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THE FUNCTIONAL SIGNIFICANCE OF MOVEMENTS AND POSITIONS OF THE PINNAE OF THE AFRICAN ELEPHANT, *LOXODONTA AFRICANA*

IRVEN O. BUSS AND JAMES A. ESTES

ABSTRACT.—Observations of wild African elephants (*Loxodonta africana*) in Uganda indicated that flapping and spreading the highly vascularized ears are probably important functions for heat dissipation. Ear flapping increased as ambient temperatures rose and decreased or ceased during cold or rainy weather. Rate of ear flapping was inversely related to wind velocity. Spreading the ears reduced ear flapping, particularly when an elephant faced downwind. Stimuli that elicited alertness, excitement, or hostility caused elephants to raise their heads and spread their ears widely and rigidly, and large elephants occasionally flapped their ears loudly and sharply. Flapping and spreading the ears for heat dissipation are generally not interpreted as danger signals by other elephants.

On the basis of laboratory studies at Makerere College in Uganda, Luck and Wright (Proc. 23rd Internat. Cong. Physiol. Sciences, p. 299, 1965) "postulated that an important and controllable source of heat loss in *Loxodonta africana* is via the circulation in the pinna. Arteries and veins are large, spaced alternately with wide separation and connected to a dense capillary bed." Using the dye dilution technique in immobilized wild elephants, they measured cardiac output and stated that "calculation from the arterio-venous temperature difference reveals that a large part of the estimated metabolic output can be lost by this channel." In addition, Wright (personal communication) measured ear blood flow and found an ear arterio-venous temperature difference of up to 35° F under the conditions of the experiment (immobilized animals with ear held still). The ear was shaded and there was a light wind blowing on each occasion. The magnitude of flow and heat loss, together with the anatomical arrangements and vascular control in the ear and the behavioral pattern of activity, convinced Wright "that this is a major controllable source of heat loss in this animal." During some of our studies we also observed large, prominent arteries and veins close to the relatively thin skin on the inner side of the ear of African elephants (Fig. 1).

Observations from a field study conducted in Uganda in 1963 and 1964 support the physiological observations of Luck and Wright (*loc. cit.*). The study was conducted to obtain information on the function of pinna movements (hereafter referred to as ear movements) and positions and their relationships to various influences.

METHODS

When possible, temperatures were taken at the site of observation by placing a thermometer in natural or improvised shade approximately 5 feet above ground. Wind velocity near the observation site was obtained with an anemometer placed on the roof

