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Clashing with Titans

SHARON LEVY



Paleontologist Len Hills, of the University of Calgary in Canada, examines the first of many mammoth trackways discovered when the St. Mary's reservoir in southwestern Alberta was temporarily drained. Nine mammoth tracks, made by a very mature female or young male, are exposed on an expanse of glacial silt.

Photograph: Paul McNeil.

Near the 11,000-year-old bones of a native horse, University of Calgary researchers recently found a stone spear point still bearing traces of horse blood, powerful evidence that the animal had been killed by human hunters. The tracks of extinct beasts—muskoxen and camels—surrounded the site in southern Alberta. Among them were prints that paleontologist Len Hills suspected had been made by woolly mammoths.

Paul McNeil, a graduate student in Hills's lab who was studying dinosaur locomotion, was skeptical when his advisor talked of finding mammoth tracks—an extreme rarity, seldom preserved. "He said he'd taken photos but the film didn't turn out," recalls McNeil. "It sounded like a Bigfoot sighting."

Still, McNeil put his dinosaur work aside and traveled with Hills to Wally's Beach, an area that had long been beneath the waters of the St. Mary's reservoir. The reservoir had been drained to allow construction of a new spillway, and a wide expanse of ancient river bed, composed of fine glacial silt, was exposed. Once he'd clapped eyes on the tracks—circular impressions 60 centimeters wide, separated by stride intervals 2 meters long—McNeil was convinced. "There's nothing else in the world that could make that sort of track. It's got to be an elephant."



An aerial photo shows a group of elephants at Shakwanki seep in Zimbabwe's Hwange National Park, during a time of drought. The many obvious elephant trails make the animals easy to track. Such trails may have made mammoths and mastodons easy prey for late-Pleistocene human hunters. Photograph: Gary Haynes.

For McNeil, the mammoth trackways at Wally's Beach brought the extinct giants dancing back to life. In one spot, a moment of play between two young animals was written in the sand. "One is probably in its late teens, the other around 10 years old," he says. "You can see them curving around, chasing one another." On another stretch of beach lay the tracks of a mother and her young calf, the juvenile almost running to keep up.

At the end of the Pleistocene Epoch, the last ice age, North America lost an array of spectacular mammals, including the woolly mammoth and four other species of elephant, native horses and camels, giant sloths, bear-sized beavers, saber-toothed cats, and dire wolves. At the same time, Clovis people—a culture of efficient hunters who left elegantly chipped spear points buried in the ribs of mammoths and other extinct creatures—spread across the continent. Many paleontologists believe that humans helped drive the big beasts to extinction, while others argue that the die-off was due to rapid climate change that radically altered habitats as the glaciers receded.

New perspectives from living relatives

The debate is among the hottest topics in paleontology. Now, a growing number of studies that use data on living elephants to help interpret the lives of mammoths and mastodons offer new perspectives on the problem and suggest that while human impacts alone may not have destroyed America's mega-

herbivores, they most likely were the straw that broke the elephant's back.

For decades, conventional wisdom held that the mass extinctions of the late Pleistocene were caused by climate change. Paul Martin, the University of Arizona paleoecologist who first suggested that Clovis hunters wiped out the megafauna in a blitzkrieg of hunting, was widely viewed as a crackpot when he proposed his theory 30 years ago. Today, many of his colleagues accept the idea that humans had a hand in the demise of America's biggest mammals, though each might envision the details differently.

One obstacle for proponents of the climate change theory is that the end-Pleistocene warming trend was no more severe than the many previous interglacial heat waves that came and went during the ice age. A scattering of creatures, large and small, faded away during these interglacials. Yet most of the big beasts survived until the end of the Pleistocene, when humans became widespread in America—and then a wave of extinctions struck, affecting only those animals large enough to catch a hunter's interest.

Tracks, bones, and human artifacts at Wally's Beach show that vanished Pleistocene mammals, including horses, camels, mammoths, and muskoxen, co-existed with people for at least 200 to 300 years along the banks of the St. Mary River. The mammoth tracks open a window to the past in ways that bones often cannot. Because modern African elephants are about the same size as woolly

mammoths, data on living elephants can reveal the size and age of the mammoth that left a track, the speed at which it was moving, the condition of a family group. The Wally's Beach trackways indicate a population dominated by adults, with juveniles making up only about 30 percent of the total.

