Elephants (*Loxodonta africana*) of Zoba Gash Barka, Eritrea: Part 2. Numbers and distribution, ecology and behaviour, and fauna and flora in their ecosystem

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Abstract

Today, elephants in Eritrea are confined only to portions of Zoba Gash Barka in the south-west where they are geographically, and possibly genetically, isolated. Data collected during 2001–2003 include direct observations of live elephants in the watersheds of the Gash and Setit (Tekezze) Rivers, and information from spoor and from eyewitnesses. We provide data on a large herd of elephants, unheard of since 1955. Observations indicate that there are no hybrids between African and Asian elephants in Eritrea. Elephants are active in portions of day and night. It appears that a symbiotic relationship exists between elephants and doum palms and between elephants and baboons, and a commensal relationship may exist between elephants and helmeted guinea fowls. We started a new method using soleprints as a possible character for reliably identifying individual elephants. Data on plants and animals help evaluate the biodiversity in Gash Barka and the role elephants play as keystone species in their ecosystem. The estimated number of elephants in Eritrea is about 100 during the dry season; in the wet season they migrate to northern Ethiopia. Further, we observed young and adults with calves less than one year old.

Additional key words: biodiversity, ecosystem, human–elephant conflict, individual identification, keystone species, soleprints

Résumé

Aujourd'hui, en Erythrée, les éléphants sont confinés dans quelques portions de Zoba Gash Barka, dans le sud-ouest, où ils sont géographiquement, et peut-être génétiquement, isolés. Les données récoltées entre 2001 et 2003 incluent des observations directes d'éléphants vivant dans le bassin des rivières Gash et Setit (Tekezze), des informations sur des traces et venant de témoins oculaires. Nous donnons des informations sur un grand troupeau dont on n'avait plus entendu parler depuis 1955. Les observations indiquent qu'il n'y a pas d'hybrides entre éléphants africains et asiatiques en Erythrée. Les éléphants sont actifs à certaines périodes, de nuit comme de jour. Il semble qu'il existe une relation symbiotique entre les éléphants et les palmiers doum et entre les éléphants et les babouins, et il pourrait y avoir une relation commensale entre les éléphants et les pintades casquées. Nous avons inauguré une nouvelle méthode, en nous servant de l'empreinte plantaire comme élément peut-être fiable pour identifier les éléphants individuellement. Des données sur les plantes et les animaux aident à évaluer la biodiversité à Gash Barka et le rôle d'espèce clé que les éléphants jouent dans leur écosystème. On estime que le nombre d'éléphants en Erythrée est d'environ 100 en saison sèche. En saison des pluies, ils migrent vers le nord de l'Ethiopie. De plus, nous avons observé des jeunes et des femelles avec petits de moins d'un an.

Mots clés supplémentaires : biodiversité, écosystème, conflits hommes-éléphants, identification individuelle, espèce clé, empreintes plantaires

Introduction

In our first paper on elephants (*Loxodonta africana*) in Eritrea we provided background information on the physical and climatic settings of Eritrea, general description of elephant habitat, and a historical perspective on elephants in Eritrea (Hagos et al. 2003). In this second part of our findings, we discuss the numbers and distribution, ecology and behaviour, and fauna and flora in the ecosystem of elephants in Eritrea.

Materials and methods

Observations reported here include those made in 2001 through early 2004. Direct observations of elephants were the preferred method of investigation. Interviewing local residents has been an extremely important aspect of this research, since the elephants are rarely seen during the day. Dung and footprints or other spoor, such as chewed vegetation and scratching posts, provided indirect data. Some dung samples were dissected in search of seeds of trees and bushes to help identify plant species on which elephants feed. Dung samples were sent to two laboratories in the United States for DNA analysis. Skin and other samples of a stillborn foetus found near the Gash River were also sent for isolation of DNA. A large number of plant samples were collected for the herbarium at the University of Asmara.

Counting elephants was done such that only the minimum number of individuals is reported. Duplication was reduced to a minimum or avoided by applying any combination of these exclusion criteria: 1) if the time and distance passed between observations could allow elephants from the nearest previous location to travel that distance, 2) if herd or group composition was identical or similar, 3) if their individual markings were the same.

Individual recognition was made using ear markings, tusk characters, body marks, or any combination of these characteristics (Douglas-Hamilton 1972; Moss 1996). In addition, we noticed that newly born and juvenile elephants have relatively flat soleprints with few distinguishing features. With age soleprint features become more evident; in adult elephants, soleprints are unique for the individual. Thus, we began a file of soleprints; but in this initial stage, it must still be used along with other characters when identifying individual elephants.

To estimate general shoulder height of an elephant from a footprint we employed the formula of Sukumar et al. (1988), that is, 2.03 times the circumference of the front foot gives the approximate shoulder height (this is a modified version of Boyle 1929—twice the circumference of the front foot gives the approximate shoulder height). We also measured the hind foot length as applied by Western et al. (1983) and Lee and Moss (1995). Scat and chewed vegetation were collected and their provenances recorded. All observations were documented in the field notebook or photographed, or both.

Results

Numbers and distribution

1996 AND 2000

Results obtained in 1996 and 1999 were summarized by Shoshani et al. (2000). Litoroh (1997) reported on 8 elephants sighted from the air, 2 in Eritrea and 6 on the Ethiopian side of the border. Yacob (1998, p. 6) reported on 20 to 50 elephants in Eritrea; Marchant et al. (2000, p. 11), however, estimated a lower minimum number, between 8 and 50.

2001–2002

On 25 December 2001, 28 elephants were observed entering a doum palm forest at 1650 near Amneyet, about 14 km upstream from Haicota (table 1). There were around 10 juveniles, some less than one year old. All appeared in good condition and some carried tusks less than one metre long. This group, which may have included others already hidden in forest, is the largest reliably documented record of elephants in Eritrea in recent times. We found the remains of a stillborn foetus and took them to the University of Asmara. Many olive baboons (*Papio anubis*) were in close association with the elephants.

2003

From 24 January to 11 February 2003 we launched an expedition to investigate information received on large numbers of elephant in the vicinity of Haicota. On the third day we found fresh footprints of adults and young close to the Gash River near the village of Ugumu. We pursued our search in the riverine forest but came too

Table 1. Elephant observations in Zoba Gash Barka, Eritrea (see fig. 2 for locations)

