Satellite Tracking of Elephants in Laikipia District, Kenya

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Introduction

Most studies of elephant movements have been carried out using conventional (VHF) radio transmitters but in recent years considerable interest has been shown in the use of transmitters which transmit to orbiting satellites, Satellite tracking has been successfully carried out on polar bears, caribou, musk oxen, wandering albatrosses and a variety of other species (see review in Harris, 1990). It is not easy to design a suitable satellite collar for an elephant. The most crucial constraint is the need for high radiated power output —which conflicts with the requirements for robustness, low weight and long life span.

Satellites move overhead on a near polar orbit. Positions of transmitters, known as Platform Transmitter Terminals (PTTs), are calculated based on the Doppler shift in the frequency of the signal received at the satellite as it moves towards and then away from the PTT. For a particular satellite overpass the chance that a position can be resolved is determined by how many signals are received from the PTT during the time that the satellite is overhead. This in turn is determined by the strength of the signal, the pulse repetition rate (usually every 60 to 200 seconds) and the angular attitude of the satellite. Both high power output and low signal repetition rate reduce battery life. This can be increased by incorporating a mechanism for switching the transmitter on and off on a regular basis, resulting in, for example, a 'duty cycle' of 22 hours on/26 hours off. Radiated power output can be enhanced by aerial design. However, efficient aerials are likely to be the most fragile, and equipment suitable for elephants must be robust. The search for an efficient, but strong, aerial has dominated the development of elephant satellite collars.

The purpose of this study was to develop satellite transmitters suitable for elephants, to test their effectiveness in the field and to assess how valuable and cost-effective the results are, compared with those from conventional radio-tracking. It was carried out as part of the Kenya Wildlife Service Laikipia Elephant Project, which has simultaneously been doing conventional tracking of elephants. The work was conducted on 01 Ari Nyiro Ranch in western Laikipia District.

Methods

Three types of transmitters were tested, Data from the Argos (satellite) system were transmitted from the satellites to the Toulouse ground station and thence to London Zoo by modem, and a printed output sent to Kenya by fax, Poor telephone links to Kenya and lack of direct communications with the study site meant that there was often a considerable delay in the receipt of this information. Data were also displayed on a screen in the elephant house at London Zoo using Elsa, the plotting programme developed by Service Argos.

In order to assess the accuracy of the locations provided by the satellite system it was necessary to find the true positions of the elephants at approximately the same time as the satellite over-passes occurred. This was done using the auxiliary VHF transmitters on the collars. In most cases true positions were confirmed by visual observation of the animal with the satellite collar. The location was found using a 1:50,000 scale map and, with the dense network of roads on the ranch, it was possible to obtain a location with an accuracy of better than 200 m. The accuracy of the map base has been confirmed using Global Positioning Systems. The ground-truthing proved difficult for a number of reasons, particularly because the proportion of overpasses which resulted in a location being calculated was extremely low and, on the first two collar designs, problems were encountered with the range and tuning of the VHF transmitters. Three collars manufactured by Mariner Radar of Lowestoft, England, with external vertical aerials (Figure 1) were put on cow elephants in May 1990. The transmitters worked for 5, 2 and 18 days respectively. During the time that they were operational a good number of fixes was obtained each day.

The loss of signal from the PTTs was thought to be a result of the vertical aerials being bent and then broken off. However, at the time that the signals failed, the aerials still seemed to be intact and were actually lost later. One of the elephants was re-darted and the collar removed on 19 October 1990. Signs of corrosion were found inside the transmitter box, indicating that poor waterproofing may have also contributed to the failure.

The Mariner Mk III transmitter consisted of a PT'T' with a folded monopole antenna inside a low profile fibreglass dome (Figure 2), The PT'T' and auxiliary VHF unit were both inside the fibreglass dome but electrically separated. A bull elephant was fitted with the Mk III collar in October 1990 and the transmitter was removed in early January 1991, although still working, because of the low number of accurate locations being received.

The final model tested was constructed by Telonics Inc. This had transmitting units totally imbedded in acrylic, with bipolar aerials sewn into the collars (Figure 3). One was put on an adult bull in February 1991. Ground-truthing was carried out from March to May 1991. The collar was still functioning after eight months.

Results

Frequency of locations
Table 1 shows two measures of the frequency with which locations were calculated. The message index for each PTT was defined as the number of times at least one message was received from that PTT, divided by the total number of transmission hours; the location index for each PTT was the total number of unique location estimates divided by the total number of Transmission hours. The later index was a rough estimate of probability of obtaining a location during each hour of transmission time (Harris *et al,* 1990). From this table it can be seen that the elephant collars gave poorer results than have been recorded from other studies.

