Scientists peg Anthropocene to first farmers

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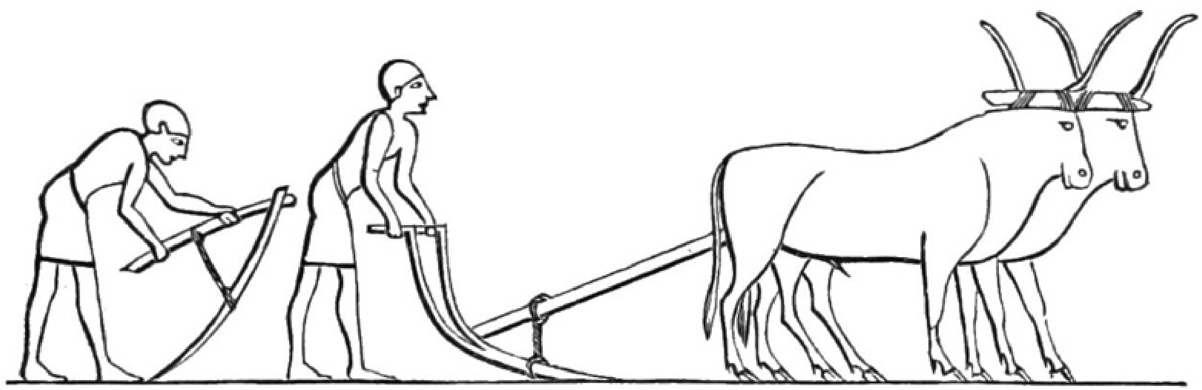

When did human domination of the planet start? A new study in the journal Nature reports a dramatic shift in one of the rules of nature about 6,000 years ago—connected to growing human populations and the rise of farming. UVM's Nick Gotelli used his world-leading expertise on ecological statistics to find the pattern. Credit: Wikimedia Commons

A new analysis of the fossil record shows that a deep pattern in nature remained the same for 300 million years. Then, 6,000 years ago, the pattern was disrupted—at about the same time that agriculture spread across North America.

"When early humans started farming and became dominant in the terrestrial landscape, we see this dramatic restructuring of plant and animal communities," said University of Vermont biologist Nicholas Gotelli, an expert on statistics and the senior author on the new study.

In the hunt for the beginning of the much-debated "Anthropocene"—a supposed new geologic era defined by human influence of the planet—the new research suggests a need to look back farther in time than the arrival of human-caused climate change, atomic weapons, urbanization or the industrial revolution.

"This tells us that humans have been having a massive effect on the environment for a very long time," said S. Kathleen Lyons, a paleobiologist at the Smithsonian's National Museum of Natural History who led the new research.

The study was published Dec. 16 in the journal *Nature*.

Species split

Gotelli and Lyons were part of a team of 29 scientists, supported by the National Science Foundation, who studied plant and animal datasets from both modern ecosystems and the fossil record stretching back to the Carboniferous Period, well before the emergence of the dinosaurs.

Examining thousands of pairs of species, the scientists looked to see how often a particular pair of plant or animal species was found within the same community. Analyses of modern communities of plants and animals have shown that, for most pairs of species, the presence of one species within a community does not influence whether the other is present or absent. "We don't expect much interaction between, say, a woodpecker and an earthworm," Gotelli explains.

But some pairs of species appear to be "aggregated," meaning they tend to appear together in nature more often than one would expect by chance—like cheetahs and giraffes who both depend on savannah habitats. Other species are "segregated," meaning that when one is found, it's unlikely to find the other there too—"say two species of woodpecker that compete for insect prey," Gotelli says—being driven apart by, perhaps, different habitat needs or fierce competition, so that they occur together less often than would be expected by chance.

