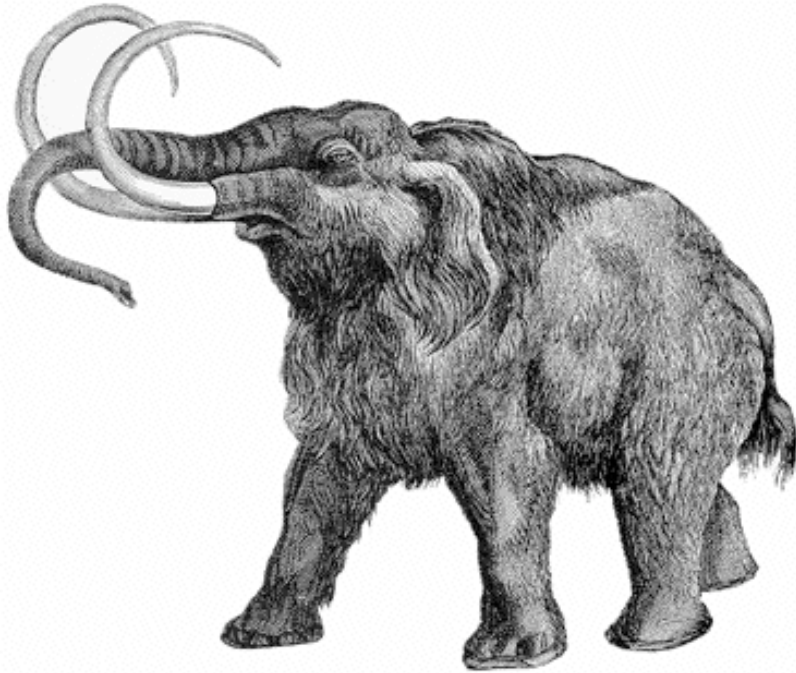


Climate Change Impacts on Ecosystem Structure: Lessons from Paleoeecology



J.L. Blois and E. A. Hadly
Department of Biological Sciences
Stanford University

How do mammals respond to environmental change?



How do mammals respond to environmental change?

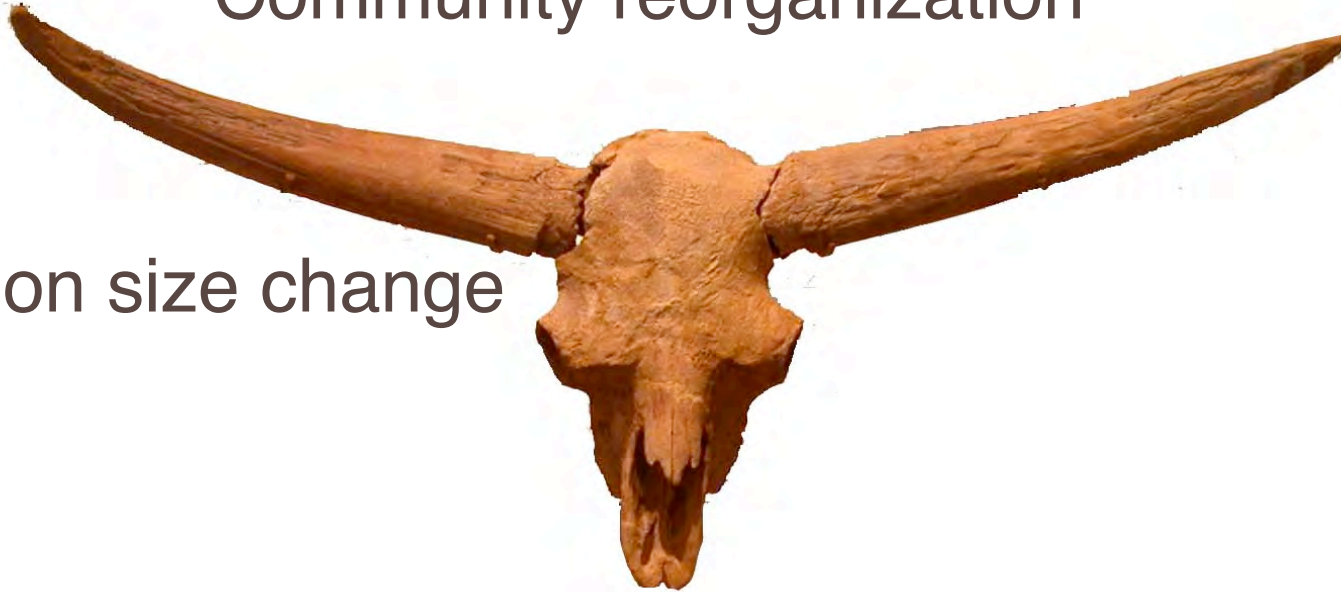
Community reorganization



How do mammals respond to environmental change?