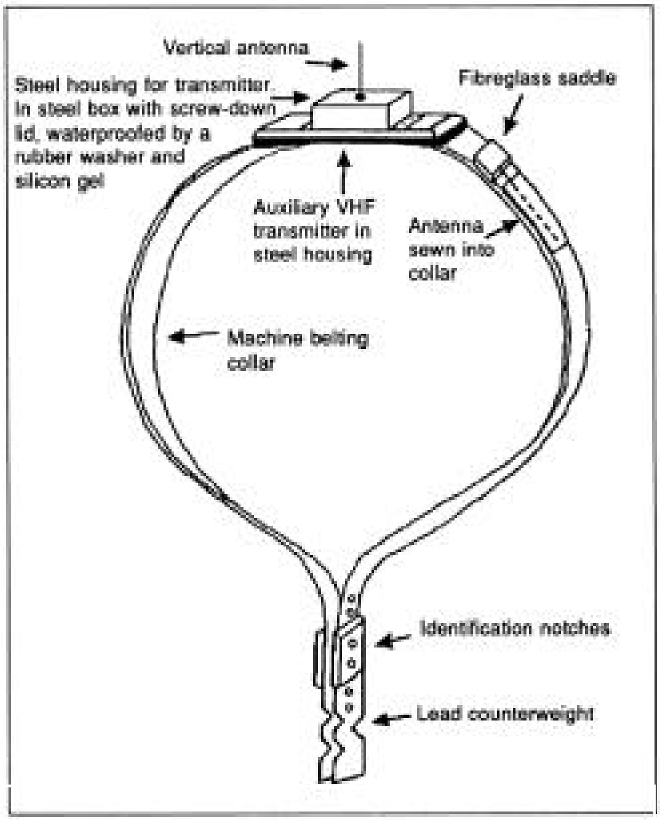

Figure 1: *Mariner Radar Mk 1 satellite collar for elephant*

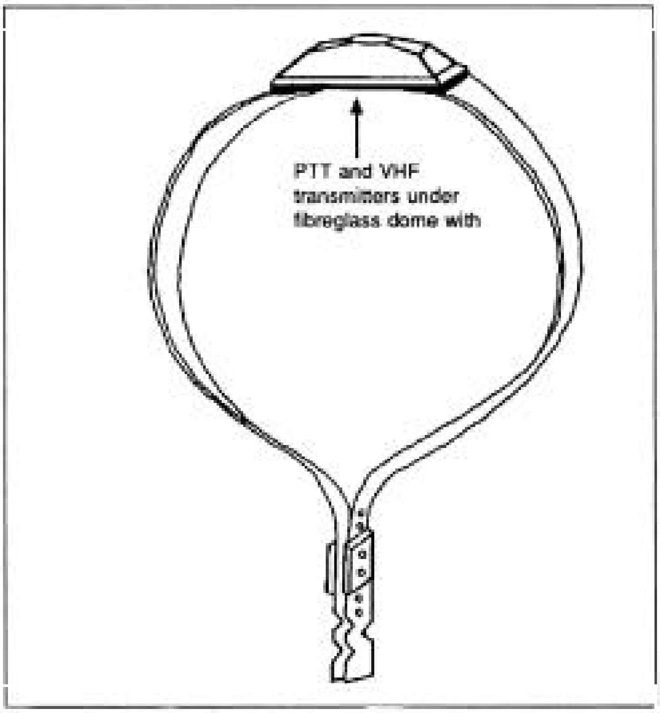

Figure 2: *Mariner Radar Mk Ill satellite collar for elephant*

Quality of locations

Table 2 shows the percentage of calculated locations which were placed in the different categories of accuracy, as determined by the satellite. Location class I (LCl) is the least accurate, and LC3 the most precise. The elephant collars produced a small proportion of accurate locations. It is worth noting how much the quality of locations declines when the transmitter is actually on a live elephant rather than being ground-tested, and thus ground tests in a particular place are not necessarily a good guide to field performance.

