EFFECTS OF CLIMATIC AND TECTONIC PERTURBATIONS ON MAMMALIAN COMMUNITIES

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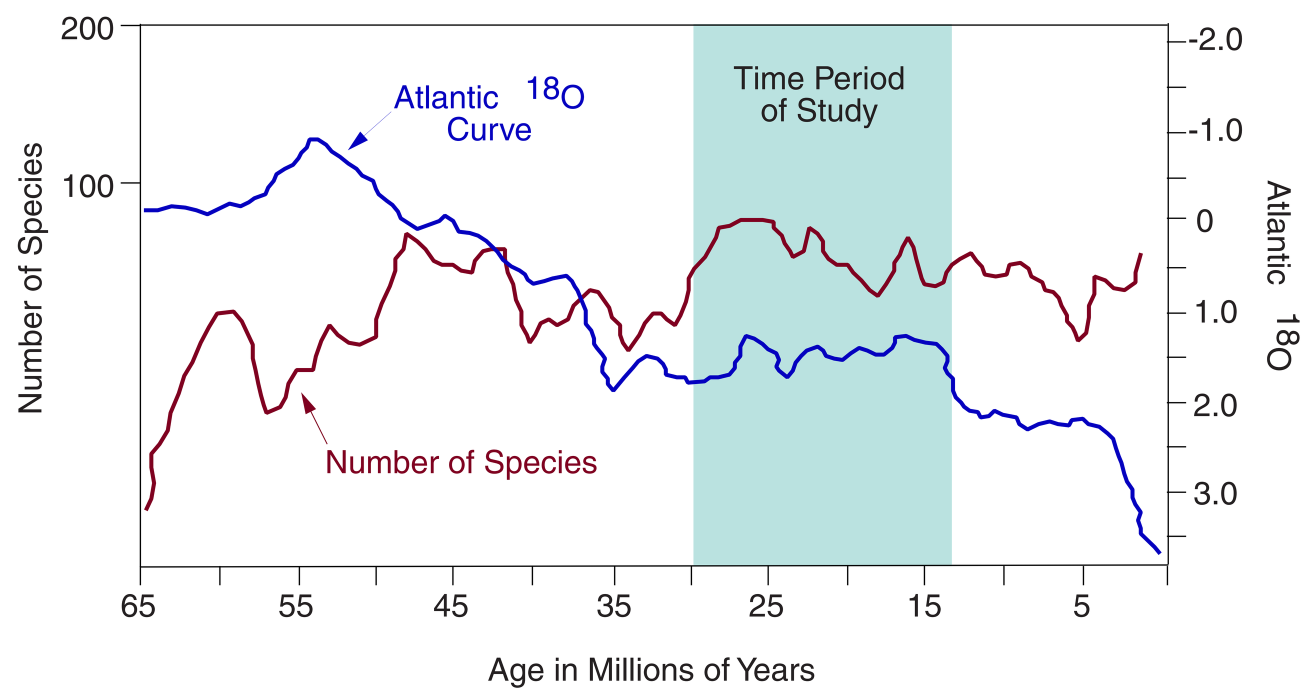
Introduction

Studies that focus on large geographic (continental) and long temporal scales (millions of years) tend to demonstrate little correlation between climate change and mammalian species turnover rates or diversity as shown below in a graph that compares the North American mammal species richness through time to the Atlantic ^{18}O curve (sources of data: Alroy, 2000, Geology 28:1024; and Miller et al., 1987, Paleoceanography2:3).