"A healthy herd of modern elephants is about 50 percent juveniles," says Gary Haynes, an archeologist at University of Nevada who has spent years studying African elephants in order to learn about the fate of their vanished American cousins. "A small proportion of young animals in a herd means that something is wrong....The calves may be killed because they're easier targets for predators, including hunters with spears, or they may be dying because of drought because they're more vulnerable than adults."

Haynes has traveled to Kenya, South Africa, Namibia, and Zimbabwe to study the ways that elephants die and the evidence they leave of their passing. When Hwange National Park in Zimbabwe decided to cull their elephant herd, which managers believed had become too large to be sustained within the limits of the park, Haynes was able to mimic the way a Stone Age hunter would have butchered an elephant and observe the impacts on the bones—a way of confirming that marks and cracks on fossil mammoth bones did indeed indicate humans at work.

Zimbabwe was hit with a severe drought during Haynes's study, and ele-



At Nehimba Pan in Hwange National Park, Zimbabwe, many elephants died of starvation during an extended drought from 1992 to 1995. Gary Haynes's studies of these elephant bones show that mass deaths of mammoths, which had been interpreted as the result of human hunting, might instead have been natural events. Photograph: Gary Haynes.

phants were clustered around dwindling water holes, slowly dying of hunger and thirst. This allowed him to compare the remains of hunted elephants with those that died of environmental causes. He found that the bones of drought-killed animals were often trampled by their desperate comrades, anchored by thirst to a water source. The trampled bones bore the kind of fracture marks that archeologists had often interpreted as signs of butchery at mass death sites of mammoths. Haynes's work changed the way he and his colleagues look at ancient elephant remains and undermined the idea that Clovis hunters had slaughtered whole families of mammoths at one go. "Even the presence of stone tools, which people undoubtedly made, doesn't necessarily mean that people killed the animals," he says. "In nature, elephants die en masse sometimes. You don't need people to make that happen."

Nevertheless, Haynes believes human hunting played an important role in the demise of America's native elephants.

"There are 14 kill sites in North America that archeologists agree on," he says. "Twelve mammoths and two mastodons that seem to have been killed by people. Some researchers look at that number and think, good lord, that has nothing to do with extinction: a dozen kills spread out over a couple of hundred years. But if you look at the archeological record anywhere in the world, there's almost no kill sites of anything *except* mammoths. In my mind, the fact that there's 12 in such a short time means there must have been many more we just haven't found."

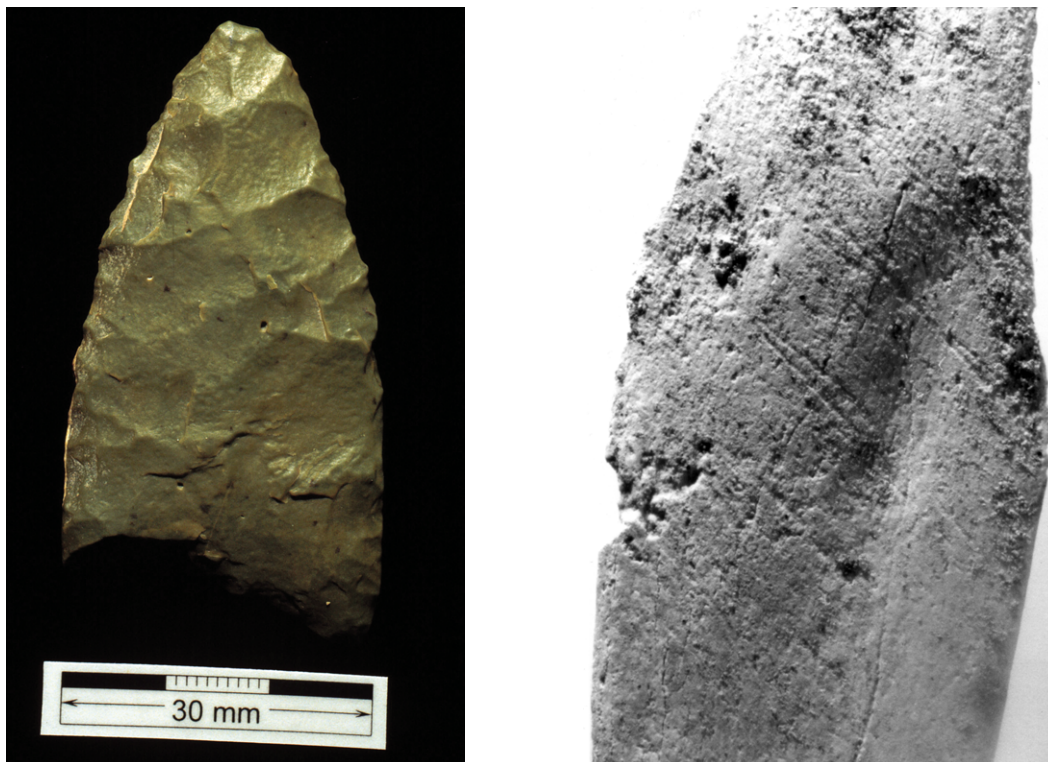
Haynes believes that a warming climate altered late Pleistocene vegetation, fragmenting mastodon and mammoth populations into small enclaves of remnant habitat. American elephants must have traveled along obvious trails, lined with dung, just as African elephants do today. And like modern elephant trackers, Clovis hunters would have learned to read elephant trails, to determine from footprints both the size of animals and how fast they were moving. Finding big