For modern communities of plants and animals, recent studies show that segregated species pairs are more common than aggregated ones. But when the team investigated the composition of ancient communities using data from fossils, they were surprised to find the opposite pattern: from 307 million years ago to about 6,000 years ago, there was a higher frequency of aggregated species pairs. Then, from 6,000 years ago to the present, the pattern shifted to a predominance of segregated species pairs. An ancient rule had changed.

Humans were here

"We don't have direct evidence to show that this pattern change was caused by humans," Gotelli cautions, but the indirect evidence is compelling. The team's statistical analyses considered nearly 358,896 pairs of organisms in 80 plant or mammal communities on different continents, with data sets that collectively covered the last 300 million years of earth history—including data sets that spanned the huge Permian-Triassic extinction (the "Great Dying" 252 million years ago), the Cretaceous-Paleogene extinction of the dinosaurs (66 million years ago), and a period of rapid global climate change around 56 million years ago.

The pattern of aggregated species occurrences remained the same across these massive disturbances and time spans, but then a dramatically new pattern started emerging about 6,000 years ago, during the great Neolithic revolution when humans developed agriculture and their populations grew and spread globally. From this time until the present, plant and animal communities exhibit less co-occurrence and a greater frequency of segregated species pairs.

The scientists explored—and eliminated—many possible reasons for why this new pattern appeared, including several kinds of statistical and sampling artifacts that might explain the shift they saw in the data. For example, Earth's climate became much more variable during modern times, and the team wondered whether this might explain the shift. But when they tracked climactic trends that occurred during the periods represented by their fossils, using data obtained from ancient ice and deep-sea cores, they found no evidence that ancient climate variability was responsible for the change in co-occurrence patterns.

"So we're left with human impacts," Lyons said. "We think it's something that humans do that causes barriers to dispersal for both plant and animal species." That idea is supported by data from modern island communities of plants and animals, which show even fewer co-occurring pairs than modern mainland communities. Island data sets, the authors note, are an extreme example of this phenomenon.

"If human activity has caused the terrestrial landscape to become more island-like, more fragmented," Gotelli said, "that would be consistent with this pattern of more segregated species pairs."

Difficult dispersal

Around the time these patterns changed, humans were becoming increasingly dependent on agriculture—a cultural shift that physically altered the environment and would have introduced new barriers to dispersal of plants and animals. Even during the initial development of agriculture and expansion of human populations, the scientists could detect a shift in the structure of species co-occurrence, perhaps suggesting that species were not able to migrate as easily as they did for the previous 300 million years.

"The pattern of co-occurring species remained stable through the evolution of land organisms from the earliest tetrapods through dinosaurs, flowering plants and mammals," said Anna K. Behrensmeyer, a paleobiologist with the Smithsonian's Museum of Natural History and a co-author of the study. "This pattern didn't change because of previous mass extinctions or ancient climate variability, but instead, early human activities 6,000 years ago suddenly began resetting a basic property of natural communities."

Climate considerations

And this change in an ancient natural pattern may have implications for modern conservation. "Isolating species has consequences—it can catalyze evolutionary change over hundreds of thousands to millions of years," Behrensmeyer said, "but it also makes species more vulnerable to extinction."

"We humans have influenced the landscape, but perhaps for a lot longer than we had previously recognized," says Gotelli, a professor in UVM's biology department. "When we look at landscapes and say, 'this is pristine or unaltered,' that's not necessarily true. We may have changed the rules over a much larger scale than we appreciate."

Modern human-driven forces, like climate change and pollution, are "orders of magnitude more destructive than what early humans were doing," Lyons said, but even at the dawn of human civilizations, people were certainly having major—and unprecedented—ecological impacts, she said. "If we are thinking about how we're going to restore ecosystems, or how they're going to respond to climate change," UVM's Gotelli said, "we need to understand how they were organized before humans ever came on the scene."

More information: S. Kathleen Lyons et al. Holocene shifts in the assembly of plant and animal communities implicate human impacts, *Nature* (2015). DOI: 10.1038/nature16447

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