Community reorganization

Population size change

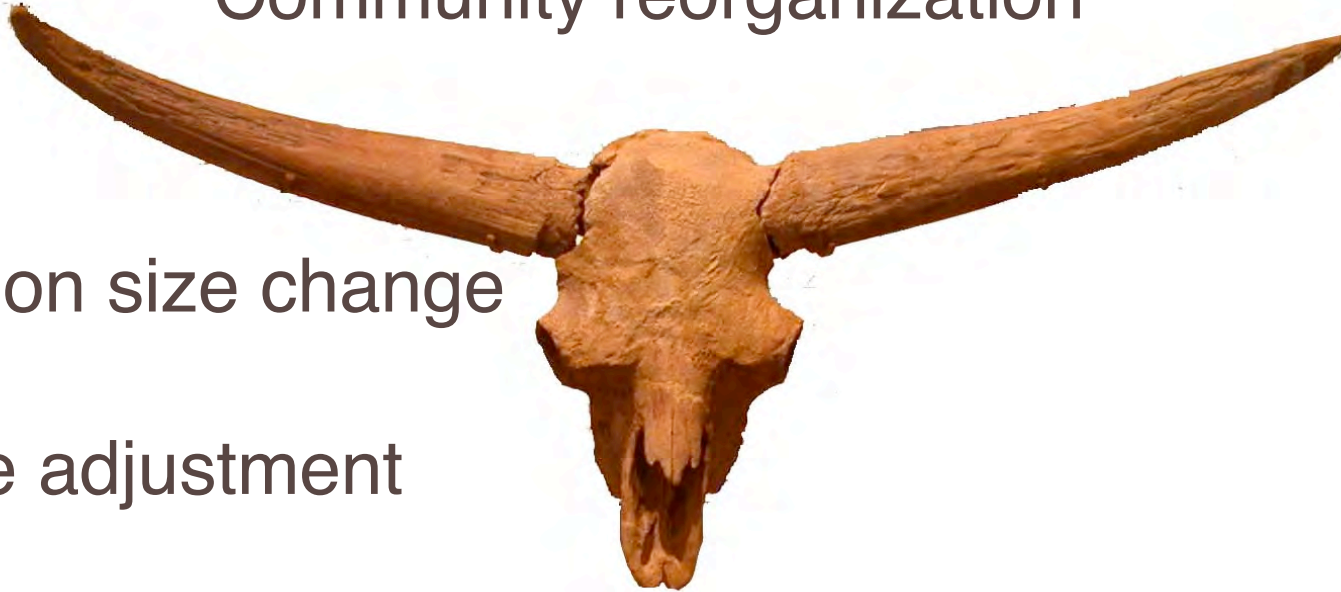


How do mammals respond to environmental change?

Community reorganization

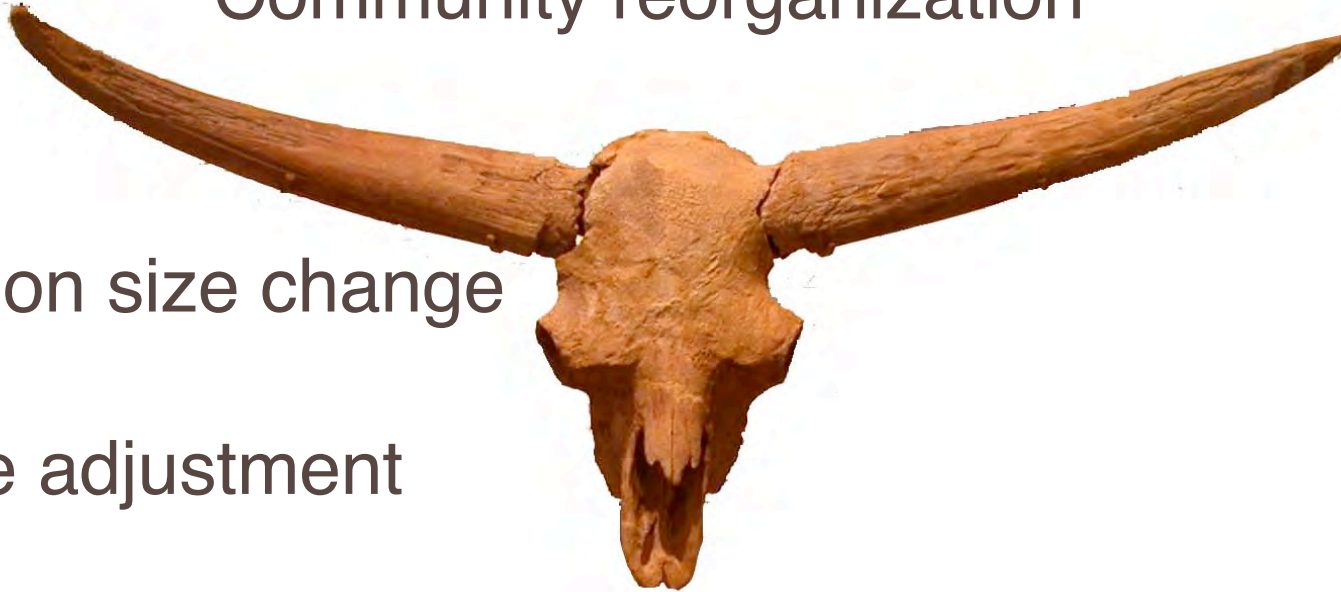
Population size change

Range adjustment



How do mammals respond to environmental change?