ID no.	Date	No. elephants	Description; observed by Observed by	Location
0a	ca.1998	—	elephants observed; one dead, tusks collected	at about Weldezghi farm, near Alebu
0b	pre 2000	—	elephant observed several years previously	Adi Omar
0c	ca. 2000	—	elephant observed three years previously	Gursub Drip Irrigation Project
	2000			
1	15 Dec	4	4 live elephants: 2 large, 2 small, seen from the air; other possible sightings at 20 km SW; observed by UN	between Kuluku and Shambiko ~15 km south of Shambiko
2	15 Dec	—	possible elephant sightings; observed by UN	
	2001			
3	1 Apr	1	one 'very large' elephant [p]; observed by UN	between Antore and Om Hager
4	18 May	3	in doum palm forest [p]; observed by UN & JS	near Ato Solomon's farm
5	1 Aug	1	calf about 1 year probably swept by river [p]; observed by YY	near Om Hager near Setit R
6	19 Sep	15	family of ~ 10 [p], 5 bulls [p]; observed by UN	Setit R 20 km east of Om Hager
7	24 Dec	2	adult elephant placenta and stillborn foetus in riverine forest; observed by JS, MG & students	near Ato Solomon's farm
8	25 Dec	>28	adults, young, newly born [p]; observed by JS, MG & students	junction of Gash R and Bayaye wadi, near Amneyet
	2002			
9	2 Feb	1	adult elephant carcass in riverine forest; observed by EK	Tekezu village in vicinity of Setit R
10	14 Mar	1	young elephant carcass in riverine forest; observed by EK	Debero village in vicinity of Gash R
—	5 Apr	~30	herd of elephants filmed [p]; observed by Mahmud M. Osman	near Awgaro
11	21 Apr	—	elephant dung of adult; observed by ET	Antore R near Awgaro–Antore Road
12	13 Jun	1	calf carcass [p]; observed by ET	Cikaba near Ugumu
13	21 Jun	1	live adult male elephant in riverine forest; observed by ET & UN	Setit R
14	22 Jun	1	one observed, others nearby; observed by ET & UN	near Antore; 3.4 km SW of dry riverbed
15	22 Jun	1	one observed, others heard nearby; observed by ET & UN	near Antore
16	23 Jun	1	adult observed; pictures taken [p]; observed by ET & UN	~7.1 km N of Antore
—	~ Oct	~40	aerial photographs [p]; observed by UN	near Setit R
17	8 Nov	1	adult elephant carcass; reported date of death; observed by EK	Tekezu area near Enda Hargeste
18	22 Nov	1	subadult elephant carcass; reported date of death; observed by EK	Awtate R, an Antore R tributary
	2003			
19	7 Jan	~40	elephants move towards Haicota [p]; observed by Tedros Kebbede, Travel House International	near Gogne, Kurkuji vicinity
—	10–11 Jan	?	live elephants, fresh footprints and scat [p]; observed by EK & JS	near Antore and Awgaro
20	26 Jan	> 83 (for ID 20–36)	footprints of 5 elephants, one calf; one elephant in dense riverine forest; observed by ET	Ugumu vicinity
21	26 Jan	1	live male elephant observed crossing Gash R from SE to NW [p]; observed by ET	Ugumu vicinity
22	27 Jan	—	fresh elephant dung and footprints; observed by ET	Adi Merig vicinity
23	27 Jan	3	observed in dense riverine forest on floodplain of Gash R; observed by ET	Kurkuji vicinity
24	28 Jan	42	all ages, in 7 subgroups; many fresh footprints and much dung; observed by ET	Musse water well
25	31 Jan	27	in ~ 4 subgroups; observed by ET	Near Amneyet
26	1 Feb	—	old footprints and dung; observed by ET	Duluk water well
27	1 Feb	3	observed in daylight; observed by ET	Banegar
28	1 Feb	4	live elephants; many dung piles of all ages; observed by ET	Kurbahebaye
29	2 Feb	1	live elephant; many dung piles of all ages; observed by ET	Kurbahebaye

Table 1. (continued)

ID no.	Date	No. elephants	Description; observed by Observed by	Location
306	Feb	—	footprints; dung piles of all ages, old and fresh; observed by ET	Mekonat
31	6 Feb	> 6	live elephants; footprints, many dung piles of all ages, old and fresh; observed by ET	Mekonat
32	6 Feb	31	observed in dim to very dim light; observed by ET	Mekonat
33	7 Feb	—	footprints adult, fresh; observed by ET	Kurkuji vicinity
34	8 Feb	4	observed in cultivated area; many dung piles of all ages; observed by ET	Musse water well
35	9 Feb	—	old elephant dung; observed by ET	Ugumu watering area
36	10 Feb	—	footprints and dung, old and fresh; observed by ET	Near Antore R
37	21 Apr	1	carcass, young, fell and died in a water well; footprints observed [p]; observed by ET	Sefera Sona water well near Awgaro
38	7 May	1	carcass, calf, fell and died in a water-well; footprints observed [p]; observed by ET	Musse water well near Ugumu
39	9 May	45	all ages, observed in twilight [p]; observed by ET	Sefera Sona water well near Awgaro
—	19 July	many	fuzzy aerial photo [p] ; observed by UN	between Om Hager and Barentu
40	25 Oct	90–100	all ages, photographed from air [p]; observed by JS & Mark Bent	near Setit R south of Antore Tahtai
41	6 Nov	~ 40	one 5-year-old killed; observed by *Haddas Eritrea* newspaper staff	Kurbayo-Dekishehay near Antore Tahtai
42	1 Dec	> 20	Observed by farmers	near Haicota
—	26–28 Dec	3–5	2–4 live, 1 carcass; observed by JS & students	Haicota vicinity
2004				
—	4 Feb	1	subadult, dead; observed by Dessalegn Hadgembes	Menderot, near Antore

Data for previous centuries were provided by Hagos et al. (2003). For completeness, some observations for the 21st century are repeated and new entries added for 2003 and 2004. Details in the text.
Setit River – also known as Tekezze River; [p] – with photograph(s)
Observers: EK – Emun Kebrom; ET– Elephant Team; JS – Jeheskel Shoshani; MG – Medhanie Ghebrehiwet; YY – Yohannes Yacob; UN – United Nations personnel

close to an elephant (possibly a female with a calf), which charged us. This incident almost ended in the death of the senior author, had he not been saved by a soldier who shot in the air (Nicholson-Lord 2003). All in all, we visited 18 localities, which included either an encounter with live elephants or finding their spoor, usually footprints and dung (details on 12 of these localities are given in table 2).

Table 2. Observation on number of elephants from 26 January to 10 February 2003

Date	Locality	No.	Notes
26 January	Ugumu vicinity	5	1 elephant seen, 5 total reported;
26 January	Ugumu vicinity	1	male crossed the Gash River in daylight
27 January	Kurkuji vicinity	3	chased by children in daylight; ?all males
28 January	Musse	42	elephants seen in seven subgroups, at sunset[a]
31 January	Amneyet	27	elephants seen in four subgroups, at sunset
1 February	Banegar	(3)	seen in daylight, possible duplicate
1 February	Kurbahebaye	4	seen in daylight; ?all males
2 February	Kurbahebaye vicinity	(1)	male, seen close to sunset
6 February	Mekonat	(6+)	seen in daylight in forest, possible duplicate sighting
6 February	Mekonat	(31)	seen after sunset, possible duplicate
8 February	Musse vicinity	(4)	chased by children in daylight; ?all males, duplicate
10 February	Antore vicinity	1	based on fresh dung and observation by locals[b]

[a] Details in table 3.
[b] 128 elephants were observed between 26 January and 10 February 2003 in 12 localities; 45 are possible duplicate counts. Thus the minimum number of individuals is 83 elephants in seven localities. There is no way of verifying if the 45 elephants observed on 9 May 2003 were part of the elephants observed during the January–February survey, and thus they are not included in these totals.