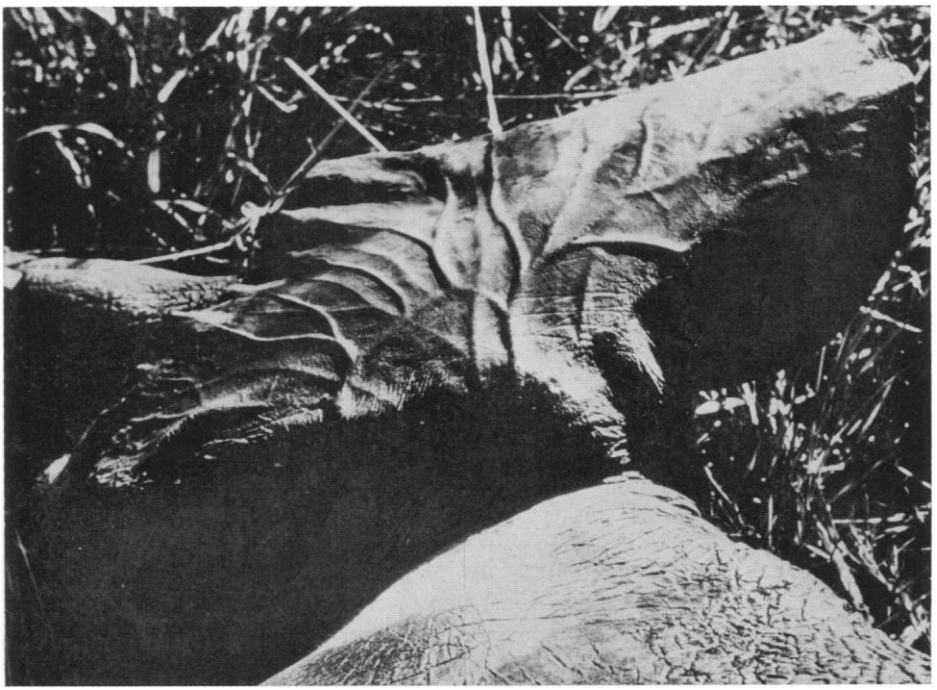

FIG. 1.—Large arteries and veins are conspicuously prominent under the thin skin on the inner side of the ear of an elephant.

of a vehicle, about 6 feet high. With few exceptions, observations were made on the Kamulikwezi area near the north shore of Lake George in the northern part of Queen Elizabeth National Park, southwestern Uganda. Observations (generally with binoculars) on ear movements were recorded only if the elephants under observation showed no overt signs of detecting the observer. The term "ear flap" refers to the movement of the pinnae, once forward and once back. If an elephant spread or flapped its ears when relaxed or unexcited, such positions and movements did not appear to elicit a response to danger by other elephants. However, when an elephant spread or flapped its ears in excitement and raised its head, such movements quickly evoked a response in other nearby elephants (Fig. 2). When detecting danger a large elephant occasionally shook its head vigorously; its flapping ears resounded sharply and loudly, like the snap of a wet towel.

RESULTS

Data on the influence of temperature and wind velocity on ear movements and positions of 20 wild elephants are presented in Table 1. During the relatively cool periods between 0700 and 1100 hours, rates of flapping for nine elephants were consistently low varying from 0 to 3.2 flaps per minute (Table 1). Wind velocity was low during these periods, reaching a maximum average of 3.5 miles per hour; temperature varied from 66 to 78° F.

During the relatively hot periods between 1100 and 1730 hours, rates of ear flapping were highly variable. Seven of the 11 observations involved relatively

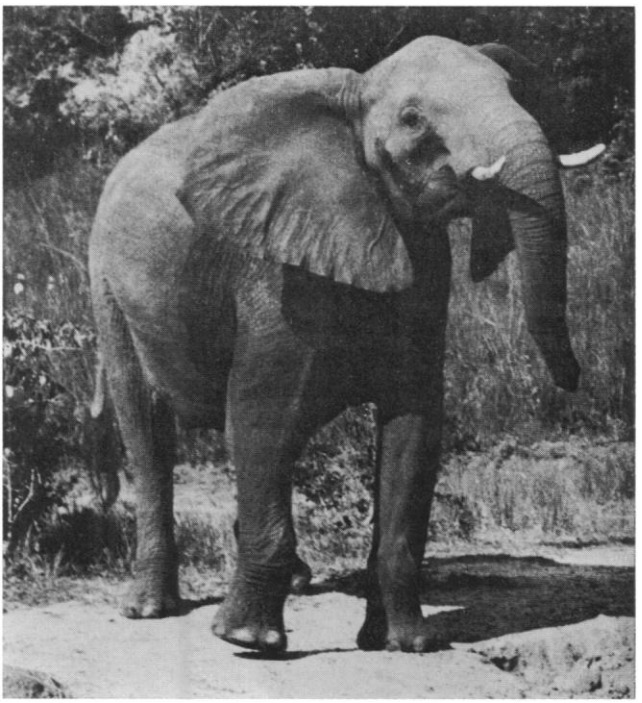

FIG. 2.—When this African elephant detected danger, its head went up, its ears spread widely and rigidly, and its trunk bent downward from the base of the tusks. Nearby elephants quickly recognize such danger signals.