Community reorganization



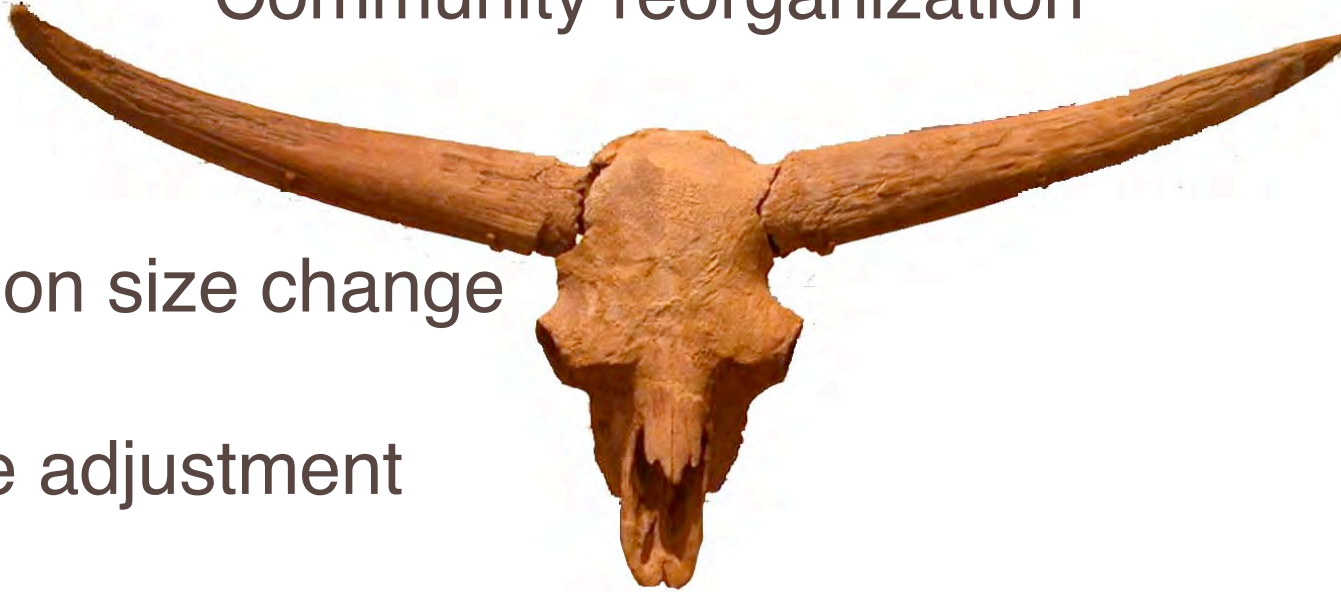
Population size change

Range adjustment

Extinction

How do mammals respond to environmental change?

Community reorganization



Population size change

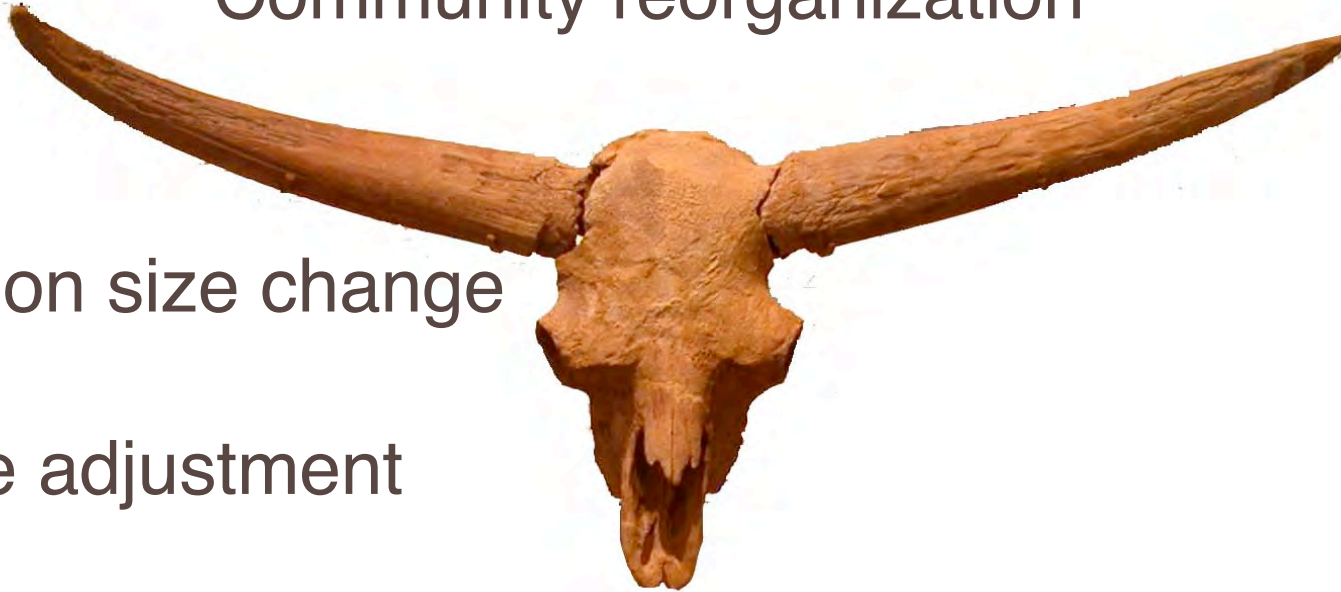
Range adjustment

Extinction

Behavior

How do mammals respond to environmental change?