Ground-truthing

Table 3 shows the results from the ground-truthing. Argos output gives two possible locations, and in all cases the nearest to the true location was taken, Mean errors were considerably larger on the east/west (longitudinal) axis. According to Argos, 68% of results from LCl fixes should be within one kilometre of the true longitude and latitude. However, from our results, only 46% of latitudinal errors and 38% of longitudinal errors for combined LC1 and LC2 were within this figure. Out of 11 LCl fixes ground-truthed, four were more than five kilometres out, and one was displaced by nearly ten kilometres. One of the two LC2 fixes ground-truthed was 5.3 km in error, despite the fact that Argos claims an accuracy of 68% of LC2 locations within 350 m. Ground-truthing of the poorer quality Location Class 0 fixes indicated that these were too inaccurate to use. For instance, of 20 fixes in April-May 1991, 15 were more than 20 km in error.

Discussion

Value of Results

The quality of locative results has been disappointing, with the exception of those from the short-lived Mariner Mk I. In the case of the Telonics collar, there were few days of transmission when more than one acceptable location was received. The Mariner Mk III was slightly better, but even so,

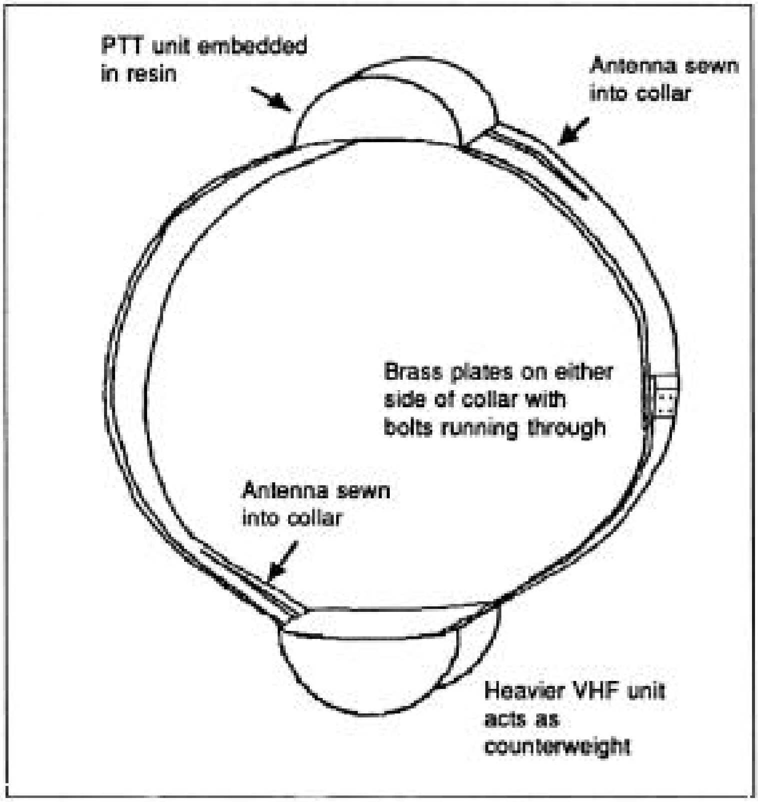

Figure 3: *Telonics satellite collar for elephan*

Table 1: Performance Indices and study locations for platform transmitter terminals (PTTs) on various species for comparison with Laikipia elephant PTTs.

Species and general location	Approximate latitude (degrees)	Location index	Message index	n
Caribou, Alaska and Yukon	70N	0.61	0.96	256
Musk ox, northern Greenland	82N	0.55	1.16	19
Polar bear, Beaufort Sea	70N	0.21	0.90	393
Elephant, Laikipia (Mk III)	0	0.19	-	3
(Mk III ground test	0	0.26	0.10	2
Brown bear, Kodiak Island	58N	0.08	0.56	4
Elephant, Laikipia (Telonics)	0	0.04	0.13	7
Telonics collar ground test	0	0.12	-	2
Elephant, Namibia (Telonics)	19S	0.05	-	40

Sample sizes are the number of PIT-months used in calculations. Additional values from Harris *et al,* 1990 and calculated from Lindeque & Lindeque, unpub. PTTs used in other studies were all manufactured by Telonics

Table 2: Percentage of locations in each of the 3 location quality index (LQ) categories for platform transmitter terminals (PTTs) on various species. LQ3 locations are the best quality

Species and general location	LO1	LQ2	LQ3	n
Caribou, Alaska & Yukon	59	37	4	*45538*
Musk ox, northern Greenland	61	27	12	966
Polar bear, Beaufort Sea	68	27	5	11078
Elephant, Laikipia (Mk III)	79	21	0	174
Mk III ground test	84	13	3	39
Mule deer, Idaho	81	16	2	630
Brown bear, Kodiak Island	92	3	*5*	80
Elephant, Laikipia (Telonics)	92	*5*	3	80
Telonics collar ground test	63	18	18	60

its performance compared poorly with satellite collars used in other studies.