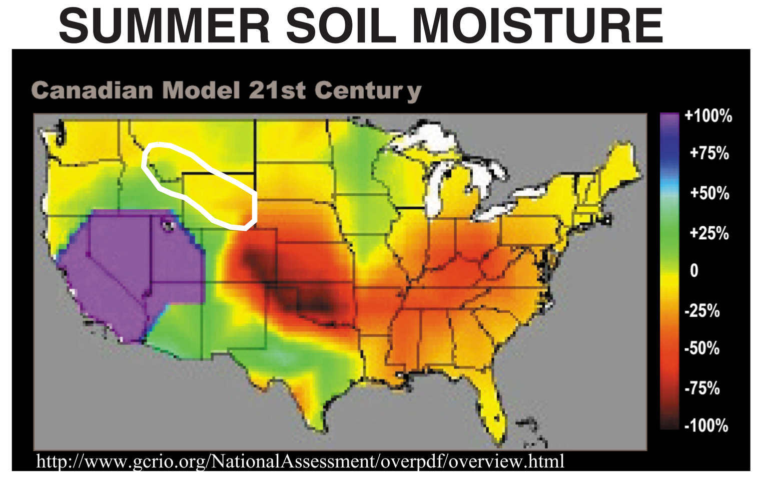
As the scales resolve to local sites over decades, centuries, or millennia, however, some species clearly appear and disappear. For example, faunal effects that have been attributed to Pleistocene climate changes in numerous studies include changes in: (1) species composition of communities, (2) biogeographic ranges of individual species, (3) relative abundance of species and individuals, (4) phenotype/genotype, and (5) extinction rates.

Study Goals and Methods

We suspect that studies that focus on too large a scale blur the effect of climate change on mammalian communities, because a given global change elicits differing local climatic responses. We also suspect that species richness by itself can be an ambiguous gauge of change in mammalian communities, in part because it is so difficult to reliably determine in paleontological samples.

We test these suppositions by examining effects of the late-early Miocene Climatic Optimum warming event on faunas of the northern U.S. Rocky Mountains. The warming event began 18.5 Ma, peaked around 17 Ma, and lasted until about 14 Ma. Thus it is of a temporal scale that characteristically demonstrates little correlation between global climate change and faunal turnover patterns. However, the geographic scale is small enough to prevent mixing of substantially different climatic zones as seen in the climate prediction model below.

SUMMER SOIL MOISTURE



This map exemplifies output from climate models that assume continued growth of world greenhouse gas emissions (source: Climate Change Impacts on the United States, U.S. Global Change Research Program). All models predict resultant global warming will change local climatic parameters to different extents. Our study area (white line) represents a region that shows a more or less uniform climate response given modern geographic constraints. While climatic patterns in the Miocene were clearly different than these, we assume that the study area also represented a uniform climatic zone then. Our lab currently is working on ways to more accurately delineate Miocene climate patterns in the western U.S.