Community reorganization



Population size change

Range adjustment

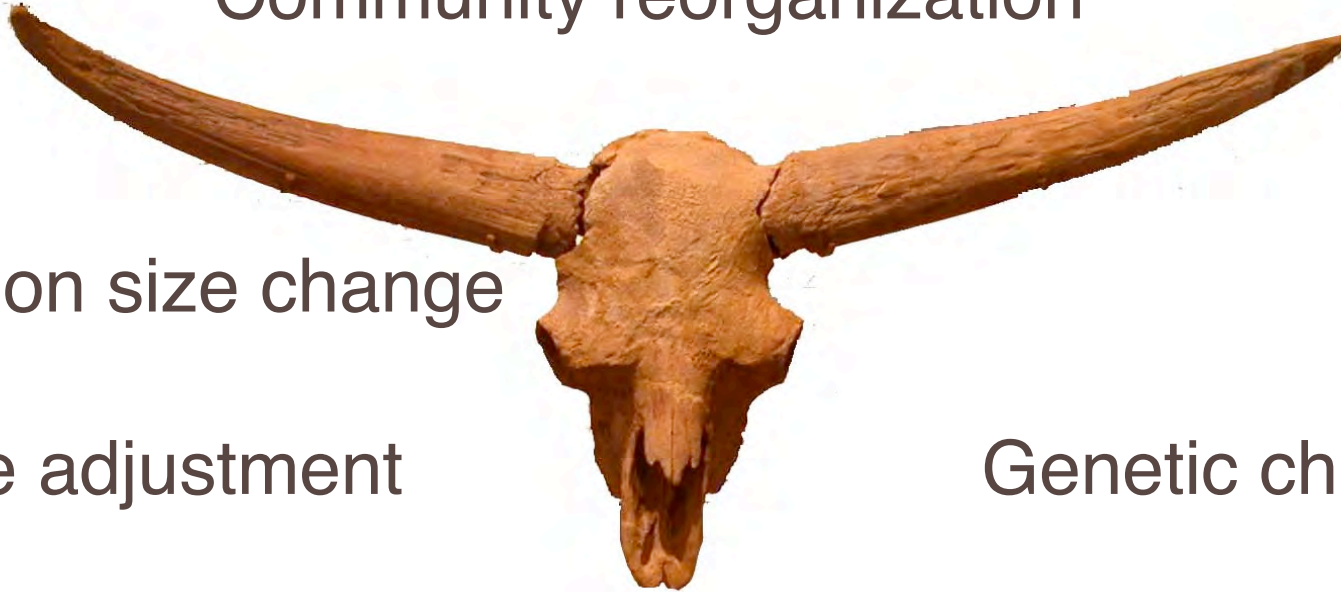
Extinction

Behavior

Phenology

How do mammals respond to environmental change?

Community reorganization



Population size change

Range adjustment

Extinction

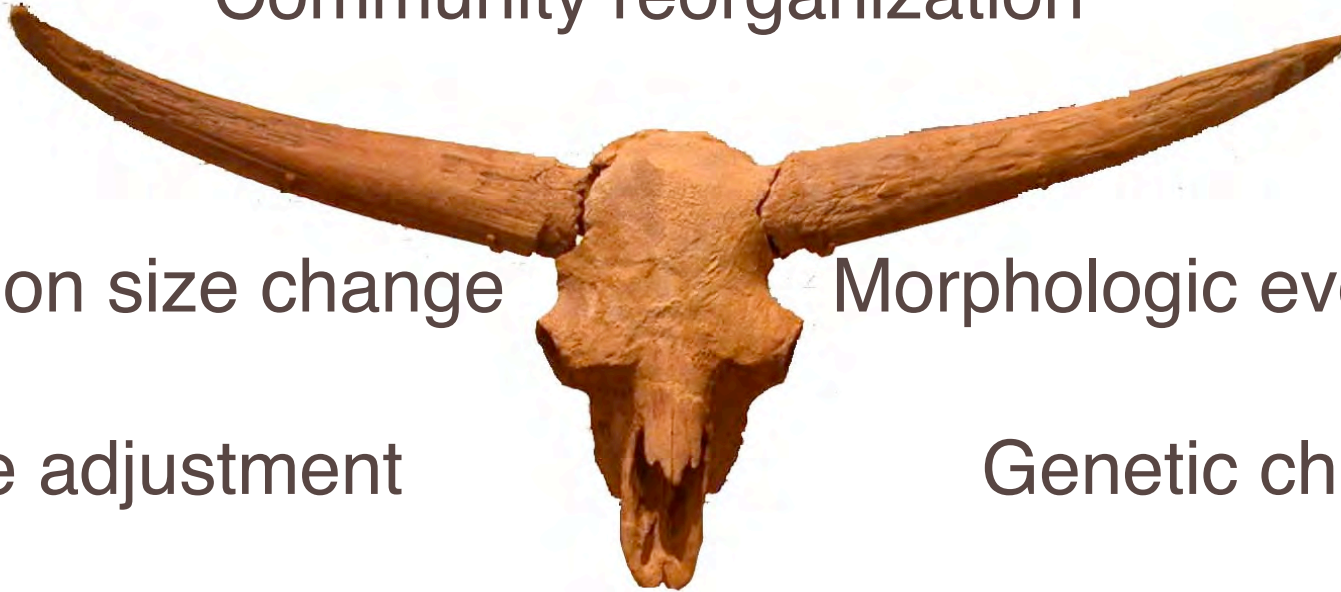
Behavior

Genetic change

Phenology

How do mammals respond to environmental change?

