories, Nairobi.

Kiiru, W. 1995. Human–elephant interaction around Shimba Hills National Reserve, Kenya. MSc thesis, University of Zimbabwe.

Litoroh, M.W., Njue, A., Bitok, E., and Omondi, P. 2001. Elephant–habitat interaction study in Shimba Hills National Reserve. Final report to WWF/KWS on analysis of data collected between 1996 and 1999 under WWF/KWS Project Ref: KE0097.72, Nairobi.

Mwathe, K.M. 1995. Elephant–habitat interaction study in Shimba Hills National Reserve: elephant density estimates (floristic composition and elephant habitat damage assessment). Annual report to Kenya Wildlife Service, Nairobi.

Norton-Griffiths, M. 1978. Counting animals: handbook on techniques. In: J.J. Grindell, ed., *African Wildlife Biology* No. 1. AWLF, Nairobi.

Pellew, R.A. 1983. The impacts of elephant, giraffe and fire upon *Acacia tortilis* woodlands of the Serengeti. *African Journal of Ecology* 21:41–74.

Poole, J.H., Aggarwal, N., Sinange, R., Nganga, S., Broten, M., and Douglas-Hamilton, I. 1992. The status of Kenya's elephants (1992). Report. Kenya Wildlife Service and Department of Resource Surveys and Remote Sensing, Nairobi.

Reuling, M., Mwathe, K., Litoroh, M., and Poole, J. 1992. A survey of the Shimba Hills elephant population. Kenya Wildlife Service, Nairobi.

Risley, E. 1966. An urgent plea for a national park to be created in the Shimba Hills. *Africana* 2(9):6–8.

Robertson, S.A., and Luke, W.R.Q. 1993. Kenya, coast forest status: conservation and management. WWF Project No. 3256. World Wide Fund for Nature and National Museums of Kenya, Nairobi.

Ross, K. 1981. Shimba Hills Reserve land-use study. Report. Wildlife Planning Unit, Wildlife Conservation and Management Department (now KWS), Nairobi.

Said, M.Y., Chunge, R.N., Craig, G.C., Thouless, C.R., Barnes, R.FW., and Dublin, H.T. 1995. *African elephant database.* Occasional Paper of the IUCN Species Survival Commission No 11. IUCN, Gland, Switzerland.

Schmidt, R. 1991. Ecology of tropical lowland rain forest: plant communities, soil characteristics and nutrient relations of the forest in Shimba Hills National Reserve, Kenya. *Dissertationes Botanicae* 179, J. Cramer Berlin, Stuttgart. 211 p.

Schmidt, R. 1992. Degradation of a forest in the Shimba Hills National Reserve, Kenya, as initiated by man and maintained by wildlife. In: J.G. Goldammer, ed., *Tropical forests in transition.* Birkhauser, Basel. p. 85–104.

Spinage, C.A. 1973. A review of ivory exploitation and elephants (*Loxodonta africana cyclotis* Matschia) in Bia National Park, Ghana. *African Journal of Ecology* 21: 175–184.

Stewart, D.R.M., and Stewart, J. 1963. The distribution of some large mammals in Kenya. *Journal of the East African Natural History Society* 24(3):1–52.