Taking a minimum conservative approach, in 16 days we saw 83 live elephants in seven places (table 2). Thus the estimated number of elephants in Eritrea is between 83 and 100. The higher estimate (100 elephants) is a guarded estimate for the number of elephants in Eritrea during the dry season (approximately from October–November through March–April); during the wet season they are said to migrate into Ethiopia. Following the criteria given under 'Materials and methods', we excluded 45 elephants from our total count of 128, as we suspected we had already counted them (see table 2). The largest number of elephants we saw from the ground in one place, where possibly there were also unseen herd members, was 31 elephants (the 42 elephants noted below were observed in seven subgroups). Most of the observations were under crepuscular (twilight) conditions, and most were either in the Gash River or in its floodplains and vicinity. All the elephants looked healthy (no bones such as scapulae or ribs seemed to be protruding from the body contour). The adults were accompanied by young of all ages, some very tiny, possibly newborns. The males in particular were in prime condition. Some were observed browsing on vegetation in an oasis-like, semi-desert habitat of doum palms, acacia, and ziziphus riverine forest.

Of particular interest were observations we made near a waterhole called Musse, where the depth of water was 100 cm below the riverbed. There were, in fact, two waterholes close to each other, one large and one small. Like many other waterholes excavated for livestock, the local herdsmen had made a trough of mud and filled it with water, usually drawn with goatskins. Late in the afternoon of 28 January 2003, we counted 42 elephants in about seven subgroups (table 3).

We counted the 42 elephants twice—once as a general count and a second count conducted with binoculars in dim light following the field method de-

Table 3. Subgroups of elephants observed at Musse locality (GPS = N 14°52.874'; E 37°17.955', elevation: 754 m), 28 January 2003

No.	Composition[a]	Estimated ages[b]	Totals
1	5 adult males[c]	20–35+ years old	5
2	3 adults, 2 young	10–30 years	5
3	1 reaches elbow of adult next to it 1 reaches anal flap of adult next to it 3 reach eye level of adult next to it	8–9 months 4–5 years 7-8 years	5
4	5 adults 2 subadults[d] 1 reaches anal flap of adult next to it	20–35+ years 10–15 years 3–4 years old	8
5	2 adults 1 subadult[d] 2 reach anal flap of adult next to it 1 reaches below belly of adult next to it	20–35+ years old 10–15 years 4–5 years less than 1 year old	6
6	2 adults 2 subadults[d] 1 reaches anal flap of adult next to it 1 reaches below belly of adult next to it	20–35+ years old 10–15 years 4–5 years less than 1 year old	6
7	A mixture of ?adults, subadults and young	10–30 years	7 42[e]

[a] As described in the field. Some descriptions after Moss (1996:67–68). Elephants in these seven subgroups may or may not have been associated as herd members; congregation may have resulted as they came together to drink.
[b] Estimated age assignment after Moss (1996:67–68).
[c] Sex identification after Sikes (1971), Hanks (1979), and Moss (1996). In profile view males have a round sloping forehead and are wider between the eyes; females have an angular forehead, narrower between the eyes. Also, male bellies slope downwards from the front legs towards the genitalia; in females the bellies are nearly parallel to the ground. According to Poole (1987), bulls, especially those in musth, walk differently from cows, but we were unable to ascertain this difference.
[d] Body seemed square rather than rectangular (after Moss 1966:68).
[e] Breakdown of the 42 elephants in these seven subgroups: 17 adults, 5 subadults, 13 aged 1–10 years, 7 mixed young and subadults.

veloped mostly by Moss (1996) on counting elephants in Amboseli National Park in Kenya.

Most recent elephant sighting (2003, 2004)

While on a survey trip during May 1993 to report on a dead calf that slipped and fell into a water well, we learned that a large herd of elephants was close to the village of Awgaro. On 9 May 2003, at about 1900 near the Sefera Sona water well we observed 45 live elephants of all ages in close proximity (that is, not all in one general location). At least 30 elephants were observed in dim light as they were marching in a file on the north-east bank of the dry riverbed of the Gash River. We observed an additional 14 elephants on the west side, plus one large adult on the far east side drinking water. These 45 elephants were not added to the minimum number of 83 individual elephants summarized in table 2, because there is no way of verifying they were or were not some of the same elephants observed during the January–February 2003 survey.

From this and previous observations, as well as from reports by local residents, it appears that the elephants avoid coming to drink during daylight. Reasons could include avoiding the heat, avoiding competing with livestock, avoiding human contact, or some combination of factors. Regardless of the reason, elephants seem to have adopted cathemeral behaviour, that is, being active partly in the daytime and partly at night.

On 25 October 2003, Mark Bent and the senior author flew towards Gash Barka in search of elephants. At 0945, south of Antore Tahtay, near the Setit (Tekezze) River lying inside Eritrea, we spotted a large herd of elephants of all ages and sizes in a deciduous woodland. It is possible that these elephants had crossed the Setit not long before we saw them, as they were close to it and also the calves were darker in colour, possibly from crossing the river. The elephants, in two major subgroups, were moving northwards. One subgroup had about 70 to 90 individuals—a figure confirmed later when we viewed photographs. The other subgroup was smaller, of perhaps about 20. We circled above a few times as we attempted to count and photograph them.

Judging from the location where the elephants were sighted, the direction in which they were moving (north towards Antore) and the time of the year we observed them, we now have corroborating evidence for the hypothesis that elephants migrate into Eritrea during the dry season. We still need to collect data on whether elephants migrate out of Eritrea and into Ethiopia during the wet season. Yet the observation made by United Nations personnel on elephants sighted on 19 July 2003 between Om Hager and Barentu (table 1) provides some evidence that some elephants are still present in Eritrea during the early summer. The Ministry of Agriculture is planning an elephant survey in June 2004.

Population structure

SHOULDER HEIGHT AND AGES CALCULATED FROM FOOTPRINTS

Data on spoor measured in 2001 and 2003 are provided in table 4. Shoulder heights were calculated using the Sukumar et al. (1988) formula only when measurements of forefeet were available (2001 data). From these heights we estimated the ages after graphs in Hanks (1979) and illustrations in Eltringham (2000). In 2003 we also collected data on hind-foot length and from that, employing the Western et al. (1983) formula and data from Lee and Moss (1995), we were able to estimate the ages of these elephants. The height for 15 elephants (given in table 4) ranges from 0.8 to 3.51 m, and the ages range from 1 or 2 years to about 40+ years of age. These results from footprints correspond to the observations we made on live elephants; we saw very small calves, less than one year old, to very tall adult females and males. Our tallest elephant was calculated at 3.51 m at the shoulder, likely a bull; the record is 4+ m (Martin 1963).

SOLEPRINT PATTERNS AS UNIQUE SIGNALS FOR ELEPHANT IDENTIFICATION

Identification of individual elephants is imperative for sound, long-term research, where data can be accurately recorded and followed for any morphological or behavioural changes over time. Douglas-Hamilton (1972) pioneered the method of recognizing elephants by their ear characters, a method widely used in elephant studies. Moss (1996) summarized the methods used in recognizing individual elephants, the reasons, and other parameters, in the section 'Individual recognition'. We started a new method, to the best of our knowledge, hitherto not employed in elephant or any other mammalian studies.