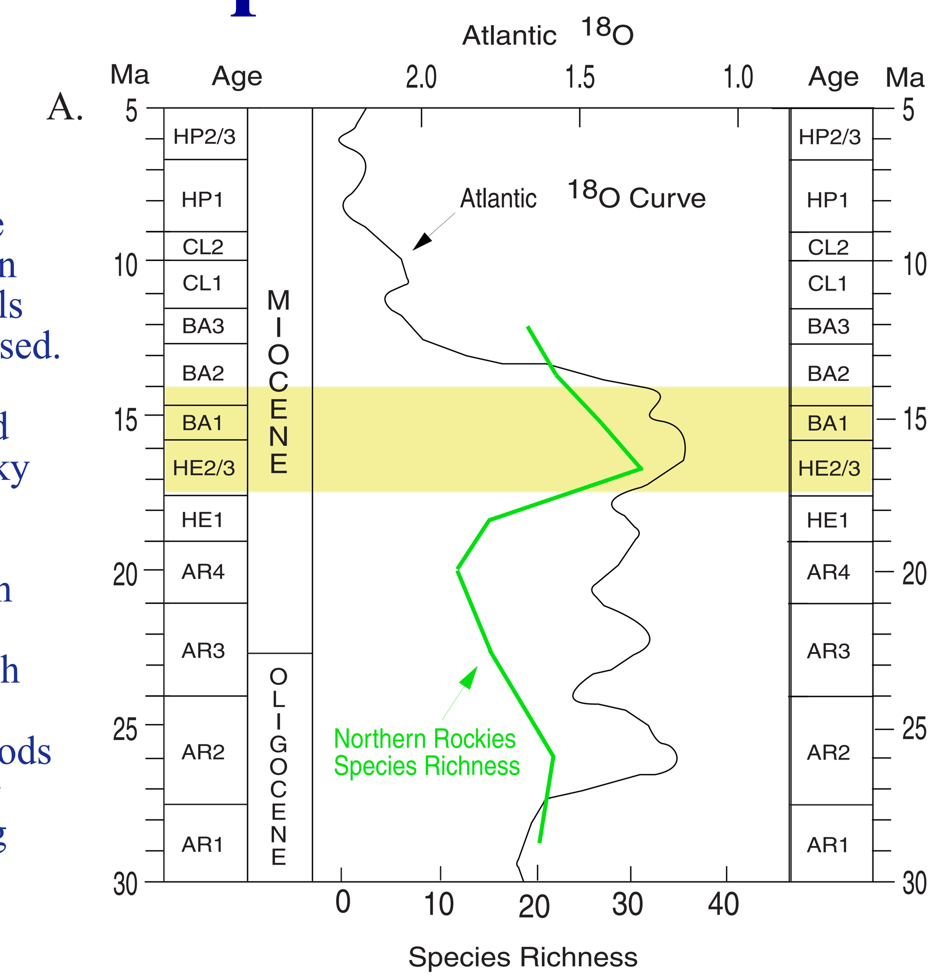
Under our MIOMAP Project, we are compiling all mammal records of Miocene age in the U.S. A Geographic Information System (ARC/INFO) and other statistical techniques are used to determine how closely species turnover patterns correlate on a region-by-region basis with the timing of the mid-Miocene Climatic Optimum and with tectonic activity in the northern Rocky Mountains and Great Basin.

Miocene Mammal Mapping Project
MIOMAP

The maps to the right indicate areas from which fossil data have been compiled and entered in the MIOMAP database. Only the northern Rocky Mountain data (Idaho, Montana, Wyoming) are analyzed in this poster. Most of the areas indicated by white dots contain multiple collecting localities. Numbers of specimens range from tens to thousands per locality. A full explanation of the MIOMAP project is available at http://ib.berkeley.edu/labs/barnosky.

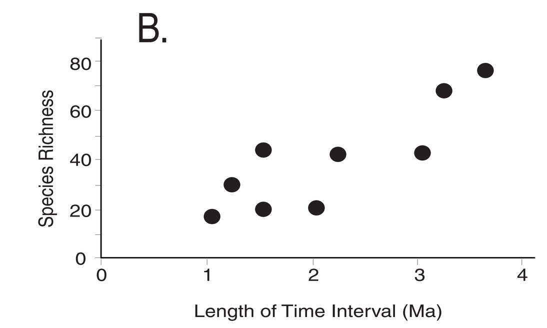
Results from the Northern Rocky Mountains