game would have been easy. In his scenario, climate change made the megamammals vulnerable, and humans gave them a killing blow.

Intense hunting pressure

Modern African and Asian elephants are the exception to a global die-off of their kind that began long before recorded history. One million years ago, a variety of elephant species lived throughout Africa, Eurasia, and the Americas. A recent study by Todd Surovell, an archeologist at the University of Wyoming, finds that elephant extinctions followed the movement of modern humans out of their homeland in Africa. The gradual northward range contraction of elephants, he says, followed by their ultimate extinction in Europe and the Americas, traces the path of human population expansion over the course of 1.8 million years.

Surovell analyzed known sites worldwide containing elephant bones along with strong evidence that humans had



A Clovis spear point (left) recovered from the floor of the St. Mary Reservoir still carried traces of the blood of an extinct North American horse, and impact shattering indicates that this projectile point was actively used in hunting. Hyoid bone (right) from the skeleton of an extinct horse found at the St. Mary Reservoir shows butchering cut marks. (Wooden excavation tools were used to prevent accidental tool marks from metal equipment.) Photographs: Gerry Newlands (left) and Brian Kooyman (right).

killed or butchered the animals. Demonstrating that a fossil elephant was used by people is difficult: With smaller creatures, elk for example, hunters cut off body parts to transport them back to camp. Elephant bones and meat are so heavy that people instead moved their camps to the carcass. Sites widely accepted by archeologists as examples of humans exploiting elephants show a pattern of a single dead animal, surrounded by flakes of chipped stone created as the hunters worked their butchering tools to a sharp edge. In a few cases—most often at North American sites—a spear point has been left buried among the bones.

The oldest evidence of people dining on elephant comes from the time of *Homo erectus*, 1.8 million years ago, in Tanzania's Olduvai Gorge. By 500,000 years before the present, modern *Homo sapiens* were hunting elephants in the Mediterranean, and people left a trail of dead proboscideans behind as they

moved north through Europe and Asia. As glaciers retreated at the end of the ice age 11,000 years ago, our ancestors penetrated the high Arctic, and woolly mammoths died out except in a few remote refuges, such as Wrangel Island in the Arctic Ocean, that were bypassed by the human tide. Around the same time, Clovis culture spread quickly across North America, and mastodons and mammoths vanished.

"The real damning evidence," says Surovell, "is the repeated global pattern. When humans colonize a new place, a wave of extinctions follows."

Out of a Pleistocene abundance that included seven genera and more than a dozen species spread over most of the Earth, only the Asian elephant, *Elephas maximus*, and the African elephant, *Loxodonta africana*, survived. Martin suggests that these elephants had the advantage of a long, slow coevolution with humans. They had time to learn that people were dangerous, to become

wary and find ways to defend themselves. In the places where elephants vanished fastest—the Arctic and the Americas—naive animals were suddenly confronted with a deadly new predator. The humans who pushed into these new territories had been honing their elephant-hunting skills for generations.

African elephants in the wild live in family groups, usually led by an older matriarch and including several females and their calves. When male calves reach their early teens and become sexually mature, they're evicted from the family group and must make their own way. A young male's first year or two on his own is a lean time, as he slowly learns how to find food and avoid conflicts with other elephants.

