PALEOECOLOGY

Mass Extinctions Pinned On Ice Age Hunters

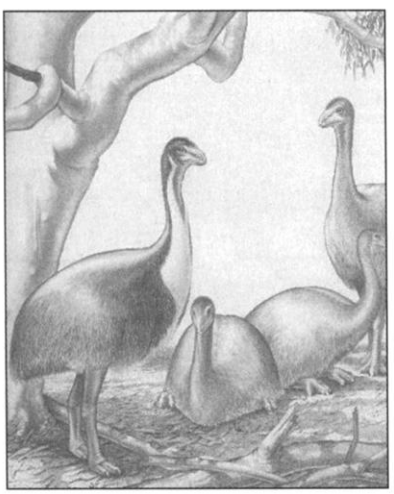
Until the late Pleistocene era, 11,000 to 50,000 years ago, big, exotic mammals and flightless birds roamed the planet. Then, suddenly, they were gone. Who killed the Pleistocene megafauna? So far the prime suspect in the prehistoric whodunit, *Homo sapiens*, has walked free, but incriminating new evidence from Australia and North America is tightening the net. If findings reported in this issue of *Science* convince the scientific jury, humans will be guilty of two counts of serial mass murder, 35,000 years apart, and rival suspects such as climate change will be off the hook.

"I think we have this problem nailed," says John Alroy, an evolutionary biologist at the University of California, Santa Barbara. On page 1893, Alroy describes a detailed computer model of North American ecology during the Pleistocene. The model, which simulates the population dynamics of humans and 41 large herbivores, shows that mass extinctions were "unavoidable" once people showed up, Alroy says.

Meanwhile, scientists led by geochronologist Richard Roberts of the University of Melbourne and mammalogist Timothy Flannery of the South Australian Museum in Adelaide claim to have settled the long-standing question of when the Antipodean megafauna disappeared. On page 1888, they identify a continent-wide extinction of large mammals and birds around 46,400 years ago—a few thousand years after people are believed to have appeared there.

"The bulk of the evidence is now clearly aligned with a human explanation for the [Australian] event," says Gifford Miller, a geochronologist at the University of Colorado, Boulder. Miller also finds Alroy's simulation a "convincing argument" that human beings had a hand in the North American extinctions.

Whatever caused them, the die-offs, like their victims, were colossal. In Australia, 28 genera and 55 species of vertebrates are estimated to have vanished—including fearsome claw-footed kangaroos that weighed in at 300 kilograms and the whopping 100-kilogram *Genyornis*, the heaviest bird ever known. Ice Age America boasted huge saber-toothed tigers, woolly bison, giant antelopes, and the woolly mammoth. By around 11,000 years ago, more than two-thirds of America's large mammals had died out.



Big bird. Flightless *Genyornis* couldn't stand up to early Australians.

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Intriguingly, all the extinctions, north and south, occurred after modern people arrived. But proving humans guilty has been a slow and hotly disputed process. Analyses of past climates, computer modeling, and conventional archaeological and paleontological studies have failed to provide conclusive evidence.

Hoping to finger a culprit, Roberts dated megafauna-bearing sediments from 28 sites across Australia. Because traditional radiocarbon dating is unreliable beyond about 40,000 years in the past, Roberts used optical and thorium-uranium methods to get ages for rocks and sediment associated with large-animal remains. Optical dating relies on the fact that electrons in buried quartz grains become excited over time to higher energies by radioactive elements in the surrounding sediments. By measuring the cumulative exposure, scientists can estimate how long ago exposure to sunlight last reset the quartz clock to zero—and thus when remains were buried. Thorium-uranium dating provides the date of calcite bands on the floors of caves, above and below the animals. This provides a minimum and maximum age of death. Taken together, the dates show that large animals at the sites were buried between 51,200 and 39,800 years ago, just as human beings were spreading across Australia.

Although the results are not a "smoking gun," Roberts believes they "definitely" implicate people. "If humans hadn't arrived in Australia, the megafauna would not now be extinct," he says. He and Miller think the lethal blow was indirect. Aborigines, they believe, changed vegetation by firing the landscape, possibly to make hunting and traveling easier. The result was less food for big browsing animals, and hunting and climate fluctuations may then have tipped them to oblivion.

In North America, by contrast, hunters may have been in the thick of the faunicidal fray. That's the idea behind the "blitzkrieg" hypothesis that geoscientist Paul Martin of the University of Arizona, Tucson, proposed in 1967. Martin reasoned that early hunter-gatherers followed their prey across the top of Asia to North America, and then south into the heart of the continent. Hungry hunters caused local extinctions, which ultimately drove total populations down the slippery slope to extinction.

To test Martin's ideas, Alroy programmed a computer to run a large-scale simulation of virtual hunters moving into virgin territory in late Pleistocene North America, starting 14,000 years ago. He included a range of parameters that let him specify how quickly the invaders traveled, how efficiently they hunted,

Doomed. Large North American herbivores such as ground sloths perished with the Pleistocene.

and how various prey species competed with one another for food. Alroy found that no matter how he adjusted the variables, mass extinctions ensued. Even the slowest, clumsiest hunters unleashed ecological devastation. Hardest hit were large animals, whose slow growth rates and long gestation periods made it difficult for them to bounce back once their populations slumped.

Not everyone is convinced. At the American Museum of Natural History in New York City, biologists Ross MacPhee and Alex Greenwood blast Alroy's model, because they say overkill can't explain why extinctions stopped 10,000 years ago, when the Pleistocene gave way to the modern Holocene era. If hunters were wiping out species tens of thousands of years ago, MacPhee says, "they should be just as bad through the Holocene." Instead, he and Greenwood suspect that the huge animals succumbed to a "hyperdisease"—a highly contagious, lethal virus introduced by human newcomers. But Alroy counters that MacPhee misses the model's main point: showing that the late Pleistocene extinctions could have occurred even without climate change.

If the two studies hold up, they carry a contemporary message, Alroy says: "The results show how much havoc our species can cause, without anyone at the time having the slightest idea of what is going on, much less any intention of causing harm."

—LEIGH DAYTON

Leigh Dayton writes from Sydney, Australia.