Table 4. Data on forefoot diameters and hind-foot lengths, and estimated height and age based on these data

Locality	Forefoot diameter (cm)	Hind-foot length (cm)	Estimated height (m)[a]	Estimated ages (years)[b]	Notes
December 2001					
Amneyet	22	not taken	1.40	4–6	juvenile, spoor in semi-firm sand
Amneyet	34	not taken	2.17	15–20	young, in semi-firm sand
Amneyet	53	not taken	3.38	25–30+	?female, in semi-firm sand
Amneyet	55	not taken	3.51	35–40	?male, in semi-firm sand
2 January 2002					
Michael farm, near Haicota	55	—	3.51	35–40	?male, in ?semi-firm sand
January–February 2003					
Musse	40	46.5	2.55/2.79	~30	male, in firm sand
Amneyet	46	51.5	2.93/3.09	~40	?male, in semi-firm sand
Mekonat	12.5	17.5	0.80/1.05	~1–2	newborn, in semi-firm sand
Mekonat[c]	17.5	21	1.12/1.26	~3	juvenile, in semi-firm sand
Mekonat	22	25	1.40/1.50	~5	juvenile, in semi-firm sand
Mekonat	23	28	1.47/1.68	~7	juvenile, in semi-firm sand
Mekonat	32	37	2.04/2.22	~20	subadult, in semi-firm sand
Mekonat	33	38	2.11/2.28	~24	subadult, in semi-firm sand
Mekonat	42	46	2.68/2.76	~29	adult, in semi-firm sand
Hadamdame	48.5	52	3.09/3.12	~40+	?male, in semi-firm sand

[a] Estimated shoulder height based on the forefoot diameter (after Sukumar et al. 1988; see under Methods). Numbers are rounded to 2 decimal places. For comparison, for the last 10 measurements, we calculated the estimated height from the forefoot diameter (to the left of the slash), and from the length of the hind-foot diameter (to the right of the slash), following Moss's (1996, p. 72) note: 'The shoulder height increases at roughly six times the [hind] foot length.' The numbers on the right are larger than the numbers on the left by about 16 cm on average.
[b] For the first four entries, the estimated ages are based on the forefoot diameter, using illustrations and graphs in Eltringham (2000), Hanks (1979). In the other entries, age is based on hind-foot length (after Western et al. 1983).
[c] At this site we also collected data on the size of dung of adult (length 25 cm x width 20 cm x height 14 cm) and young (11 cm x 11 cm x 8 cm).

We began with a digital photograph file of footprints of elephants, depicting the unique crease pattern, something similar to fingerprints in humans. Figure 1 gives examples of soleprints, showing differences in the architecture of these individuals. We observed, for example, that newly born and juvenile elephants have flat, featureless soles. With age, the crease pattern and architecture of the sole increasingly become distinct and individualized. That is, as the elephant grows older, the pattern is unique for the individual elephant. We are only beginning to employ this method. With time, we hope to be able to include soleprints as a reliable character, along with characters such as ear features, tusk appearance and body scars. Such character recognition would be especially useful in riverine forested areas where it is difficult to see elephants, but their spoor could identify the individuals who left it.

Ecology and behaviour

LOCAL AND REGIONAL ELEPHANT MOVEMENTS

Based on data presented in tables 1 to 3 we learned that local movements of elephants are within the Setit River and the Gash River water catchment areas (watershed), especially along their floodplains where

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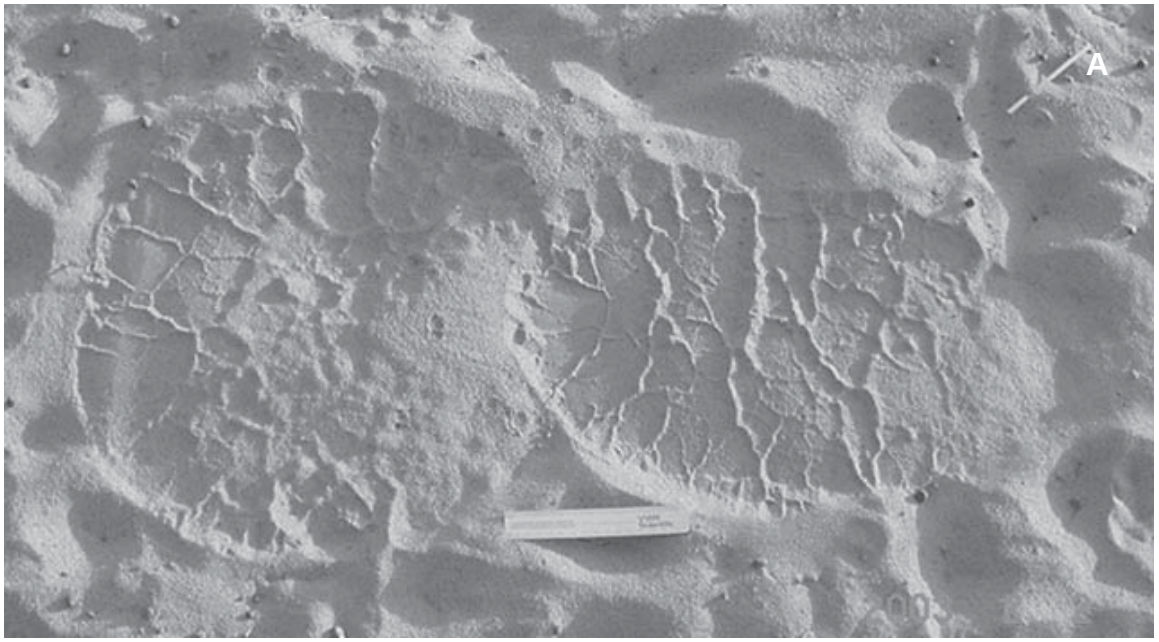