Using data on the life cycle of modern elephants for context, Daniel Fisher of the University of Michigan reads signs of intense hunting pressure in fossil mastodon and mammoth tusks. Tusks grow throughout an elephant's life,



These tusk fragments are from Shabi Shabi seep, Hwange National Park, Zimbabwe. The ivory tips broke off as elephants used their tusks to jostle each other in a struggle for access to a tiny water supply during a drought. These tusk pieces are very similar in size and shape to fossil mammoth and mastodon tusk specimens often mistakenly interpreted as made by human hands. Photograph: Gary Haynes.

adding new layers of dentin. Like the growth rings of a tree trunk, the width of dentin layers reflects easy or hard times. When animals are in good condition, they add more tusk material in a given length of time; when they're stressed by shortages of food, the dentin increments get thinner.

In a sample of 10,000- to 12,000-year-old mastodon tusks from the Great Lakes region, Fisher found a steep drop in tusk growth rate in males at about the age of first sexual maturity. In females, tusk growth rate drops in a different pattern, one that reflects the added need for calcium and phosphate during pregnancy and calving. Over the course of 2000 years at the end of the Pleistocene, he found that the age of sexual maturation in mastodons decreased by about

three years, from age 13 to age 10. This earlier maturation is the opposite of what Fisher would expect to find if climate change—and a subsequent loss of food sources—was the main stress facing the megamammals. In hungry times, living elephants will delay sexual maturation until the age of 20 or so, building their reserves before they begin the energy-intensive process of mating.

A rush to sexual readiness fits with the idea that the mastodons were suffering from hunting pressure. Under heavy predation, many animals mature earlier, giving them more of a chance to reproduce before they're hunted down. "We have analogies that support that idea in everything from fish to large mammals," says Fisher.

Although male elephants leave their natal groups in their early teens, they don't start courting females until they go into musth, a heightened hormonal state that can turn otherwise calm animals into aggressive hotheads. Most African elephants begin to go into musth in their mid-20s. During musth, they fast and fight with other males for access to females in estrus. Fisher has studied evidence of musth battle injuries in the skeletons of male mastodons and mammoths, and now he's begun to analyze a record of musth in their tusks, a seasonal thinning of the dentin layers that begins after age 20. Although he cautions that he needs more data in order to draw any firm conclusions, he's beginning to suspect that late Pleistocene mastodons were going into musth at unusually young



These mopane trees were killed by foraging elephants in Hwange National Park, Zimbabwe. Elephants are powerful ecosystem engineers, capable of transforming woodlands into savanna or shrubland.

Photograph: Gary Haynes.

ages—a possible symptom that they lived in a declining population whose social structure was disintegrating.

A modern example occurred in the mid-1990s in Pilanesberg National Park, South Africa. Elephants had been wiped out in the area, and when the park was established, young orphaned animals were brought in to reestablish an elephant population. In normal elephant societies, mature bulls keep the younger males in line and somehow regulate the onset and length of the youngsters' musth. There were no mature bulls in Pilanesberg, and in their absence, several young males went into musth at younger ages and for longer periods of time than had previously been known. Hyped up on hormones, the young bulls ran amok, attacking rhinos and, in two cases, people. Pilanesberg's angry young elephants were brought under control when several older males were transplanted from Kruger National Park. The males each found a niche in a hierarchy ruled by the older bulls, their periods of musth grew

shorter and less frequent, and the unusual attacks stopped.

For Fisher, the Pilanesberg story raises intriguing questions about the future of modern elephants, as well as the last days of the mastodon. "How long do you have once you start radically reducing population numbers," he asks, "before animal populations start to self-destruct?"

Life without ecosystem engineers

To understand how hunters armed with only Stone Age technology could drive multiple elephant species into extinction, it's important to understand the ponderous process of elephant reproduction. In the wild, African elephants bear their first calf at about age 12. In good times, when enough food and water are available, they'll birth a calf every four years. In times of drought, most females don't go into estrus at all.

"There's no need to consider any other explanation beyond direct human predation as a cause of late Pleistocene extinctions of the very largest mammals, so-called megaherbivores," says Norman

Owen-Smith, an ecologist at the University of the Witwatersrand in South Africa. He calculates that the maximum potential growth rate of an African elephant population is no more than 6.5 percent per year. "If predation losses exceed this proportion," he says, "that species is doomed if it has no refuge at low density." Owen-Smith believes this exactly describes the situation of Pleistocene elephants in Europe, the Arctic, and the Americas. The great majority of known examples of humans killing ice age megafauna involved mammoths or mastodons, even though there were plenty of smaller kinds of prey around to sustain them, as well as plant foods. Human hunting pressure did not let up as elephant numbers dwindled.