There are probably three reasons for the small number of locations per day. The most important is that the polar orbit of the Tiros satellites means that there are fewer overpasses per day on the equator than in temperate or polar latitudes. With two satellites receiving data there are typically 28 daily overpasses at high latitudes, compared with eight at the equator (Fancy *et al*, 1986). With eight overpasses, the highest potential location index is 0.3, compared with observed figures of less than 0.2 for Mk III and less than 0.1 for the Telonics collar. It is also clear that putting the transmitter on an elephant greatly reduces the effective radiated power. There is some evidence that the large body mass of elephants is a contributory factor (Harris *et a!*, 1990). Except for those on bears, most other studies have used partially protruding aerials, which give more efficient signal radiation than internal ones.

Sources of error

The errors found from the ground-truthing were surprisingly large. The principal sources of error that would affect Argos' calculations are errors in actual versus predicted altitude, displacement of the PTT during the satellite overpass and oscillator instability.

Altitudinal errors are primarily longitudinal because the satellites travel in near north-south orbits. When signals come from PTTs that are higher than the assumed elevation, Argos interprets them as coming from locations that are closer than they actually are to the satellite (Harris *et al*, 1990). This was unlikely to have been a major source of error in this case because the altitude range of collared animals was less than 200 m.

Displacement errors that are caused by a PTT moving during the course of a satellite overpass are also unlikely to exceed more than a few hundred metres.

Table 3 : Results of ground truthing from Mariner Mk III and Telonics satellite transmitters.

Transmitter type	Location class	North/south error (km)	East/west error (km)	Time difference (mins)
Mariner Mk III	1	0.1	0.6	0
	1	1.0	2.5	16
	1	3.5	8.2	20
	2	1.7	5.0	26
	1	1.3	5.0	24
Telonics	1	0.5	0.5	19
	1	0.4	4.5	0
	1	1.7	0.1	0
	1	0.2	2.5	30
	1	0.5	0.0	7
	2	0.2	0.4	24
	1	6.4	6.5	30
	1	2.0	6.4	4
Mean		1.5	3.2	

If the frequency of signal output by the PTT changes during the course of a satellite overpass then inaccurate locations may be obtained, particularly in the longitudinal axis. The oscillators used for wildlife PTTs are sensitive to steep temperature gradients. Argos investigated some of the overpasses made while Mk I PTTs were operational and found that a number of fixes were rejected on the basis of excessive instability although, on the basis of the number of messages received and the geometry of the overpass, high quality locations could have been expected. It is possible that direct sunlight falling on a PTT on a stationary elephant in the open could make it hot enough to affect oscillator stability. In any

Table 4 : PTTs used during the course of the study.

	Duty cycle: hrs on/off	Date put on	Date failed	Date removed	Sex	Reprate
Mariner Mk I						
10014	cont	08/04/90	24/04/90	-	F	90
10015	cont	06/04/90	07/04/90	-	F	90
10017	cont	05/04/90	09/04/90	19/10/90	F	90
Marnier Mk III	22/26	19/10/90	-	10/01/91	M	70
Telonics	24/48	28/02/91	-	-	M	70

Rep rate — signal repetition rate (seconds).

future studies where this is likely to be a problem it might be worth including a temperature sensor in the PTT. Satellite locative errors are caused by inaccuracies in the orbital path of the satellite, but they are claimed by Argos never to exceed 300 m.

Lindeque and Lindeque (in prep) working in Namibia, used reference beacons to calibrate their locations. However, this would only be effective in eliminating the error caused by orbital inaccuracies, and since no systematic ground-truthing was carried out in their study, it is not clear how valuable this is in reducing total error.

Comparison with VHF tracking

Quality of results

Because of the locative errors from satellite tracking, it is not be able to provide this. Satellite tracking under these circumstances is only useful for looking at the broad pattern of movements, where errors in the order of ten kilometres do not lead to faulty biological interpretations.

