COMPUTER, COMPUTATIONAL, AND STATISTICAL SCIENCES

Impact of the loss of large mammalian herbivores on the global methane cycle

Researchers have found that the massive loss of large herbivores during two historical events and the terminal Pleistocene extinction of megafauna have led to detectable changes in the atmospheric concentration of methane, a greenhouse gas. Examining the consequences of these earlier events yields insights into contemporary ecosystem function. ***Proceedings of the National Academy of Sciences*** published the work in the journal's special feature on Megafauna in the Earth System.

Figure 4. Artist's depiction of the late Pleistocene landscape with some of the megaherbivores that became extinct. Credit: Karen Carr

Herbivorous mammals contribute methane to the atmosphere as a by-product of anaerobic digestion of plant material, with most of the gas released as burps. Although methane is approximately 200 times less abundant than carbon dioxide in the atmosphere, the greater efficiency of methane in trapping radiation and its reaction with other gases leads to a significant role in the radiative forcing of climate. Today, livestock are major contributors to the atmospheric methane budget, with as much as 85% of methane in countries such as New Zealand coming from this source. In the United States, about a third of anthropogenic methane output comes from livestock.

Wild animals are not normally considered important in global methane inventories, and their role in ecosystem function remains poorly characterized. Moreover, most large mammals are endangered or vulnerable across the globe. The team determined a potential decrease in methane production as a result in the decline of large herbivores. The scientists examined three time periods where large-scale losses of megaherbivores occurred: 1) the African rinderpest (cattle plague) epizootic of the 1890s that wiped out tens of millions of herbivores, 2) the massive extermination of more than 30 million Great Plains bison in the 1860s, and 3) the terminal Pleistocene extinction of more than 1 billion megafauna approximately 13,500 years ago. The authors used a series of mathematical relationships between body size, population density, geographic range, and methane production to estimate the impacts of the large-scale loss of mammals on the global methane budget. The scientists compared their calculations of tropospheric inputs from herbivores with methane concentrations derived from ice cores and other sources.

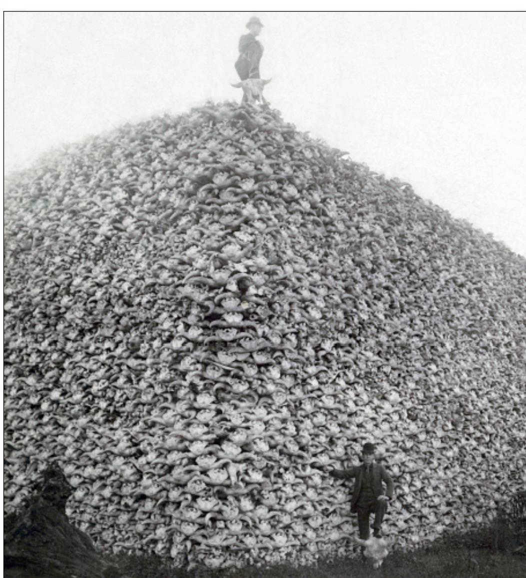

Photo. A massive pile of American bison skulls resulting from harvesting circa 1870.

The results give clues to the striking influence that large mammals can have on ecosystems and global processes such as climate. The methane record is not resolved finely enough to examine historical events directly. However, ice cores indicated an abrupt drop in methane concentrations immediately following the megafauna extinction in the late Pleistocene, and the isotope signature of methane transitioned abruptly from one largely produced by mammals to a system dominated by boreal and tropical wetlands. The team used a simple atmospheric model to estimate that the late Pleistocene megafauna extinction and associated surface albedo alterations from mammoth-mediated vegetation changes may have led to a global temperature decrease by as much as 0.5° C. The authors suggest that the integrated effects of the late Pleistocene extinction approximate the magnitude of anthropogenic climate change over the last century.

