To what extent can humans be blamed for the end-Pleistocene mass extinction of the megafauna?

By Tiegan Hannah Ansell, University of Durham

Abstract

The end-Pleistocene mass extinction is an event at the boundary of the Pleistocene and Holocene that killed the majority of animals larger than 44kg (megafauna). The possible causes of this event include humans as invading species/predators, climate change and a potential asteroid impact. This article concludes that humans appear to have had a significant role in this event, in tandem with climatic changes.

1. Introduction

The end-Pleistocene mass extinction was a taxonomically selective (Gill *et al.*, 2009) event that killed 73% of large herbivore species (Alroy, 2001), resulting in the loss of 50% of all mammal species over 32 kg, and all species over 1,000 kg (Gill *et al.*, 2009). Megafauna are defined as animals greater than 44 kg in weight (Barnosky *et al.*, 2004), and their disappearance at the boundary between the Pleistocene and Holocene has been theorised to have been due to several factors. These include the arrival of humans as an invading species and predator (Alroy, 2001; Diamond, 1989), natural climatic change (Barnosky *et al.*, 2004), and an asteroid impact (Firestone *et al.*, 2007; Benton and Twitchett, 2003) or natural competition. This essay will assess the extent to which human actions were responsible for this event, and at which scales, spatially and temporally.

2. The role of humans in the end-Pleistocene mass extinction

Humans are thought to have influenced the mass extinction (ME) in two main ways: Blitzkrieg (overkilling of prey species) and sitzkrieg (inducing fire, habitat fragmentation and the introduction of disease and exotic species), though blitzkrieg is presented as the main player (Barnosky *et al.*, 2004). The most convincing indicator that humans had a significant role in this event is that many species were thought to have gone extinct around the same time that humans arrived in the area (Barnosky, 1986), and human arrival has always preceded a mass extinction in island biota (Diamond, 1989). For example, the demise of New Zealand's moas (large flightless birds, similar to an emu) coincided with the Maori colonisation around 1,000AD. 100,000 moa skulls have been found in archaeological butchering sites and Maori ovens. Dating puts the Moas extinction within 500 years of human arrival (Diamond, 1989), suggesting blitzkrieg was the most likely cause of their extinction. Blitzkrieg's efficacy in causing ME depends on the human population's hunting ability: higher abilities can support more humans resulting in greater proportions of prey species being killed (Alroy, 2001). Megafauna were preferentially targeted by humans, with ~28 people per $100km^2$ predicted to be receiving ~30% of their calorific intake from large animals

(Barnosky *et al.*, 2004), because killing larger animals resulted in more food, so less hunting was necessary to sustain the population than if they were living on smaller animals alone.

Dating and archaeological evidence demonstrate an overlap between humans and megafauna of 1,200 years in North America, with the earliest Clovis artefacts (remnants of tools belonging to the earliest known ancestors of Native Americans – (Waters and Stafford, 2007)) found at 13,400 years before present – BP – and the first megafaunal species apparently becoming extinct at 12,260 years BP. This shows that the blitzkrieg, if it was the cause, was not instantaneous, and that the extinction may have occurred in three distinct waves with most true megafauna became extinct in the 1,200 years of the first two (Alroy, 2001).

The only megafaunal survivors of the ME in Australia, Eurasia, the Americas and Madagascar were slow breeding, nocturnal and lived deep in forests (Barnosky *et al.,* 2004), which supports the blitzkrieg hypothesis, since it is harder and less convenient to hunt nocturnal animals and those protected by large canopies. Had this been a climatic event, the expectation is that all animals, regardless of the time of day that they were active, would have been affected equally. This counters the common argument against blitzkrieg that it should have been complete as some large herbivores did survive (Alroy, 2001), likely being those in the forests.