The calculus is very different for some of the less massive herbivores that vanished at the end of the Pleistocene: native American horses, for instance, and the stag-moose, an outsized deer. These creatures bred much faster and were probably more numerous than mammoths and mastodons. In theory, they should

have been able to withstand hunting pressure, as the bison and the white-tailed deer did. Owen-Smith believes that elephants went first, and with their passing, entire landscapes changed forever.

Elephants are powerful ecosystem engineers. They knock over whole trees when they feed, opening up woodlands and transforming them into savanna or shrubland. Where elephants live, habitats become open enough to support grass, and there is soon enough grass to support widespread fire, another strong force for vegetation change. Owen-Smith points out that these elephant-driven habitat characteristics benefit a range of other herbivores in Africa. In South Africa's Hluhluwe Game Reserve, populations of wildebeest, water buck, and zebra plummeted after elephants were extirpated and thick woodlands grew up.

As Owen-Smith sees it, midsized herbivores in Pleistocene America died out from a combination of human hunting and unfavorable habitat changes that followed from the demise of megaherbivores. The mammoth and the mastodon shaped a landscape of plenty that could not survive their loss.

Preventing further conflict

About 50,000 elephants survive in Asia, and an estimated 400,000 to 660,000 remain in Africa. Populations that once roamed throughout the two continents, and numbered in the millions, have suffered a wave of extirpations that must resemble those that hit mammoths and mastodons during the Pleistocene.

A 1990 ban on international trade in ivory helped limit astronomical hunting casualties among African elephants (during the 1980s about 100,000 animals were being killed per year, and 80 percent of herds were lost in some regions of Africa), but elephants are still poached. In both Africa and Asia, growing human popu-

lations are converting more and more elephant habitat into cropland. With increasing frequency, elephants are raiding crops at the edge of wildlife reserves, bringing them into a conflict with farmers that sometimes proves deadly for both sides. The ever increasing human pressures threaten the survival of the planet's last elephants.

A new study by Thure Cerling, a geophysicist and biologist at the University of Utah, uses stable isotopes of carbon and nitrogen to track the diets and the movements of elephants in the Samburu National Reserve in Kenya. Stable isotope ratios have been used by Paul Koch of the University of California–Santa Cruz and his colleagues to study the diets of fossil animals. (Mastodons, Koch found, browsed on trees and shrubs, while mammoths were grassland specialists.) The technique holds promise as a new tool that can help wildlife managers to keep modern elephants out of dangerous conflicts with people.

Low ratios of carbon 13 to carbon 12 indicate that an elephant has been eating trees and shrubs, whereas high ratios show consumption of grasses or crops like corn and millet. Ratios of nitrogen 15 to nitrogen 14 show where the animals have been foraging: Plants in dry areas like the Samburu Reserve have high ratios, and the wetter forests on Mt. Kenya have low ratios. The travels of elephants in the study were also tracked using GPS collars.

Cerling and his colleagues found that most of the elephant herd spent their time in the arid lowlands of the reserve. In the dry season, the elephants ate trees and shrubs; when new growth sprang up in the wet season, they switched to grasses. The lone exception to this pattern was a bull the researchers named Lewis. He spent the rainy seasons in the safe haven of Samburu, but in the dry seasons

he moved 40 kilometers cross-country to a forest nearly 2000 meters up on the flank of Mt. Kenya. He sheltered there during the day, making nighttime raids into the corn fields of nearby subsistence farmers.

Corn is more nutritious than forest browse, and Lewis was risking conflict with humans to get the best food, following his innate drive to keep himself buff for future musth battles with other males. "It's a high-risk, high-gain strategy," says Iain Douglas-Hamilton, a co-author of the study and founder of the Save the Elephants Foundation. "In our elephant's case, it did not pay off. Shortly after the research was done, Lewis suffered multiple gunshots, very likely a result of crop raiding. He died in the Samburu reserve a year after the study was done."

The clash between elephants and people is as old as our species—and elephants have been slowly losing the battle to survive amid a growing sea of humans for millennia.

"The best way to protect elephants," says Owen-Smith, "is to increase the space available for their movement, as is being done through the establishment of megaparks crossing political boundaries." That's a lesson that also applies to America's surviving megafauna—bison, wolves, and grizzly bears—all endangered in a time of warming climate and growing human population pressures. For all the complex arguments that focus on the tragedy of the mammoth, the take-home message seems simple: We now face our last chance to find a way to coexist with a diversity of giants.

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