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Mammoths in Musth

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The phenomenon of musth, first systematically observed and recorded in ancient India, is now a thread running through a deep history of elephants.

Michael Cherney, a postdoctoral researcher at the University of Michigan, and several of his colleagues have published strong evidence confirming that male mammoths had musth.

Mammoths have gone extinct, so the evidence comes from skeletal remains of dead animals. The earlier evidence was of fights to the death by males, hypothesised to be in the grip of musth. The new evidence is of recurring seasonal surges of testosterone, recorded in the tusks.

Cherney's teacher, Daniel Fisher, pioneered the analysis of tusk growth records to reconstruct the life histories of mammoths and mastodons. He published evidence of musth-like behaviour in remains of the mammoth (Fisher 2004, 2008). But it remained to show evidence of the hormones behind it from tusks. This has now been done.

Musth, ancient and modern

The phenomenon of musth, first systematically observed and recorded in ancient India, is now a thread running through a deep history of elephants that is being built with new science, supported by excavation and analysis of bones, and especially of tusks.

"Musth" is of course the Hindi word *mast*, borrowed from Persian, meaning 'intoxicated', and answering to Sanskrit *mada*. It is the intoxication of love that drives the musth elephant to seek out a receptive female, and drive off all rivals (or the human observer) with a limitless fury.

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This Hindi word comes to the fore because behind it lie some four thousand years of the capture and use of Asian elephants in India. The Indian elephant of war, invented in North India at some time between 1000 and 500 BCE (Trautmann 2015), is the key, because the male-on-male aggression of the tusker in musth is highly valued and channelled for human advantage in battle. For this reason, it became a convention of poetry and visual portrayals in ancient India that elephants in battle are always shown as being in musth, by a black streak of musth-fluid flowing down from the temples, midway between the eye and the ear of the elephant.

Musth was a closely observed phenomenon, because use of war elephants had a long history, and because musth was highly valued for warfare. For example, the treatise in Sanskrit on elephant-science (*gaja-shastra*) by Nilakantha, called *Matangalila*, published by Ganapati Shastri (1910) and translated by Franklin Edgerton (1931), contains a chapter on musth. It breaks it down into seven stages: swelling temples; downward flow of musth fluid; dribbling urine; pungent scent; fury toward opponents; surpassing rage; diminution of musth and a return to the normal non-musth condition (*Matangalila* 9.12-18). This knowledge of musth, traditionary in India, fed into the modern scientific study of musth in Asian elephants by zoologists.

In the 1960s, zoologists believed that musth was confined to the Asian elephant. That was changed by an article of Joyce Poole and Cynthia Moss, in 1981, in the journal Nature, with evidence of musth in African elephants.

> Dominance amongst African elephants divides into two phases: for elephants who are not in musth, and for those who are.

Moss, the senior scholar, had been studying the sexual behavior of female elephants at Amboseli National Park in Kenya, and assigned Poole, then still an undergraduate, to the study of the males, of which much less was known. Their discovery of musth in the males was the first extension of the scientific evidence for musth beyond the Asian elephant.

Poole had read an article on domestic elephants in Ceylon, which featured a photo showing a male elephant with both downward flow of musth fluid and dribbling urine (Jainuddin et al. 1972; Moss 1988:108; Poole 1996:48). It confirmed what she had been observing among African male elephants. Long before this, though, the *Matangalila* described both features for the second and third stages of musth.

Zoologists studying animal behaviour pay a lot of attention to the social condition of dominance. From Poole and Moss we see that dominance amongst African elephants divides into two phases: for elephants who are not in musth, and for those who are. Amongst elephants in a male group, not in musth, there is a dominance order that is well-known and settled by non-lethal fights that show who is the larger and stronger of every pair. If the group comes upon a tree that has blown over, the most dominant gets the best leafy branch, the second most dominant the second best, and so on.

Musth makes an elephant dominant over all other males not in musth, for the duration (Moss 1988:112). When an elephant goes into musth it will fight another furiously, head-to-head, and if it can turn its opponent, it will put a tusk through its head or flank and kill it.