Mammoths are one of the most recognised species to have gone extinct during this period, with overkill and habitat modification/fragmentation cited to be the main drivers of their extinction (Cooper *et al.*, 2015), particularly in North America. This is evident in butchered mammoth remains found in southeast Wisconsin, showing humans were active there between 14.8-14.1ky ago (Gill *et al.*, 2009), at around the estimated time of mammoth extinction. It is likely that growing areas of human occupation contributed to their extinction through hunting and interrupting their subpopulation connectivity by inhibiting them from moving between areas of high-quality resources needed for survival (Cooper *et al.*, 2015). In Eurasia, however, mammoths were less severely affected by humans, experiencing a five to tenfold increase in population size between 34ky-19ky BP, 10,000 years after the first human contact (Lorenzen *et al.*, 2011). This contradicts the blitzkrieg hypothesis as humans clearly hunted mammoths without causing them to go extinct. Mammoth remains are found in 40% of all European Palaeolithic sites (Lorenzen *et al.*, 2011). This is likely due to the co-evolution of humans and mammoths (Barnosky *et al.*, 2004). Despite this, there are indicators that humans must have significantly altered their ability to survive (Cooper *et al.*, 2015) such as a lack of evidence for large-scale ecological regime shifts during earlier climatic changes in the last glacial, and no extinction events during previous recent glacials. It is therefore likely that humans had a role in the extinction of mammoths, albeit a less pronounced one in Europe.

Humans may have altered the environment enough to inhibit the survival of the mammoth in Europe outside of overkill through the effects of sitzkrieg. Utilisation of the vegetation (e.g. for construction, food and clearance) could have triggered a multitude of ecological changes owing to eventual collapse. For example, the intensification of fire regimes would remove necessary food sources for the mammoth, leading to its extinction in this region (Gill *et al.*, 2009). This also explains an issue with the overkill hypothesis in that there are no recorded kill sites for 33 genera of extinct mammals, like camels and sloths (Diamond, 1989); they were more likely victims of sitzkrieg. This may also have included the introduction of new species, such as cats and rats, which have been known to cause extinctions of huge birds, as the naïve native species would not have evolved any behavioural defences against the introduced species (Diamond, 1989). Thus, it currently appears that humans have played a very significant role in the end-Pleistocene ME, both directly (via hunting (Alroy, 2001) and overkill (Barnosky *et al*., 2004)) and indirectly (by introducing predatory species and changing land use (Gill *et al*., 2009).

3. The role of climate change in the end-Pleistocene mass extinction

Climate appears to be a significant driver of this ME event as the proportion of species that went extinct was greatest on the continents with the most dramatic climate change (Lorenzen *et al.*, 2011), and appears to have been the sole cause of several species' extinction, like the European musk ox (which had no distribution overlap with Palaeolithic humans and was found in just 1% of European archaeological sites (Lorenzen *et al.*, 2011)).

Another example is the Irish Elk (Barnosky, 1986). Humans were only present in Ireland from 9,000 years BP, whilst the Irish Elk went extinct at 10.6kyr BP during a recorded major climatic change between 10-11kyr BP (Barnosky, 1986). Clearly, humans cannot be blamed for this extinction, challenging the earlier conclusion of humans being a main driver, as there is no overlap between humans and Elk in Ireland. Instead, the climate switch during the Midlandian Glacial and Woodgrange Interstadial resulted in the demise of the Elk, since they only appear in the top of the second lithologic layer of the Ballybetagh Bog. As the lithology changes between layer 2 and 3, the Elk remains disappear (Barnosky, 1986). The onsets of interstadials are the most rapid and extreme changes in the late Pleistocene record, causing abrupt shifts in temperature and precipitation patterns (Cooper *et al.*, 2015), and are likely to have reduced the Elk's ability to survive by disrupting the vegetation, removing their food source. This is mirrored in other areas of western Europe, where humans were present from 44kyr BP and yet the distribution, range and taxonomy of the species present only changed with the onset of interstadials (Cooper *et al.*, 2015). Interstadial climate change explains the discrepancy of the woolly mammoth extinction timings, having gone extinct later in Europe than the Americas despite longer exposure to hunting in Europe. Although mammoths seemed to have been able to tolerate hunting pressure in Europe, the addition of the new climate regime would have been enough to create a trophic cascade of disrupted taxa resulting in ecological collapse and conditions incompatible with mammoth (and other megafaunal) life.