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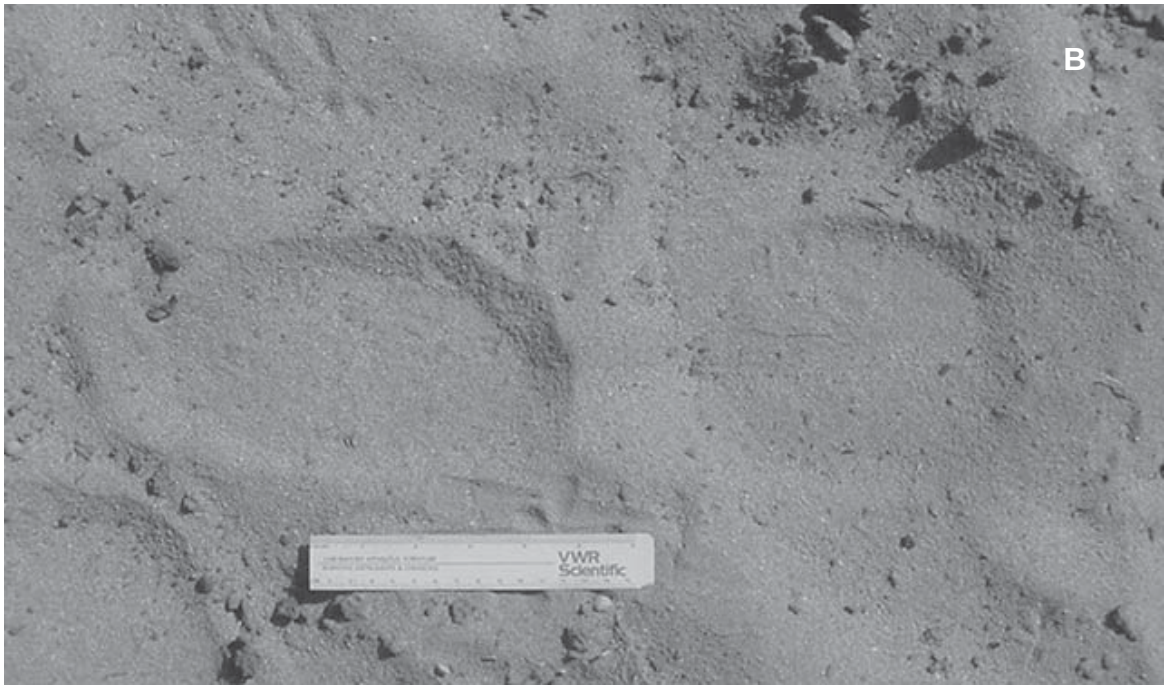

Figure 1. Soleprints of elephants in the Gash River. A) Soleprints of adult elephant (circular footprint on left is of the front foot, elongated footprint is of the hind foot). Direction of walking is towards the right. B) Soleprints of a calf elephant (circular and elongated footprints as for A). Direction of walking is towards the left (ruler is 16 cm). As elephants grow older the architecture and pattern of the creases becomes increasingly distinct and unique. This new identification method, combined with ear, tusk and other characters, we hope will prove to be a reliable one, especially in riverine forested areas where although it is difficult to see elephants, they could easily be recognized by their spoor.

doum palm trees are plentiful and water is not too distant (fig. 2). There are no records of elephants north of the Barentu–Tesseney road (fig. 2). Figure 3 gives the names of Eritrean villages and places between Tesseney and the Setit River that elephants are believed to frequent during the dry season. At present, our data indicate that elephants in Eritrea do not move into Sudan, possibly because there are no doum palms in that part of the country. If this observation turns out to be correct, this would imply that elephants and doum palms are obligate symbionts, rather than facultative ones. That is, the elephants migrate to places where there are palms rather than visiting them coincidentally. In figure 3 the distances between places are rough estimates in a straight line between two points along the terrain as calculated from the map (fig. 2). The two-headed arrows indicate that the elephants move in both directions, generally within the watersheds and floodplains of major rivers.

All the data that we, United Nations staff and local residents have collected thus far on the whereabouts of elephants confirm the general times of their movements. Thus, elephants migrate from Ethiopia into Eritrea from the south during the dry season—October–November through March–April or longer—and return southwards in the wet season—May–July through October–November (fig. 4). It is not yet understood why they migrate in this pattern. The phenomenon could be tied to old migratory routes when elephant habitats between the two areas they visit were contiguous. Yacob (1998) noted that during the wet season elephants move southwards into the Setit River valley and possibly cross the river into the adjacent Shire Wildlife Reserve of Ethiopia. This reserve, according to Blanc et al. (2003, p. 83–87) is devoid of elephants. Maps in Blanc et al. (2003) indicate that the elephant population closest to the Gash–Setit in Eritrea is in the Dabus Valley Controlled Hunting Area in western Ethiopia, some 500 km south to southwest. Elephants in Sudan are mostly in the southern part of the country; the remaining population in the eastern sector of Sudan (for example, in Dinder National Park) is adjacent to Ethiopia and could migrate back and forth into Ethiopia (Blanc et al. 2003). Available information implies that the elephants in Eritrea are geographically isolated. They are the northernmost population in eastern Africa; only Mali's elephants are found farther north, and only by about one degree latitude (Blanc et al. 2003). Certainly more research is needed, perhaps with the use of GPS satellite collars, to better understand elephant ecology and migratory patterns.

Flora and fauna

FLORISTIC ELEMENTS OBSERVED

We collected samples, especially of plants browsed by elephants, to learn about the ecosystems of the area with focus on finding what plant species elephants eat and how their feeding will affect the biodiversity. Based on our observations, either direct or by dissecting dung, and from information from local residents, we note that elephants eat 11 plant species, of which 7 are classified in the family Fabaceae, subfamily Mimosoideae, which includes acacias. They also eat parts of baobab trees (*Adansonia digitata),* family Bombacaceae, and desert dates (*Balanites aegyptiaca),* family Balanitaceae (Bein et al. 1996). Depending on local conditions, each region has its specific tree species from which elephants choose their favourites. Perhaps the most favoured food species in the Gash Barka zone is the doum palm (*Hyphaene thebaica*, family Arecaceae, known as 'arkokobai', fig. 5) found in the floodplains of rivers and wadis. Doum palm is followed in choice by ziziphus or Christ's crown of thorns (*Ziziphus spini-christi*, family Rhamnaceae, locally known as 'gaba'), by the thorn tree (*Acacia tortilis*, with the Tigrigna name 'alla' or 'akba'), and by blackthorn or hookthorn shrub (*Acacia mellifera,* fig. 6).

FAUNISTIC ELEMENTS OBSERVED

Summarizing the animals or their spoor, observed on trips to Gash Barka (1998–2003) minimum counts were 1 amphibian, 10 reptiles (3 orders, 10 families), 104 birds (15 orders, 42 families), and 38 mammals (9 orders, 17 families). References consulted include Kingdon (1997), Largen (1997) and van Perlo (1995). The Gash Barka zone, we quickly learned, is richly diverse in its fauna and flora.

Of particular interest was the presence of helmeted guinea fowl (*Numida meleagris)* almost everywhere we saw elephants in an open area, such as a dry riverbed, not necessarily close to a water well. Flocks stayed about 50 to 100 m from the elephants. They moved fast, sometimes hopping or jumping off the ground in areas elephants visited. These flocks can clearly be seen running about in the background of a