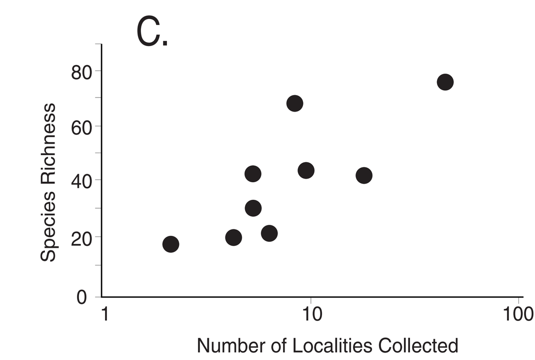
Species Richness

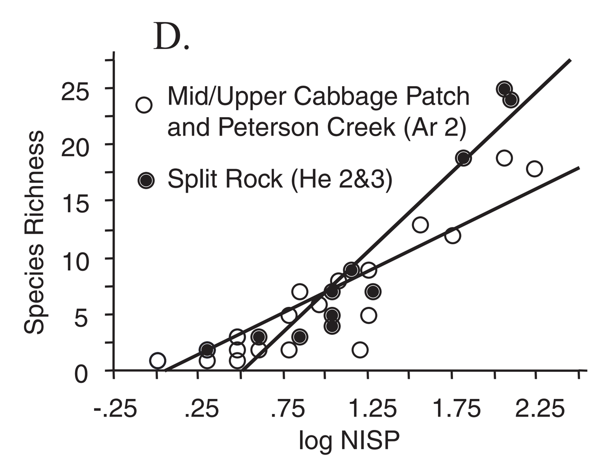


Because species richness correlates with the duration of the time interval spanned (shown in Graph B), analyses in which time intervals are standardized (Graph A) are frequently used. A comparison of the Atlantic ^{18}O curve during the Miocene to a time-standardized species richness curve for the northern Rocky Mountains suggests an increase in richness corresponds with the warming event (highlighted in yellow). However, as shown in Graph C, species richness also correlates with the number of localities sampled, which is a proxy for the number of individual specimens collected. Other analytical methods (Graphs D through I) attempt to account for such potential biases but provide conflicting results.