Climate alone does not explain why the extinctions happened in each area after human colonisation, but not in areas experiencing similar climatic changes that were yet to see human infiltration (Diamond, 1989). Whilst it is important to note the different dynamics of each environment mentioned may have had a role (e.g. island vs continent) – it is more likely that the paired stressors of climate change and human hunting caused the ME, since previous climate shifts have not had the same detrimental effect on megafauna. For example, 15 species became extinct during the Younger Dryas (YD) cold period, but similar cooling events have occurred in the last 80kyr without producing a ME (Firestone *et al.*, 2007). Clovis populations were observed in North America between 11.4-10.8ky BP (Barnosky *et al.*, 2004), coincident with the YD, and with the extinction of some megafaunal species – it is likely that the introduction of humans at a time of climate stress led to the species reaching its ecological tipping point and succumbing to extinction. Climate reduced the range of megafauna, placing them and humans in the same area, and limiting their ability to seek refuge from human actions (Barnosky *et al.*, 2004).

4. Alternative explanations for the end-Pleistocene mass extinction

Some events cannot be explained by either climate or human influence, implying causes not yet known. This is evident in the Australian extinction pulse, when 12 genera went extinct before 80kyr BP, pre-dating both the arrival of humans (at 71.5-44.2kyr BP) and the climate change of the last glacial maximum (Barnosky *et al.,* 2004). This may be the expression of natural competition for food (particularly with introduced species), as herbivores typically share food sources with many other species (Alroy, 2001), or the result of an extra-terrestrial (ET) impact, either killing the megafauna directly or destabilising the Laurentide Ice Sheet causing the observed Younger Dryas cooling. Proposed evidence for this includes a carbon rich black layer covering 50 Clovis sites containing Iridium (an element precipitated by space) and fullerenes containing ET Helium (Firestone *et al.*, 2007). This evidence, however, is weaker than that already proposed for the impact of either humans or climate, particularly with the progressive decline of some species prior to the actual ME ruling out such a sudden impact (Gill *et al.*, 2009). An ET collision was also proposed as the cause of a previous mass extinction event, the end-Permian, which resulted in a loss of 95% of all genera (Benton, 2003), but this was also later debunked due to a lack of available evidence. The end-Permian ME has been deduced to have been the result of mass volcanism from the Siberian Traps, where 2 million km^2 of basaltic lava covered 1.5 million km^2 of Eastern Russia to a depth of 400-3,000m in less than a millennium (Benton and Twitchett, 2003). Whether the extinction was the direct result of the volcanism, or the resultant runaway greenhouse atmospheric event (global warming of 6 degrees due to the release of methane gas hydrate) remains uncertain (Benton and Twitchett, 2003), but it does indicate that climate may have a larger role in MEs than previously thought, lending itself to the conclusion that the end-Pleistocene event is unlikely to have been entirely the fault of humans.

5. Conclusions

In conclusion, humans shoulder a lot of the responsibility for the end-Pleistocene ME of megafauna due to blitzkrieg and sitzkrieg; however, the damage done by humans would be considerably less were it not for the interplay with climate. Humans had the least impact during the Australian extinction pulse, prior to 80kyr, and yet there is insufficient evidence for a climatic cause, showing that there are other mechanisms yet to be explored. Human responsibility, where they were present, also appears to be species, and by extension spatially, specific. Humans had the greatest impact in North America on the mammoth population 14kyr BP; however it appears that, of the given sources, humans had the least impact in Europe, instead coexisting with the mammoth, potentially indicating that they were better able to adapt to change and cohabit than their North American counterparts. It could therefore be argued that climate had a greater impact in Europe, particularly with reference to the Irish Elk, whose extinction 11kyr BP is attributable to climate prior to human habitation. It is difficult to accurately quantify how far humans should be responsible for the event, but, of the contributing factors described, they had the biggest influence on overall outcomes within the sources used, based on palaeo-environmental evidence showing species' responses to human introduction and hunting techniques.

6. References

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