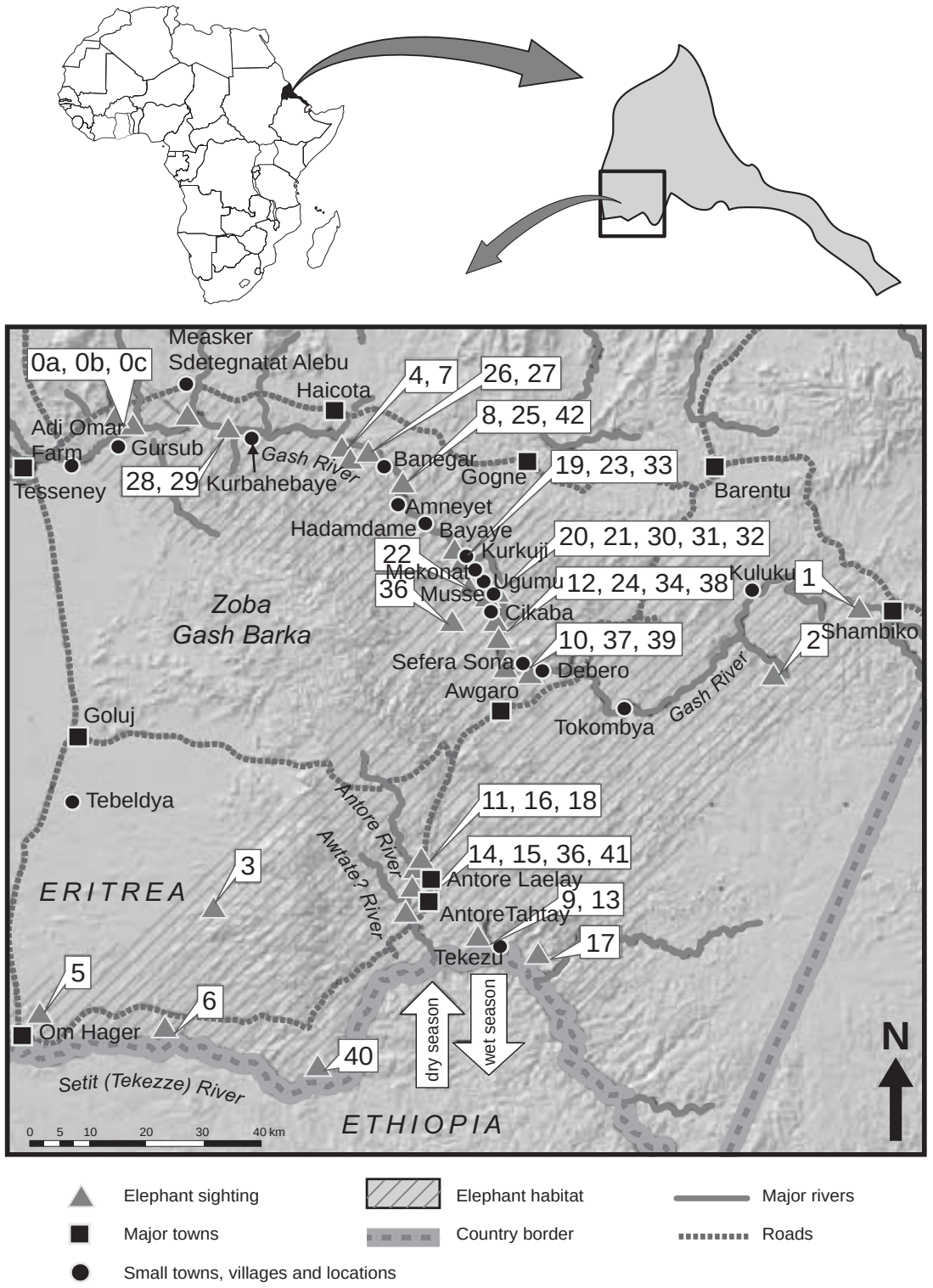

Figure 2. Location map of Eritrea in Africa and distribution of elephants in Zoba Gash Barka, based on data presented in table 1 (technical and artwork by Maria Christine Hill).

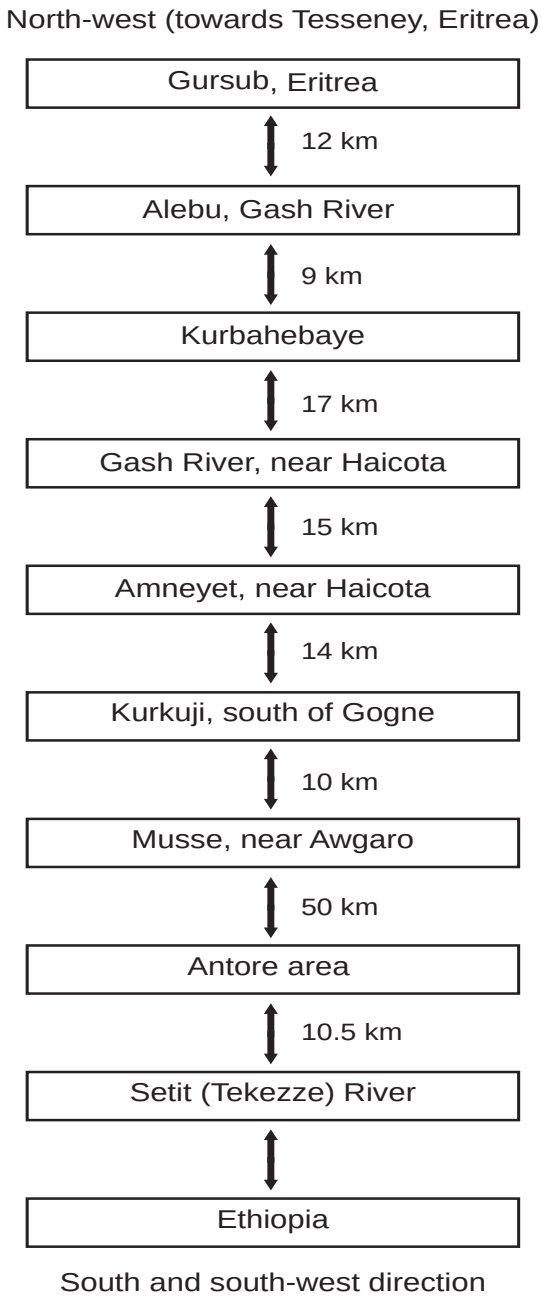

Figure 3. A simplified chart with names of villages and places between Setit River and Tesseney in Eritrea where elephants were observed during the dry season. The two-headed arrows indicate movement in both directions, within the watersheds of the Setit and Gash Rivers. Distances in kilometres are straight-line estimates between places, obtained from the map.

video taken at Musse of a male elephant next to the water well. A possible interpretation for this association follows.

Discussion

Estimated number of elephants in Eritrea

According to our 2003 data, the minimum number of elephants for Eritrea during the dry season is 83. This is a conservative estimate. In all probability, there were additional elephants deep in the riverine forest that were missed. In addition, we might have been overly cautious by subtracting 45 elephants from the total we observed, apprehensive that they were duplicate counts (table 2). From these data we may thus restate that our guarded estimate for Eritrea is about 100 elephants. Based on aerial photographs (fig. 4), the possibility exists that this number may even be as high as 150. Regardless of the exact number, it is the highest estimate since the estimate of 100 to 200 made by Leuenberger in 1955 (table 1 in Hagos et al. 2003).

Herd composition

As noted, of the 28 elephants counted on 25 December 2001, about 10 were newly born, some less than one year old. This is a healthy herd composition. Most of our observations were under crepuscular conditions, and only for relatively short times. Thus, we are not able to provide a detailed breakdown of the elephants observed, except for the 42 we saw at Musse on 28 January 2003 (table 3). We infer that these 42 elephants were not members of one herd but a congregation that gathered at a water well. The ratio of young and newly born to other members appears high. There were three newly born elephants (less than one year old), an additional seven calves aged 3 to 10 years, a minimum of five subadults, and at least five adult males; the rest were of mixed ages and sexes.