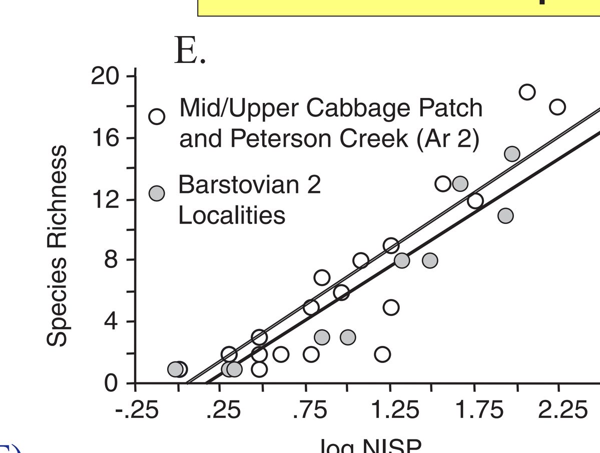
RICHNESS = Species / Interval Length

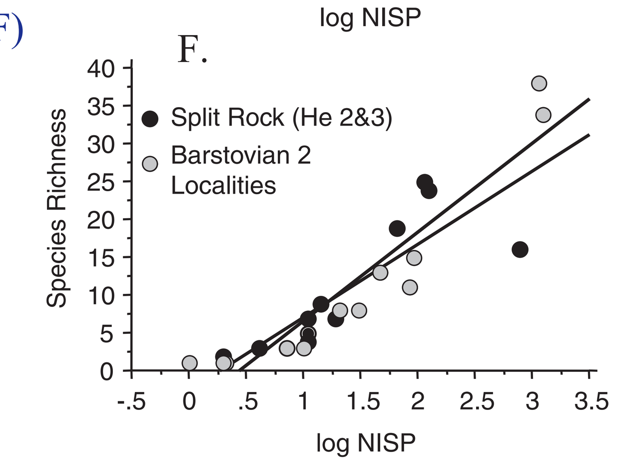




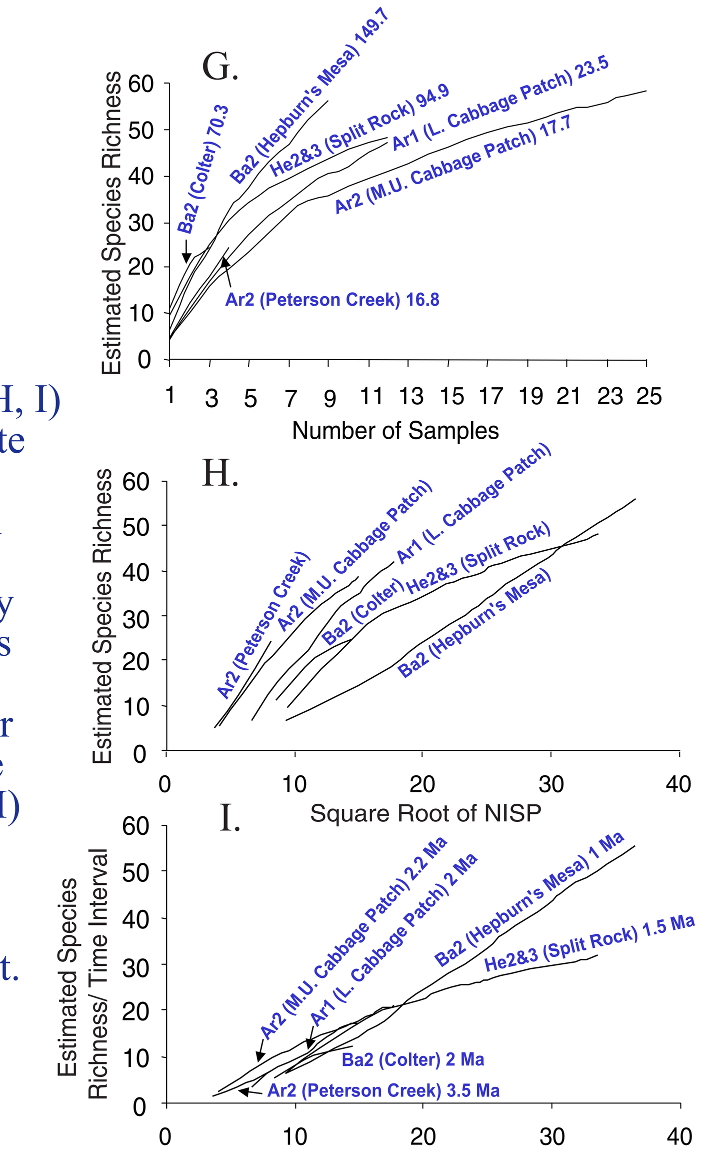


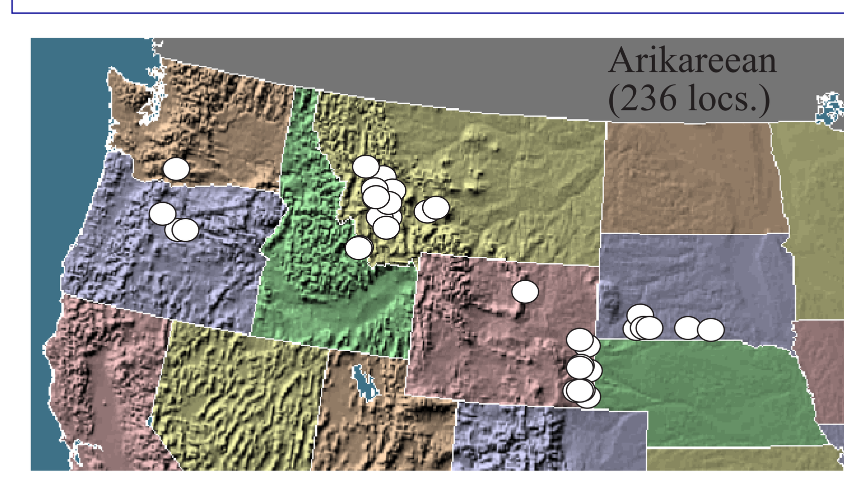
ALPHA DIVERSITY (Graphs D, E, F)
Species diversity at discrete localities may have increased coincident with the Miocene Climatic Optimum. The He2&3 localities contain the most species at sample sizes of 30 to 200 specimens. However, these point estimates are potentially subject to time and community biases.