We have compared the cost of satellite tracking with VHF tracking using figures derived from this study (Figure 4). Figures for VHF tracking using aircraft are derived from the true costs of the study described in Thouless and Dyer (see pp 34-39). Basic running costs for satellite tracking are given as the concessionary rate of FF80 per day plus LC0 information at FF15 per day. It should be noted that the standard rate is more than double this. We have excluded salaries and the costs of data transmission and analysis. Capital costs are calculated on the basis of a two-year study. VHF collars are expected to last for at least two years, so the cost of two capture operations, one to deploy, and one to remove the collars is included. The cost of darting operations is estimated at $500, which covers the cost of a spotter aircraft, drugs and a fee to the vet performing the immobilization. Two figures are given for satellite

possible to use this technique for detailed analysis of habitat use, as has been planned in a project in the Ivory Coast (Lavenue *et al*, 1990). Nor would it be possible to look at short term movements, such as those during a 24-hour period. Techniques have been developed in high latitudes to improve the quantity of data by eliminating erroneous locations. However, these are dependent on comparing several fixes during the course of a day. Any study of eleohants close to the equator is unlikely to tracking. In one, it is assumed that the collar needs to be

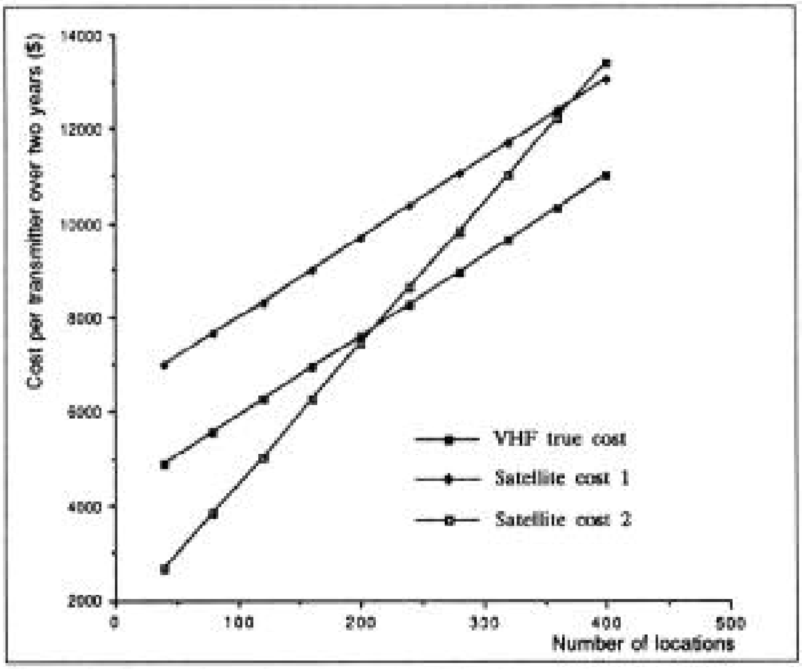

Figure 4 : *Comparison of satellite and VHF tracking costs*

replaced after six months, so that five darting operations are required; in the other it is assumed that the satellite collar lasts for one year. Equipment costs are $450 for a Telonics VHF collar, $3,800 for a Telonics satellite collar, and the lower figure for satellite tracking also assumes that one is using a Mariner Radar collar costing $2,720. No figure for VHF receiving equipment is included, since this would also be needed for satellite tracking to locate the animals for ground-truthing and relocation for immobilization.

These figures show that for the present project involving 16 elephants the cost per location would be the same for satellite and VHF tracking if locations were required every four days for the cheaper satellite costs or every two days for the more expensive estimate. It should be pointed out that, with such low sampling intervals, the total cost of radio-tracking over the two-year period would be extremely high. In reality one would have to compromise, by using either a small number of satellite collars with frequent locations, or a larger number of VHF transmitters with relatively infrequent locations. Our study population consists of 2,500-3,000 elephants. All 16 animals collared have shown independent movements, so a reduction in the number of collars would have resulted in a poorer understanding of the movement patterns.

Future of satellite tracking

Our work shows that, with the current state of technology, satellite tracking of elephants has some serious limitations: it is expensive; location information is inaccurate; it does not provide information on habitat use and group sizes; there is a lack of flexibility in the sampling procedures; and transmitters last for a shorter time than VHF ones. The level of error may be substantially greater than we have found, if elephants are moving over a large altitudinal range.

Despite its problems, satellite tracking may be of value under circumstances where VHF tracking using aircraft is not a viable alternative. Aircraft may not be available on a regular basis, and they may be very expensive because of need for commercial hire or because they are based a distance from the study site. Conventional tracking may be impossible if elephants are crossing international boundaries.

Although the value of satellite tracking could be enhanced if effective radiated signal strength were increased, it is unlikely that a sufficient improvement could be made to existing designs. The technology exists for much more accurate location systems using passive positional satellite locative systems (GPS) and it is likely that future satellite tracking will be based on this, rather than the Argos system.

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