Community reorganization



Population size change

Morphologic evolution

Range adjustment

Genetic change

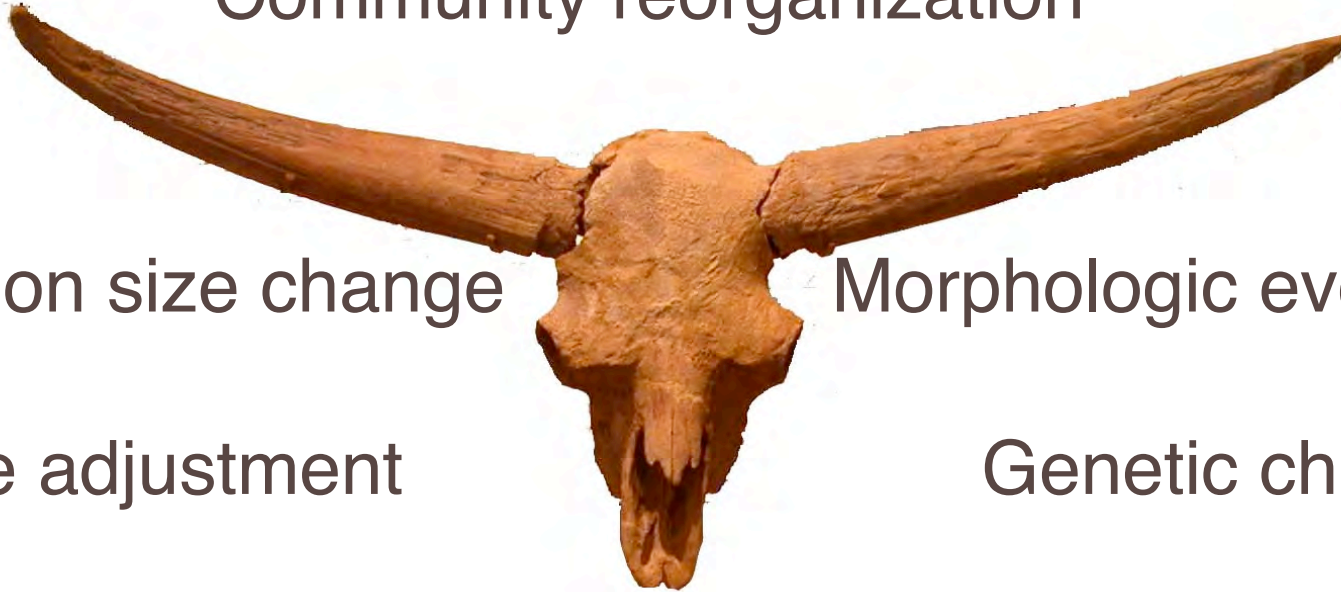
Extinction

Phenology

Behavior

How do mammals respond to environmental change?