The other large group we observed (on 31 January at Amneyet; table 2) also had young calves, but we could not ascertain their numbers as there was constant movement among 12 elephants near the water well. Based on photographs from our observations of 45 elephants on 9 May 2003, we estimated that about one-fourth to one-third of the elephants were between 1 and 10 years old.

Despite these meagre observations, there appears to be enough data for a preliminary assessment that

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Figure 4. Herd of elephants photographed from the air (25 October 2003) near the Setit River, south of Antore Tahtay, in a deciduous woodland.

J. Shoshani

Figure 5. Doum palm (*Hyphaene thebaica)* forest on the floodplain of the Gash River at Banegar, where we observed three elephants close to noon, 1 February 2003. As our observations were usually at dusk, this was an unusual sighting, possibly because these were three subadult to adult males. Elephants and doum palms appear to have a symbiotic relationship—elephants feed on the fruits and use the trees for shade and concealment; in turn the elephants help distribute the palm seeds.

Figure 6. Blackthorn or hookthorn (*Acacia mellifera),* a favourite tree consumed by elephants. Here, on a hill near the Gash River, one such tree, with Emun Kebrom standing to show its size, has been stripped, presumably by elephants; dung was found close by. A similar shrub (*Acacia oerfota),* which has a strong, pungent odour, grows in the same habitat as *A. mellifera,* but elephants and other wildlife do not feed on it.

in at least half of the total elephants in Eritrea (42 out of 83) the number of calves between 1 and 10 years old is 13, that is, about 31%—definitely a reproductively active population.

From aerial photographs provided by the United Nations (19 September 2001; see table 1), we know that there were at least 5 adult males in the southwestern part of Eritrea in 2001. Of the 83 elephants observed in early 2003, about 16 (~19%) were identified as males. Is this proportion high? It is difficult to assess this situation, because if the assumption is true that the elephants in Eritrea are geographically isolated, then their movements are restricted and they cannot disperse to neighbouring elephant populations. It appears, therefore, that the movement of male elephants from one deme or subpopulation to another is restricted to within Eritrea (in elephant societies when a male reaches sexual maturity, his mother and other females force it out of the herd, presumably to avoid inbreeding; cf. Sikes 1971; Douglas-Hamilton and Douglas-Hamilton 1975; Moss 1988). In other countries where it is possible for elephants to mix with neighbouring populations (for example, those in the Masai Mara Game Reserve in Kenya might mix with elephants in the Serengeti in Tanzania), males have the opportunity to disperse, and thus avoid inbreeding. Assuming this hypothesis is valid, wildlife management authorities will be eager to learn what will happen in the coming years, and what measures should be taken if any.

Ecological considerations

CATHEMERAL BEHAVIOUR

Elephants may be classified as cathemeral, that is, they are or can be active in portions of both day and night. From interviews of wildlife scouts and farmers in 1991, we learned that elephants invaded crops at night, possibly to avoid human harassment. We also learned that elephants drink from excavated wells late in the afternoon or in the evening when livestock movements are reduced. In 2003, most the observations we made were under dim light conditions. During the day, as was observed in Banegar (1 February 2003), they are in the riverine forest to avoid the heat. Even though the elephants are elusive and avoid humans, they are more diurnal and crepuscular than nocturnal. These changes in behaviour are testimony to the elephants' ability to adapt to a changing environment.

HYBRIDIZATION

As noted by Hagos et al. (2003) there have been rumours that some of the elephants (*Elephas maximus*) brought from India in 1868 to Eritrea by the British General Sir Robert Napier (in pursuit of the Ethiopian King Theodore of Magdala, Myatt 1970) escaped from camps and mated with the native African elephants. Thus, descendants of these supposed matings would be hybrid elephants that roam Ethiopia and Eritrea. All the elephants observed in Eritrea appeared typical African elephants (*Loxodonta africana*). Further, initial genetic results confirm our field observations.

HUMAN–ELEPHANT INTERACTIONS

Elephants are not the only animals that cause damage to farmers and their crops. Rodents (especially rats and porcupines), monkeys and wild boars also damage them. The loss to farmers is high. Inhabitants informed us of conflict between them and the elephants that destroy or uproot crops. In recent years angry farmers have shot and killed elephants on their cultivated fields (see photos in Shoshani et al. 2000). These human–elephant conflicts have stimulated discussion, and plans to erect electric fencing to prevent elephants from invading plantations are being considered. Hoare (2003) discussed some of the problems arising from electric fences, especially the problem of maintaining them. Monetary compensation to victim farmers was also considered or relocating the farmers to areas where elephants visit less frequently (Hagos 2000). Both compensation and relocation are complex issues, for they require detailed assessments of the damage to farmers and building trust that the translocated farmers will not end up suffering a loss. Some of these issues are discussed in a publication of the IUCN African Elephant Specialist Group Human–Elephant Conflict Task Force (2003).

From a global and historical perspective, long before humans arrived in the area known today as Zoba Gash Barka, elephants and other animals roamed the area freely. Once people started to cultivate the floodplain of the Gash River, elephants found it irresistible to taste the fruits and vegetables that people planted. Bananas and citrus are the most favoured. Eritrea is not unique in the respect that both animal and humans compete for the most fertile lands. Strictly speaking, using the word 'damage' by elephants to human crops is not correct since the damage is simply what happens when the elephants seek food in a land where their forebears foraged for generations.

Traditional methods used by the Kunama and Nara farmers to chase elephants and reduce crop damage include making noise with empty cans or by cracking whips, and lighting fires in various places or gently waving lit torches. Aragai Haileselassie, the Ministry of Agriculture representative, however noted, 'Elephants will adapt to any threat. Integrated and controlled measures are better than repeating the same method; innovations are needed.' Another approach to avoid damage to crops is 'preventive medicine'. Thus, as soon as the arrival of elephants has been detected, it is suggested that farm produce be collected, ripe or not, and sold or stored before the elephants get to it.

Elephant conservation and management in Eritrea

Should translocation of farmers be necessary (in case the electric fence is ineffective), the approach would be unique, and it is hoped that it would be an example for future similar programmes. Most field observations on elephants deal with aspects of ecology and ethology (such as Douglas-Hamilton and Douglas-Hamilton 1975; Moss 1988; Sikes 1971). We are not aware of any conservation-related projects on elephants in which wildlife authorities are recommending translocating the people with goodwill and cooperation from a previously inhabited elephant range (Hagos 2000), rather than translocating the elephants, as discussed in the literature. Nonetheless, long-term management plans to protect elephants and their ecosystem in Eritrea will, undoubtedly, necessitate the cooperation of three governments: those of Eritrea, Ethiopia, and possibly Sudan.