low rates of ear flapping (1.3 to 4.5 flaps per minute), which were associated with relatively high temperatures (81 to 94° F) and with ear spreading. Elephants were observed with ears spread or angled away from their bodies when temperatures rose to 80° F, when winds reached a velocity of 2.5 miles per hour, and when they faced or walked downwind. Apparently the air circulated fast enough about the ears to preclude the necessity for rapid flapping. The three highest rates (14.7, 20.7, and 22.8 flaps per minute) were observed when temperatures were 86 to 88° F and wind velocities were 5.3, 3.1, and 1.9 miles per hour, respectively. These three elephants did not spread or angle their ears away from their bodies while they were under observation. One of the 11 elephants observed during this hot period flapped its ears 5.3 times per minute but there was no ear spreading. Evidently the temperature of 78° F was low enough to preclude the necessity of ear spreading.

After 1730 hours when temperatures declined and winds subsided, ears flapped at rates (1.6 to 3.5 times per minute) similar to those recorded during the cool morning periods.

The relationship between rate of ear flapping and ambient temperature is shown in Fig. 3. Excluding the seven individuals that spread their ears,

TABLE 1.—*The influence of temperature and wind velocity on pinnae movements and positions in elephants.*

Observation time (minutes–seconds)	No. of flaps	Flaps per minute	Ears spread	Wind	Temp. (°F)
		Observations between 700 and 1100 hours			
28–00	0	0.0	no	none	66
14–00	43	3.0	no	none	66
336–00	0	0.0	no	1.0	67
42–00	129	3.1	no	1.0	67
17–00	23	1.4	no	2.6	72
5–40	16	2.9	no	1.9	72
60–00	0	0.0	no	2.3	74
12–30	4	0.3	no	3.5	74
12–00	38	3.2	no	1.9	78
		Observations between 1100 and 1730 hours			
10–00	53	5.3	no	5.9	78
239–00	309	1.3	yes	5.1	81
245–00	344	1.4	yes	2.5	82
10–00	45	4.5	yes	4.3	82
10–00	207	20.7	no	3.1	86
5–05	116	22.8	no	1.9	87
9–00	132	14.7	no	5.3	88
9–00	12	1.3	yes	8.0	89
5–38	20	3.6	yes	8.0	90
00–46	3	3.9	yes	5.5	93
15–00	29	1.9	yes	6.5	94

a correlation coefficient of 0.85 (based on data from 13 observations in Table 1) was found in this relationship—significant at the .001 level.

DISCUSSION

The seven elephants that spread their ears away from their bodies (Fig. 3) had conspicuously lower ear-flapping rates than elephants that did not spread their ears, although both kinds of behavior frequently occurred under the same environmental conditions. These elephants presumably took advantage of the wind by spreading their ears, particularly while feeding and facing downwind, and thus reduced the necessity for increased ear movements (Fig. 4).

During rains, particularly when there were accompanying winds, elephants generally ceased ear flapping and either spread their ears or held them close to their bodies. Twenty-three elephants were observed in a rather compact group walking into a cool breeze on 17 October 1963. About half of the