Community reorganization



Population size change

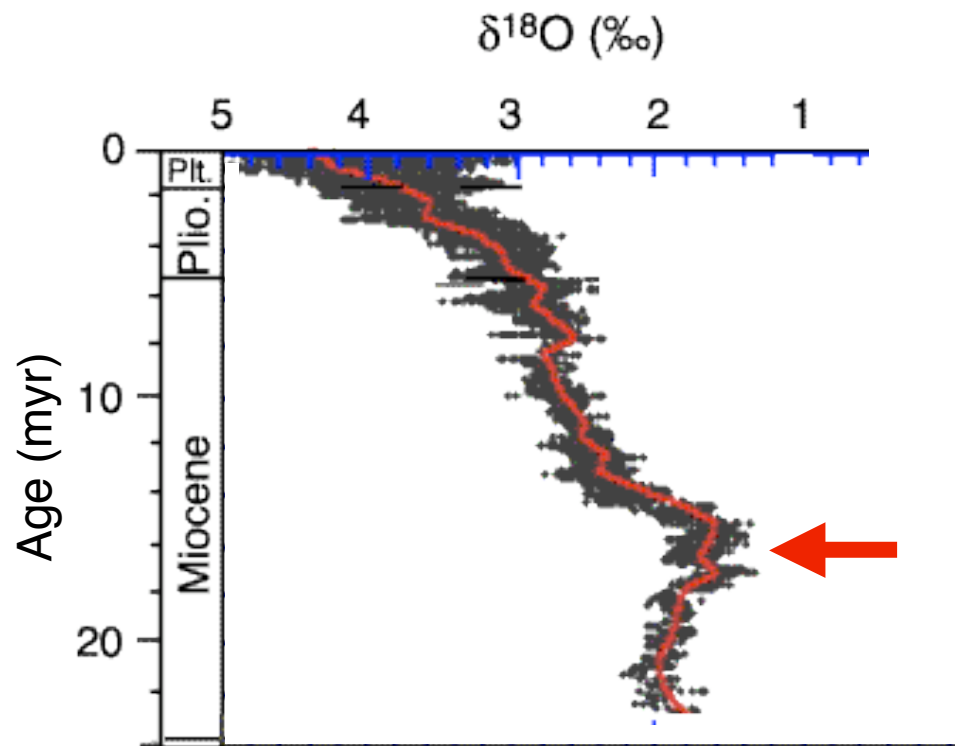
Morphologic evolution

Range adjustment

Genetic change

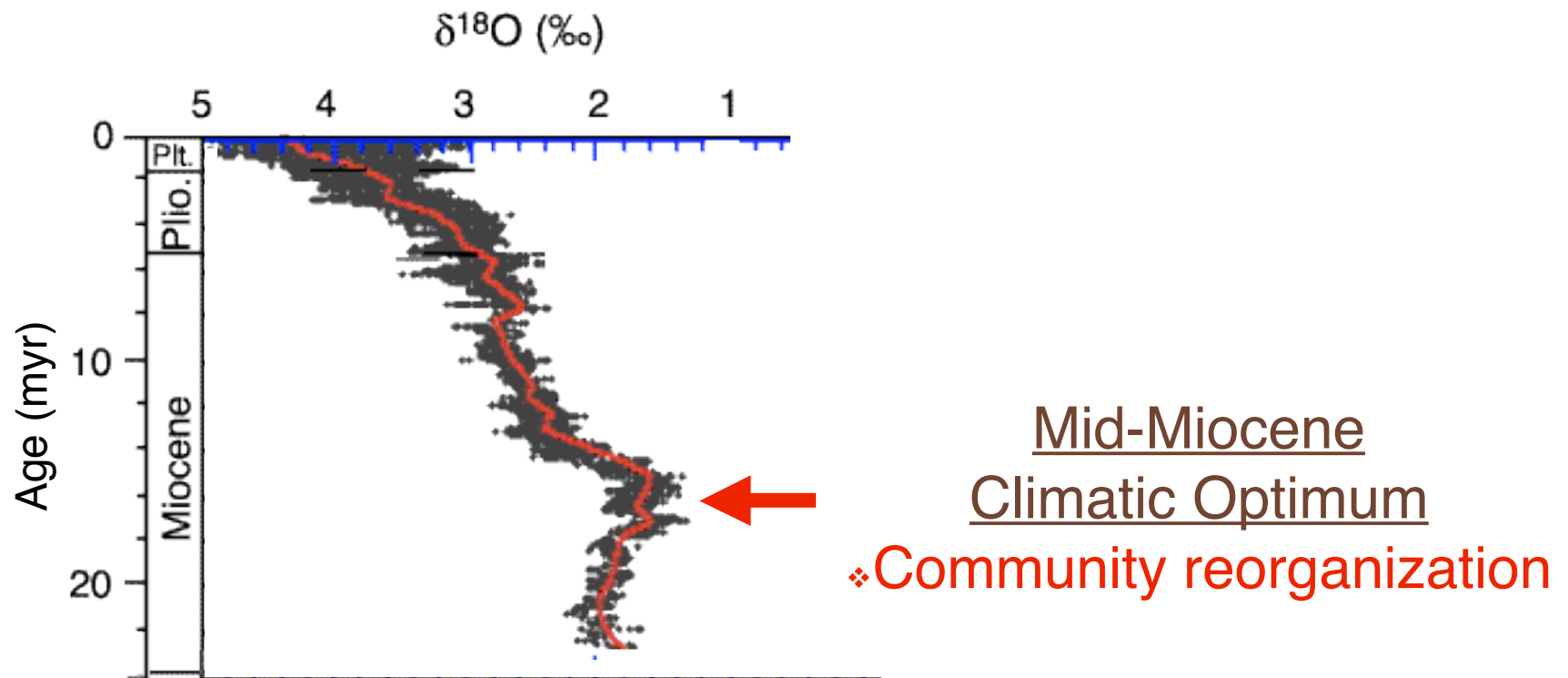
Extinction

Global Temperatures- Last 20 Myr

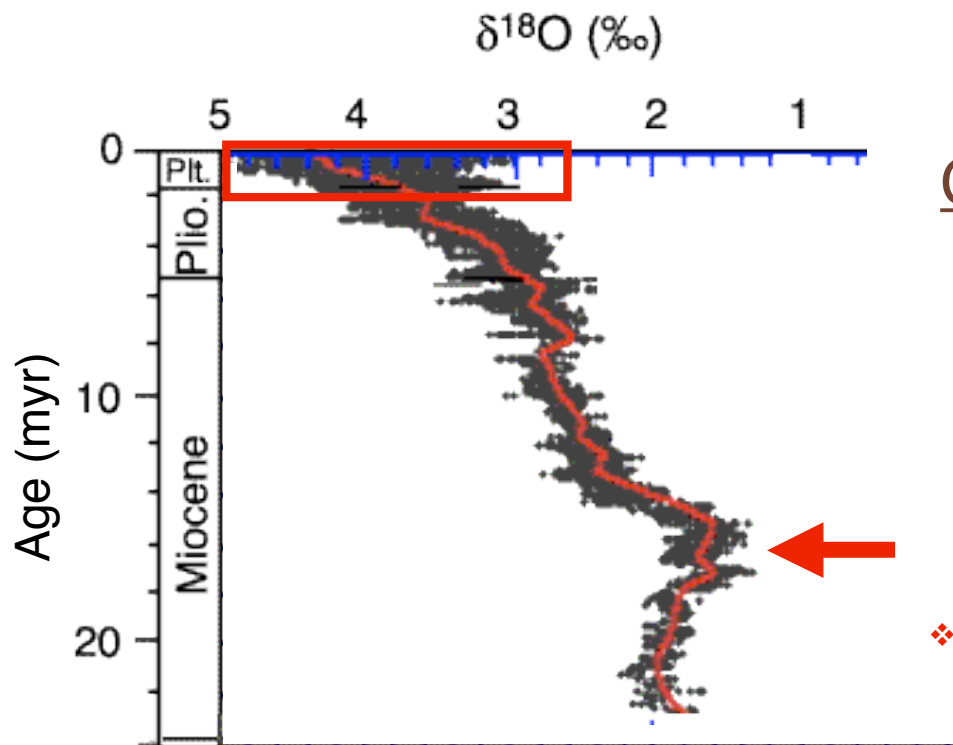


Mid-Miocene
Climatic Optimum

Global Temperatures- Last 20 Myr



Global Temperatures- Last 20 Myr