These observations, if they are valid for Asian elephants – and there is reason to think they are – explain the artistic convention in ancient India always showing a war elephant in battle as being in musth. They also tell us well why means were employed to artificially provoke the onset of musth before going into battle by giving the war elephant wine or some other alcoholic drink, by the playing of martial music, or setting off fireworks.

Evidence in the tusks

Human knowledge of musth in elephants had expanded from Asian to African elephants, with increases accruing to both lineages. The recent work of Cherney and Fisher and their associates constitutes a second expansion of scientific knowledge of musth, for the first time, to a lineage of elephants that is no longer living: the extinct mammoth.

Modern elephants and their extinct near relatives are part of the proboscidean family tree. In geological times considered recent, the family has had five main lineages: the Asiatic and the African elephants, still living in the wild, plus three extinct lineages of mammoths, mastodons and gomphotheres. The first three have now been shown to have musth, with but slight differences of detail.

In the case of African elephants the proof was supplied by the close observation of their behavior. Additional evidence came from surging testosterone levels found in recently produced urine made by a bull elephant in a dangerous state, which was gathered (quickly!) by syringe from small puddles. (Moss and Poole 1981; Moss 1988:101-118; Poole 1987).

Without living specimens to observe or provide body fluids to examine, how can musth be proven to exist in the extinct lineages? Because there are no living individuals to observe and get body samples from, the evidence for musth comes from two sources, which together reveal a surprising amount of detail.

The first is the bones, which yield a certain amount of evidence of male-on-male fighting, and give information of approximate age and condition at the time of death.

At the Museum of Paleontology of the University of Michigan are the remains of the Buesching Mastodon, a specimen found in a peat bog from the nearby state of Indiana. A hole in its skull suggests it was killed after a tremendous fight. Its opponent drove a tusk through 20 inches of cheek muscle on the right side and punched through the skull above the upper molars. It appears to have been in musth, and in battle with another mastodon, also in musth. The overall condition of the skeletal remains seems to rule out death by old age or poor nutrition and shows it to be a healthy adult.

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But very much more detailed evidence resides in the tusks, if they have been preserved and are complete.

Tusks have annual growth rings like trees. One can imagine the tusk as a series of cones stacked upon one another. Unlike trees though, tusk grow from the pulp inside the tusk, adding a new cone to the *bottom* of the stack, each year. The first year produces the outermost cone and the tip of the tusk – which after time may be worn away or broken off. If the whole tusk is intact the annual

layers are added one by one and can be counted to get the age at death, accurate to the nearest year.

Within one year's band of new tusk material one can identify changes by season, or weeks, or even a single day, by identifying ever-thinner bands. One can, as in this case, identify a surge of testosterone, and show that it recurs from year to year, at the same time of year. This is highly significant evidence that musth is a stable, recurring feature of an individual male in prehistoric times, as in the two lineages of living elephants.

This is essentially what Cherney and Fisher and their associates have done in their recent article in the journal *Nature*. The article is the culmination of several earlier articles showing evidence of musth-like behavior in skeletal remains of mammoths (Fisher 2004, 2008). It remained to show evidence of the hormones behind it from tusks. This has now been attained.

What about the remaining two lineages of extinct elephant relatives, the mastodons and the gomphotheres?

The Buesching mastodon has shown striking skeletal evidence consistent with the manner of fighting between pairs of individuals in musth.

There is also new skeletal evidence of musth in the fifth lineage of elephant relatives that endured till recent times, the gomphotheres. These close relatives of mastodons arrived in South America 2 million years ago, when volcanoes created the Isthmus of Panama, a land bridge linking North and South America. It became extinct recently, less than 15,000 years ago.

A specimen found in Chile and analysed by the methods of Fisher and his associates shows the death of an adult male at the peak of health, consistent with death by fighting due to musth, and inconsistent with death by disease or accident (El Adli *et al.* 2017).

We may expect that in the not-too-distant future, suitable remains of tusks will be used to test the skeletal evidence favouring musth and deliver a stronger case for or against musth in these two remaining of the five lineages. It will be a welcome validation of the work of elephant keepers and trainers of ancient India.

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