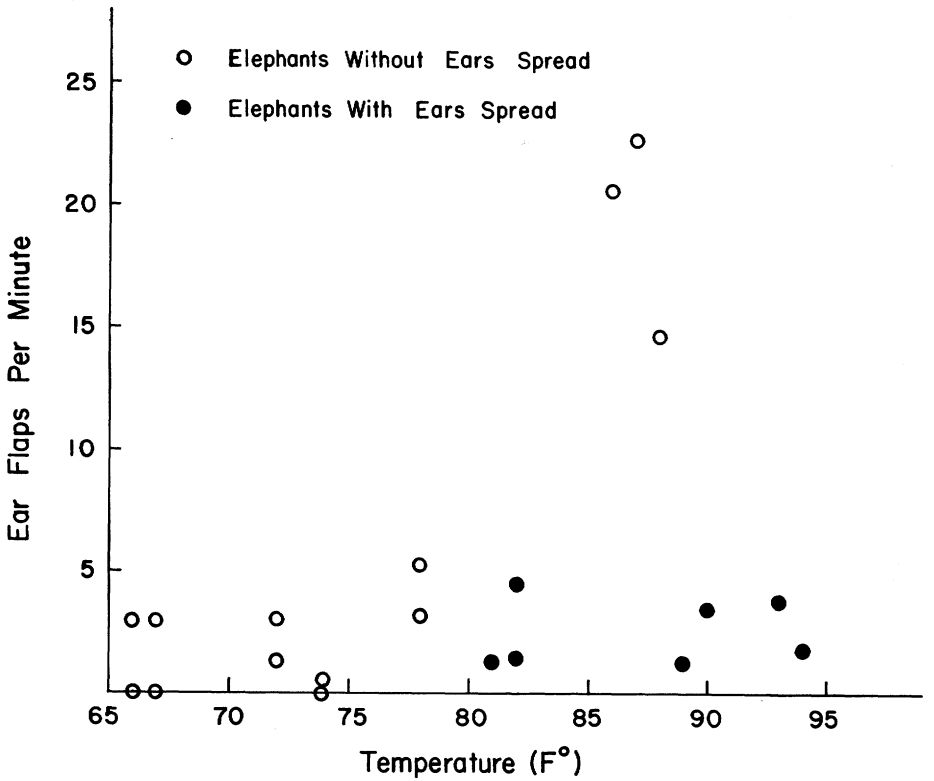

FIG. 3.—The relationship between rate of ear flapping and temperature for 13 elephants without ears spread and seven with ears spread.

elephants flapped their ears at widely separated intervals. Approximately 15 minutes later the herd began stringing out into the wind, which reached a velocity of nearly 15 miles per hour. When rain began falling 15 minutes later all ear flapping stopped. Within the following 4 minutes, the ears were folded close to bodies, and every elephant in the herd moved ahead with ears held continuously and closely against its body. Soon two big bulls joined and followed the herd through the rain for nearly a half hour; their ears also were motionless.

Elephants observed utilizing shade generally showed decreased rates of ear flapping. Four adult bulls were observed standing under a large tree (*Acacia* sp.) at the edge of a forest at noon on 5 November 1963. Two bulls were completely shaded and flapped their ears less frequently than two smaller bulls standing in partial shade. About 400 yards from this site, two other bulls approached across a flat, open area where they were exposed to a 4-mile