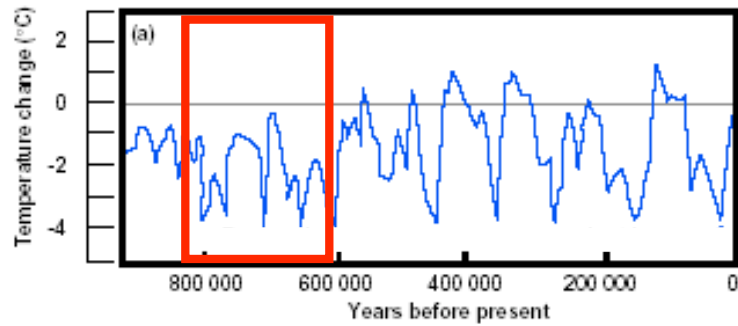
Quaternary Climate Events

Mid-Miocene
Climatic Optimum

❖ **Community reorganization**

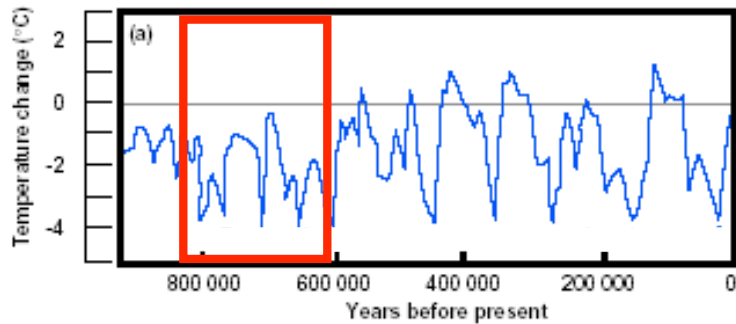
Quaternary Climate Events

Mid-Pleistocene



Folland et al. 1990, NOAA data

Quaternary Climate Events



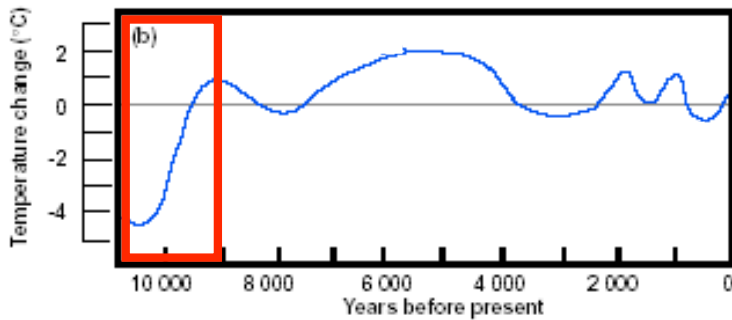
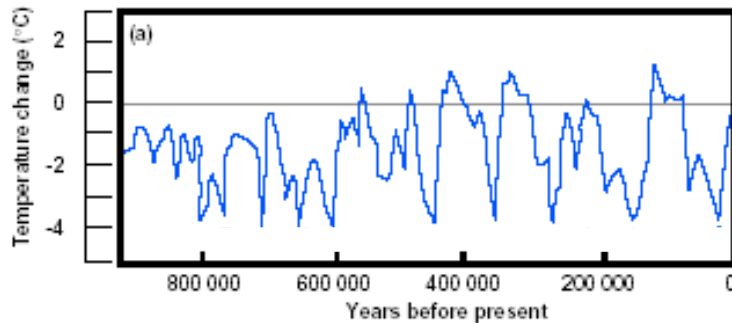
Mid-Pleistocene
❖ Morphologic change