Interspecific relationships

By definition, a keystone species is an animal that modifies its habitat and other animals benefit from this change (as in Western 1989). Elephants are good examples of keystone and super-keystone species (Shoshani 1993). An example of the role the elephant plays as a keystone species in the Gash Barka zone is the symbiotic relationship it has with the doum palms that are present in the Great Rift Valley and the Levant. The fruit of these palms, about the size of a pear, is called 'akat'. In season it sweetens and attracts many wild and domestic

animals—monkeys, elephants and humans included. Elephants use their foreheads to shake trees and then feast on the fallen fruits. They chew only the sweet outer coat; the rest of the digestion is done in the stomach. It is possible that the sweet outer coat evolved to attract animals to eat it and then dispose of the inner portion, the seed, and thus disperse the species. After several hours or more, the inner portion containing the seed is dropped in dung 5 to 10 km away from the original feeding site. Elephants thus are important seed dispersers of this palm. They also eat the leaves and use the trees to shelter from the heat and as hiding places and scratching posts.

In more than one locality we observed elephants and olive baboons in close association. One hypothesis proposed is that the elephants and the baboons have a symbiotic relationship. Deep in the forest, high in the trees, the baboons have a better visual advantage and from them the elephants quickly learn of human presence. In return baboons benefit from elephants, especially when water is scarce—they follow the elephants to the riverbed where they take advantage of the waterholes the elephants dig.

A possible commensal relationship may exist between elephants and helmeted guinea fowls (*Numida meleagris)*. We observed in a few locations that guinea fowls were in close association with the elephants (see 'Faunistic elements observed'). Perhaps they pick up seeds from the dung, or possibly catch insects attracted to the dung or that the elephants disturb. Additional observation would help to shed light on this newly reported association. Commensal relationships between elephants and cattle egrets and piapiac have been reported in the literature (Quick 1965).

Recommendations

We present two suggestions here; they are interrelated but it is easier to treat them separately. From previous discussions with staff of the Wildlife Conservation Unit, Ministry of Agriculture, and from the map presented in the report of Yacob (1998, p. 6), it appears that the current plan of the ministry is to establish one reserve area of about 500 km^2, south of Haicota. No human activities will be allowed inside the reserve. The other part of this plan is to create a corridor that will connect the proposed reserve area to the Setit River through Antore. Such a corridor will allow free movements of elephants between the Haicota area and the Setit River and Ethiopia. In all likelihood the human population in Zoba Gash Barka will continue to increase. Thus should it be possible, we recommend that the creation of this reserve area be expedited because more and more elephants and other wildlife are being killed (mostly as defense against crop raiding), and wildlife will soon learn where it is safe. This proposed protected area will perhaps be named the Gash-Setit Reserve, as suggested by Hagos (2000).

Our second recommendation is to install a few artificial watering sites along the path of elephant movement. Based on measurement of the depth of water in five wells in the Gash River (three wells around Musse, one each in Kurbahebaye and Mekonat), we noted that the depth ranges from 75 to 150 cm below the riverbed, with an average depth of 121 cm. With careful planning, pools with a low water level could be excavated. Alternatively, water could be supplied with a pump into pools in a convenient location. Some southern African countries are using this technique of supplying water into artificial pools to keep elephants in designated areas, rather than have them wander outside park boundaries and into human settlements (Conybeare 1991).

We are hopeful that implementing these suggestions and constructing an elephant-proof fence powered by solar energy, as mentioned above, will encourage ecotourism. These ideas and recommendations are interrelated and will require careful planning and funds.

Conclusions

Previous attempts to collect ecological data on elephants in Eritrea produced important information, but there is a desperate need for additional data on a broad scale to better understand the biodiversity, ecology and behaviour of these elephants to suggest long-term management programmes. Local people as well as indigenous students should be involved and benefit from these conservation programmes. Should erecting the electric fence be a successful pilot project, it will not only provide protection and security for these elephants but will, it is hoped, reduce conflict between humans and wildlife in the area.

Data collected during past years have added significantly to the existing pool of knowledge about elephants in Eritrea. The estimated number is close to 100; those observed in the Gash River constitute a healthy, fecund and viable population.

Based on initial assessment and comparing this population to other elephant populations in Africa, we believe that the number of males relative to females is high. Elephants inhabit areas where doum palms dominate, and a symbiotic relationship seems to have developed between these two species that may be critical to their mutual survival. Baboons and elephants also have a symbiotic relationship.

Throughout Africa, the estimated total population of *L. africana* and *L. cyclotis* combined is less than 500,000 elephants in the wild (Blanc et al. 2003). The small population of elephants in Eritrea may be isolated, although it appears that these elephants have been crossing into Ethiopia but not to Sudan (as reported by farmers and others in the area). Isolation of elephants results in islands of demes or separate subpopulations, developing their own behaviour and 'cultures' (Redmond 1986). These islands, if not well monitored and protected and depending on their size, may soon lose genetic diversity and be engulfed by the growing human population. The elephants in Eritrea may be a classic example of isolation; they are relict, confined to a small area of about 100 by 50 km.

Thus only a fraction of what has been documented as elephant habitat in historical times is currently available for them. The vulnerability of the elephants in Eritrea, their keystone-species role in the ecosystem, and their value as part of the international wildlife heritage cannot be overstressed. If elephants in Eritrea cross the border to Ethiopia, then the only possible broad exchange of genes would be with the elephants in Ethiopia, but even this possibility appears to be remote. International efforts must be made to protect this relict population. Their value cannot be expressed only monetarily; it is also in their ecological integration within their ecosystem, both as keystone or super-keystone species and in the context of ecotourism. We emphasize that saving elephants will automatically save large areas that will also protect other wildlife in the same ecosystem.

Acknowledgements

This study would not have been possible without the cooperation received from the Ministry of Agriculture, Government of Eritrea, in Asmara, Barentu and Haicota. The Born Free Foundation in the UK provided funds to conduct research on elephants in Eritrea. United Nations personnel in Asmara (especially officers Benjamin S. Anderson, A.J. Kessel, Christian Logoz and Philip Minez) have been extremely helpful in data collecting on elephant movements. Simon Nhongo of UNDP helped us in the initial stages of research. People from Gash Barka have been helpful in many ways; they include Abraha Garza, Dessalegn Hadgembes, Solomon Hagos, Aregay Haileselasse, Osman Arafa Hamid, Yohannes Ogbalidet, Solomon Tewelde, and Michael Zeraizghi. Special gratitude is extended to Julian J. Blanc for comments on a previous version of this manuscript and to Maria Christine Hill for preparing the distribution map (fig. 2). These people helped in various aspects of the investigation: Mical Abraha, Dawit Berhane, Matt Brown, Messimo Delfino, David Duthie, Jann S. Grimes, Colin Groves, Filmon Haile, Joann Holden, M. Philip Kahl, Sergey Kotelnikov, Hiruy Maharena, Gary H. Marchant, Chris Molinaro, Saleh Muhamed, Alfred L. Roca, Sandra Shoshani, Redea Teclai, Thor Thorsson, Rudy Wiens, Christer G. Wiklund, Merih Woldai, and Dietmar Zinner. All those who contributed to the information in table 1 are deeply appreciated. Mark Bent (country manager, Perenco Company, Asmara) is particularly acknowledged for flying his private plane to Gash Barka in search of elephants. Additional acknowledgements were given in Shoshani et al. (2000) and in Hagos et al. (2003).

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