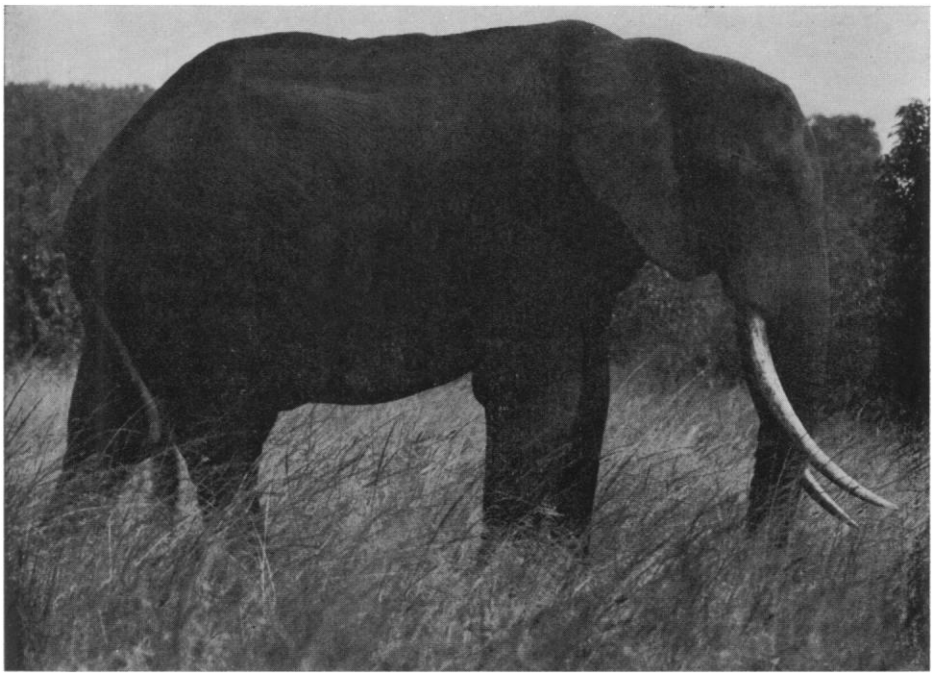

FIG. 4.—While feeding and moving slowly downwind, this large bull in Queen Elizabeth National Park held his ears outward about a foot thus exposing their inner side to a tail wind of 8 miles per hour. Relative wind direction is registered by the bull's tail and the bending grass.

wind. These two bulls each flapped their ears once for every 3 to 4 flaps recorded for the two partially shaded bulls under the acacia tree.

The various elephant activities preceding our observations probably affected body temperature thus accounting for some of the variation in ear flapping under the same or similar environmental conditions.

Ear positions as danger signals

The following four observations illustrate the use of ear positions as signals or warnings of danger. A herd of 28 elephants moved slowly along the shoreline of Lake George during late afternoon of 14 October 1963. A rain storm was developing, and a cool breeze swept across the lake. No ear flapping was observed among the 28 elephants until they reached a point downwind from the observers. At this point the animals showed much excitement, paused briefly with trunks raised in "tea-kettle" position, and with much ear flapping and heads held high turned and ran from sight into the nearest shrubbery.

A large cow accompanied by an elephant estimated at 4 to 5 years of age and a calf about 1.5 years of age were observed feeding in a marsh during the early afternoon of 5 October 1963. A sudden movement by the observer from

a downwind position apparently caught the attention of the cow. She quickly turned to face the observer, lifted her head, cocked her ears rigidly, and held her trunk extended straight downward. Almost immediately the two accompanying elephants showed similar responses, looked in different directions, and then all three animals moved quickly from the marsh into the nearby forest.

A group of nine bulls fed and moved slowly through a marsh during mid-afternoon on 5 November 1963. The elephants were well dispersed with a young bull following rather widely at one flank. Suddenly the young bull showed concern over a small group of marabou storks (*Leptoptilos crumeniferus*) standing close to where he was walking. He raised his head, flapped his ears, and with tail raised, walked stiffly toward the rest of the herd. The other elephants stopped, lifted heads, ceased all ear movements, and faced toward the young bull, which had stopped about 20 feet from the nearest elephant. At this point the young bull turned, faced back toward the maribous, and lowered his head. Almost simultaneously the other elephants resumed feeding and continued moving slowly. Evidently lowering the head terminated the signal.

While we were approaching six big bulls in the remote area north of the Galana River, Tsavo Royal National Park (East), Kenya, on 12 February 1964, one of the bulls detected our approach. His head raised until the tusks were pointed nearly straight forward, his ears were partly spread out, and his tail was held stiffly upward as he started walking off into the dense stand of trees and shrubs. Within a few seconds the other five bulls assumed practically identical postures and moved off with the first bull. An attempt was made to follow them, but the bulls made a complete circle without once permitting a close approach. Even when the bulls paused upwind under several large trees surrounded with dense shrub and vine cover, they appeared tense and gave the distinct impression of readiness to charge.

With one exception, these observations of wild elephants in Uganda and Kenya showed behavior similar to those reported by Kühme (Internat. Zoo Yearbook, 4:118–121, 1963) who studied behavior of three 11-year-old East African bush elephants in an enclosure at Krönberg, Germany. In summarizing his observations on ear movements, Kühme stated that "these observations permit the conclusion that when the *a* animal flaps his ears because it is warm this is also understood as implying aggression." Although we did not observe this behavior, it could have occurred without our recognizing it, or perhaps (as Kühme stated) "this behavior may be a captivity phenomenon arising from living in a confined space with insufficient environmental stimuli."

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