**Fast climate change drives pronounced changes in species’ genetic diversity**

Species responded to past climate change by tracking suitable climatic conditions, resulting in range shifts and, in the alteration of their intraspecific genetic diversity ***{Lorenzen:2012kw, Hewitt:2004gj}***. Future climate change will likely outpace species’ tracking abilities ***{Schloss:2012gt}***, leading to further changes in genetic diversity ***{Hofreiter:2009dr}***, local extirpations (REFS, e.g. Bellard, C. et al (2012) & Parmesan, C. (2006)) and ultimately to the extinction of some species (REFS). It has been hhypothetized that stable climatic conditions drive species to stationary demographic conditions and therefore to stable levels of genetic diversity (REFS). Similarly, studies based on simulations have shown that stable ranges retain high levels of intraspecific genetic diversity. However, these studies also showed that, counterintuitively, fast range contractions better preserve species levels of genetic diversity compared to slow range contractions ***{Arenas:2012bv}***. The complex interaction among climate, range dynamics, demography and genetic diversity hinder our ability to predict species responses to future climate change. For this reason, analyses of the response of species’ genetic diversity to climate changes are of the critical importance.

Megafaunal replacements and extinctions in the Northern Hemisphere have been linked to abrupt climate changes based on Greenlandic ice core records (Cooper). Although informative, the use of extrapolated hemispheric trends contradicts recent studies showing that species with different ecological strategies experience climate change differently (Parmesan). Furthermore, a high variance in the velocity of climate change is also expected at continental scales and during the Late Quaternary (Serra-Diaz). Spatial and temporal variation in climate change velocity can be assessed now with the use of global paleoclimatic reconstructions for consecutive time bins for the last 50,000 years, the extensive fossil record and ancient DNA sequences. Which will allow us to better understand species genetic dynamics during the Late Quaternary. To our knowledge, species’ genetic responses to climate change has not before been related to the pace climate change.

Climatic fluctuations during the Late Quaternary have been characterized as occurring with different paces (Steffensen, REFS). For example, the Last Glacial Maximum was a cold but relatively stable period (Cooper –REFS). Oppositely, Younger Dryas and the Bølling-Allerød events showed substantial changes in temperature over a short period of time (Steffensen). Previous estimations of past climate change velocities have been limited to two time bins (Sandel) impeding both the comparison of periods with different velocities, and subsequently the estimation of the effect of climate velocity on species genetic diversity. Here for the first time we estimated climate change velocity for 36 time bins –from 50,000 years to present- for the Northern Hemisphere. We then used x radiocarbon-dated fossils, x ancient and x modern DNA sequences for 11 species of mammals, and tested the prediction that there is a positive correlation between the velocity of climate change and the magnitude of change in genetic diversity.

Climate change velocities experienced by Holarctic species varied across taxa. Some species showed large transitions in climate change velocity (e.g. *Mammuthus primigenius*) while other species showed relative stability during the last 50 kybp (e.g. *Crocuta crocuta*) (Fig 1). Noteworthy, *M. primigenius* and *C. antiquitatis* showed several fast changes in climate velocity in quick succession before going extinct (Fig 1), which suggest a link between the velocity of climate change and species extinctions. Patterns in species climate change velocities concord with population extirpations and extinctions previously published. For example, the extirpation of the Northeast Siberian clade of *O. moschatus*, which previously have been associated with environmental changes,occurred around 48 kybp (Campos), and our estimate for the fastest change in climate for this species was 46 kybp (Fig 1). Similarly, the fastest climate changes experienced by Bison (Fig 1: 15 to 10 kybp-) correspond with the most pronounced decline in population size estimated for this species (Drummond 2005), followed by a period of climatic stability. In general, climate change velocity was predominantly fast during Bølling-Allerød and Younger Dryas, while, contrastingly, climate stability was observed before and after these periods (Fig 1).

* Results paragraph on genetic diversity:
  + Fast changes lead to more pronounced changes in genetic diversity especially for haplotype diversity
* Discussion:
  + **It’s important to acknowledge that species are not impacted by climate changes to the same degree** 
    - Move away from solely extrapolating climate tendencies for a whole region 🡪 Spatial metrics
    - It also depends on the landscape 🡪 Buffering effect of topography
    - How species are affected likely depends on life history traits e.g. such as thermal tolerance, dispersal ability, diet breadth
    - Dispersal ability determines whether species are able to track changes
    - Will likely affect genetic diversity differently
    - Demographic instability leads to changes in genetic diversity
  + **The importance of maintaining genetic diversity** 
    - Loss of haplotypes will homogenise populations
    - Loss of adaptive potential and increased chance of inbreeding
    - Some species might benefit from changes e.g. warm-adapted species
  + **Future climate changes are different from those during the Late Quaternary**
    - Future high climate change velocities will likely outpace species’ ability to track changes
    - Fragmentation of landscape will make it more difficult for species to track changes in climate which will likely affect genetic diversity
    - Populations could become more fragmented and isolated in small habitat patches not optimal for survival, population growth and maintenance of genetic variation
  + **Climate change velocity and conservation** 
    - Protected areas might not enable species to track changes
    - The location and extent of protected areas is, more or less, constant but the location of species ranges changes
    - With a high velocity, will be conservation areas big enough to allow the moving of species to track changes?

**References:**

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