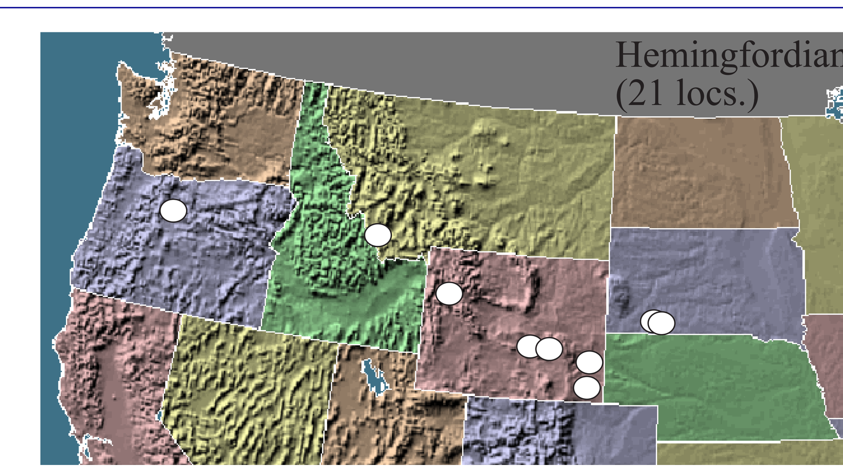


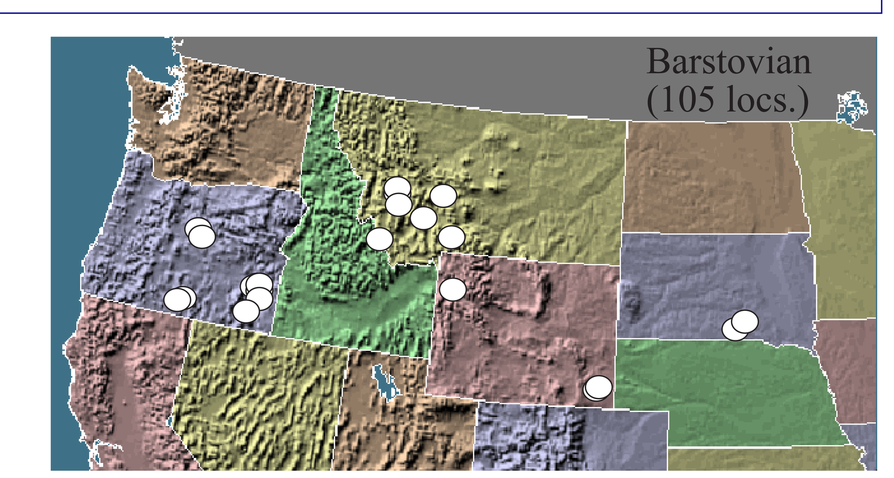


BETA DIVERSITY (Graphs G, H, I)
Bootstrap analyses that accumulate species with successive samples suggest higher species richness in He2&3 and Ba2 (Graph G); however, these results may simply be an artifact of differing numbers of individual specimens (NISP). Bootstrap analyses that control for numbers of specimens per sample and assume either equal (Graph H) or best estimate time spans (Graph I) for each collecting area suggest a decrease in species richness across the warming event. However, these analyses may be biased if different habitats were sampled.