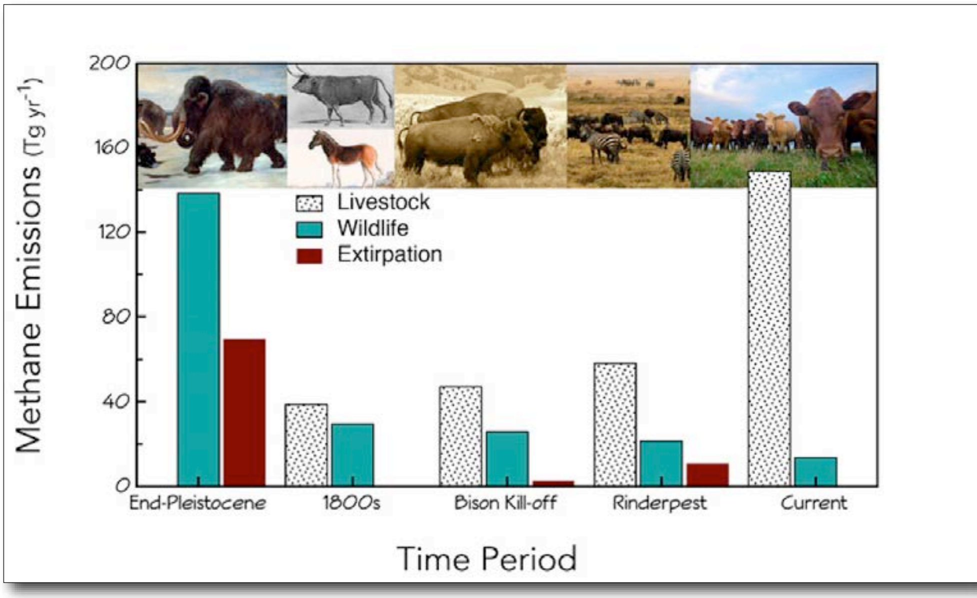

Figure 5. Enteric methane emissions by wild (*teal*) and domestic (*spotted*) herbivores. Red color indicates the reduction in methane emissions resulting from extinctions or extirpation of animals. The rinderpest epizootic epidemic affected both domestic and wild animal sectors. Emissions by domestic animals outpaced wild mammals just before 1800 AD.

The authors' quantitative approach yields unique insights into the role of wild mammals on global biogeochemical cycles over the historic and ancient past and contemporary ecosystem function. The findings demonstrate that wild mammals are a significant source pool of enteric emissions and should be included in the Intergovernmental Panel on Climate Change (IPCC) inventories. The methane emissions are just one aspect of the megaherbivores' influence on biogeochemical cycling. In the absence of heavy grazing by animals, water tables can rise, leading to a slowdown in the rate of nutrient breakdown and recycling, an increase in organic matter accumulation, and a decrease in soil fertility. Selective foraging can also lead to shifts in vegetation structure and composition, which in turn can influence the albedo of the landscape and result in changing heat absorption and reflectivity. The findings underscore the importance of large mammals in regulating ecosystems and feedbacks on climate.

The authors also conclude that humans have been influencing biogeochemical cycling longer and in more complicated ways than previously thought. For example, outbreaks of rinderpest have followed invading armies throughout much of human history. Thus, the long-term cumulative impact of rinderpest may be considerable. Their research shows that the mass removal of millions of mammals can have consequences on global processes and that the specific impacts are dependent on the physiology and ecology of those organisms.

Science Highlights (11-25-15)

Reference: "Exploring the Influence of Ancient and Historic Megaherbivore Extirpations on the Global Methane Budget," ***Proceedings of the National Academy of Sciences***, published online ahead of print (2015); doi: 10.1073/pnas.1502547112. Authors: Felisa A. Smith, John I. Hammond, Meghan A. Balk, Melissa I. Pardi, Catalina P. Tomé, and Marie L. Westover (University of New Mexico); Scott M. Elliott (Computational Physics and Methods, CCS-2), S. Kathleen Lyons and Peter J. Wagner (Smithsonian Institution).

The research supports the Lab's Global Security mission area and the Science of Signatures science pillar through the study of the impact of animal populations on a greenhouse gas and the potential resulting climate change. Technical contact: *Scott Elliott*