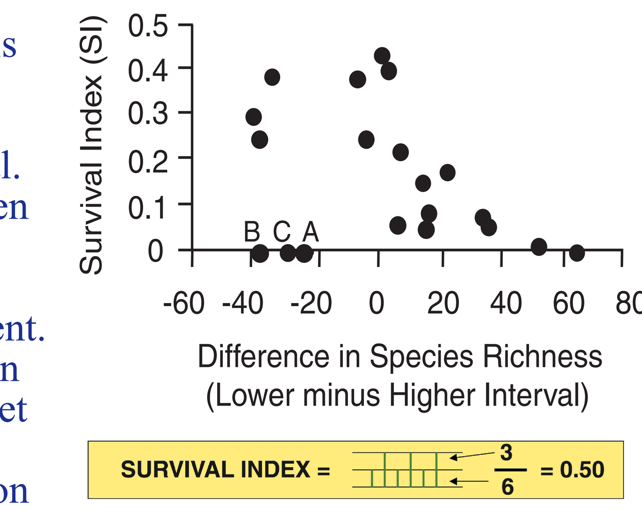




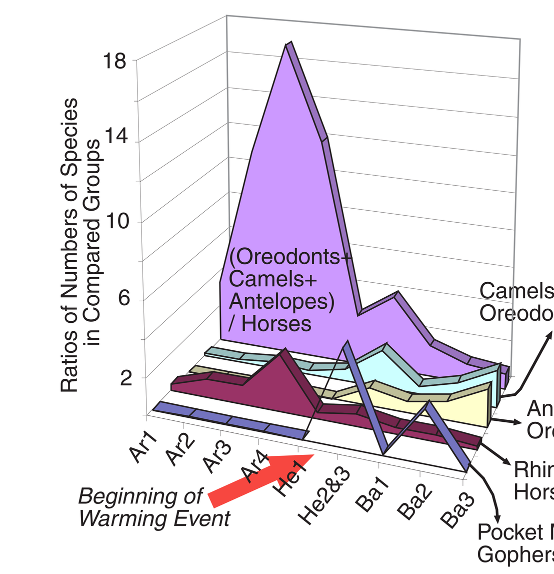


Faunal Turnover

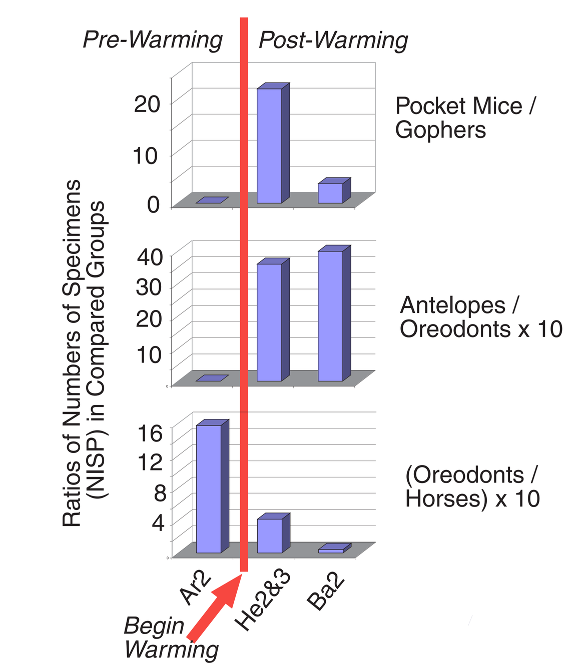
The survival index provides a crude estimate of faunal turnover and is computed as SI= (Survivors/Species Pool), where 'Survivors' is the number of species surviving across an interval boundary, and 'Species Pool' is the number of species found in the lower interval. Plotted as a function of the difference between species richness in adjacent stratigraphic intervals, anomalous SI values appear coincident with the onset of the warming event. A and B designate the points for the transition between He1 and He2&3 for the entire dataset and for the 'mountains only' dataset, respectively. C denotes the Ar1-Ar2 transition for the localities near the Wyoming-Nebraska border only.



Relative Abundance



The relative abundance of species within higher taxa (left graph) changes dramatically at the warming event. Pocket mice replace gophers. Antelopes, camels, and horses become more dominant over rhinos and oreodonts.



The available data suggest shifts in the relative abundance of individuals within species (right graph) accompanied the warming event. Numbers of identifiable specimens (NISP) overestimate actual numbers of individuals, but nevertheless provide a reliable gauge of relative abundance. Unfortunately, requisite data for the critical time intervals Ar3, Ar4, and He1 do not yet exist.

Conclusions

Within the northern Rockies coincident with the late-early Miocene Climatic Optimum:

- Alpha diversity most likely increased
- Beta diversity may have changed
- Species compositions changed dramatically
- Relative abundance of species within higher taxa shifted
- Relative abundance of individuals within species shifted

Future Work

Tectonic uplift as well as climate change characterized the study area during the Miocene Climatic Optimum. As the MIOMAP database becomes more complete, we will test hypotheses designed to tease apart the relative effects of climate change and tectonism on mammal faunas. Currently we are analyzing data we have just finished compiling for the northern Great Plains and Pacific Northwest.

Funded by
National Science Foundation
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