Quaternary Climate Events

Mid-Pleistocene

❖ Morphologic change

Pleistocene-Holocene Transition



Folland et al. 1990, NOAA data

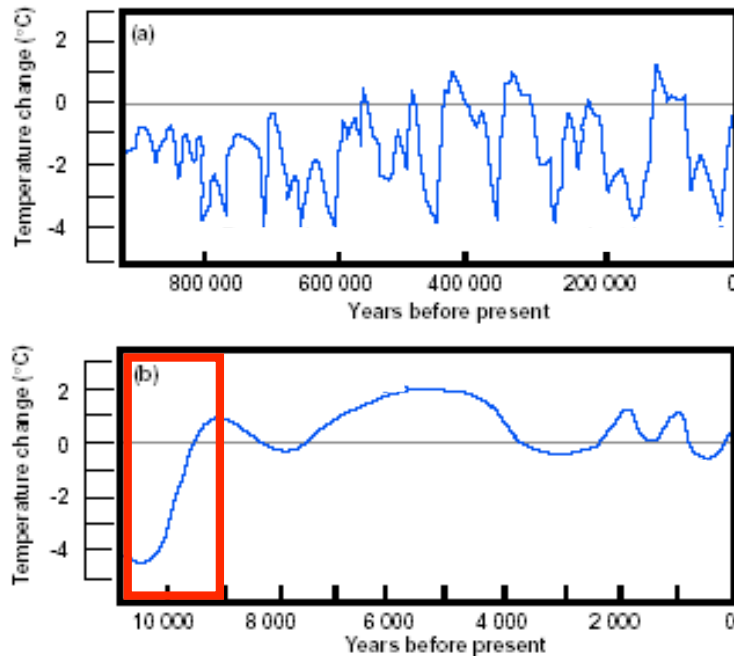
Quaternary Climate Events

Mid-Pleistocene

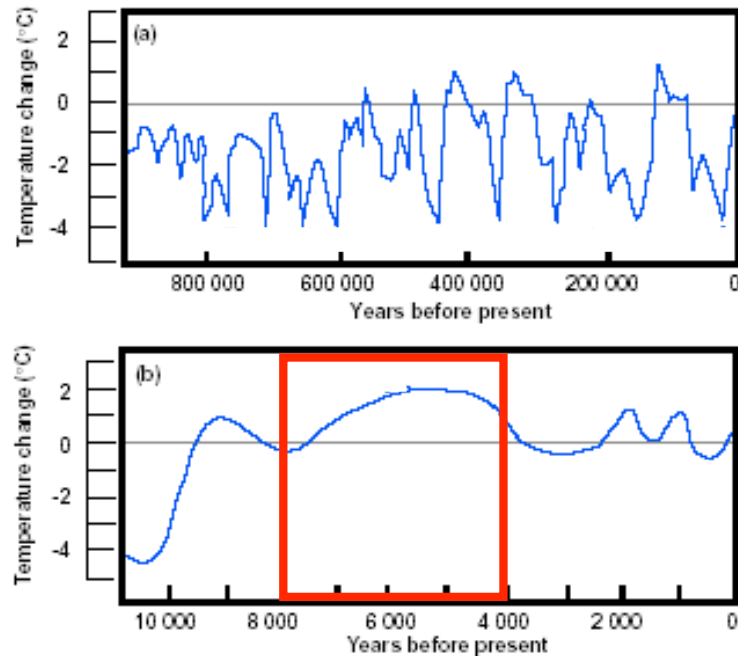
❖ Morphologic change

Pleistocene-Holocene Transition

❖ Range adjustment, morphologic change, extinction, community reorganization



Quaternary Climate Events



Mid-Pleistocene

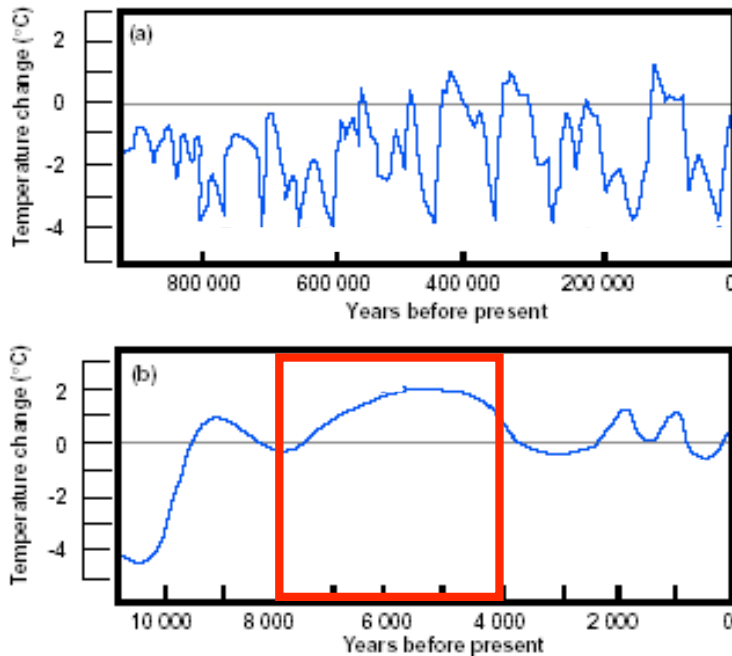
❖ Morphologic change

Pleistocene-Holocene Transition

❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

Quaternary Climate Events



Mid-Pleistocene

❖ Morphologic change

Pleistocene-Holocene Transition

❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

❖ Population size change, range adjustment

Quaternary Climate Events

Mid-Pleistocene

❖ Morphologic change

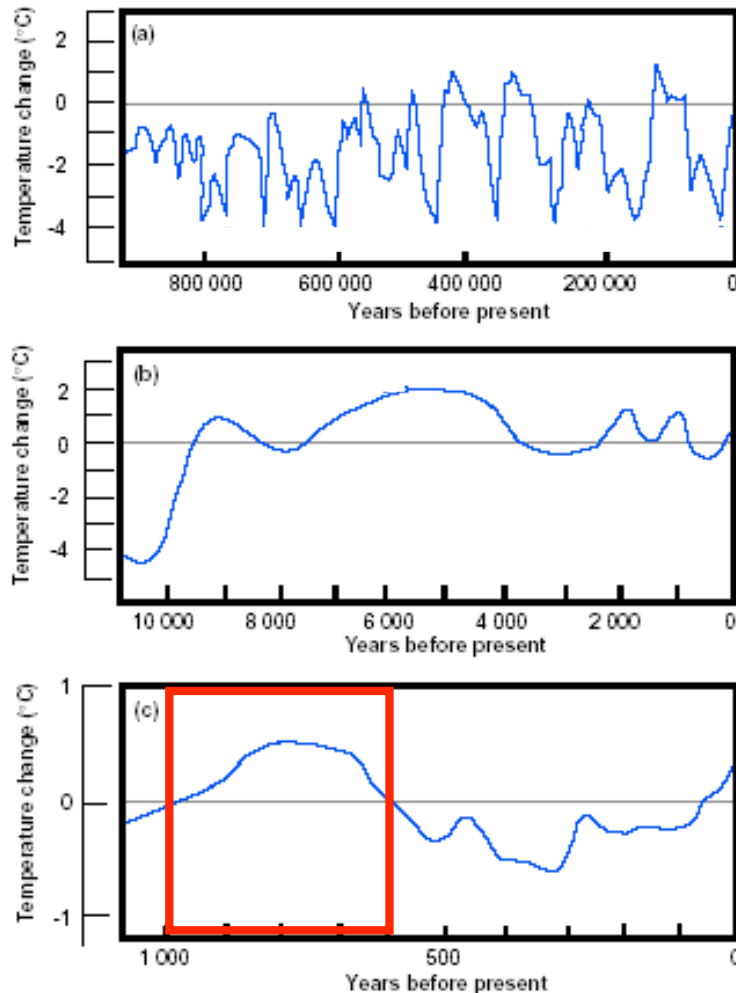
Pleistocene-Holocene Transition

❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

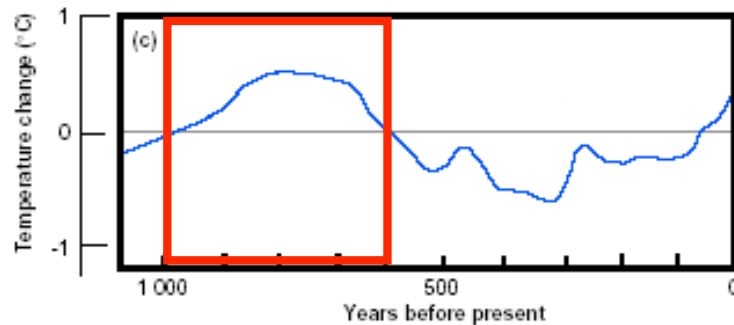
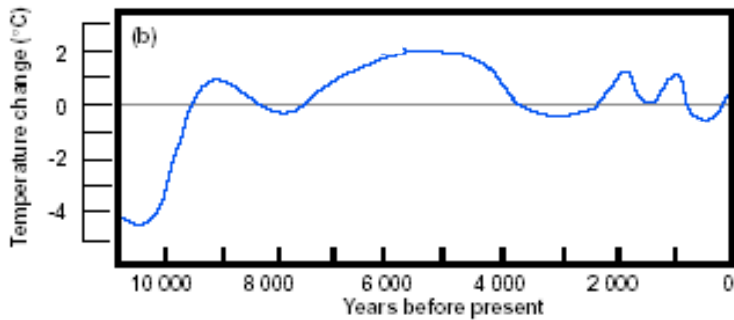
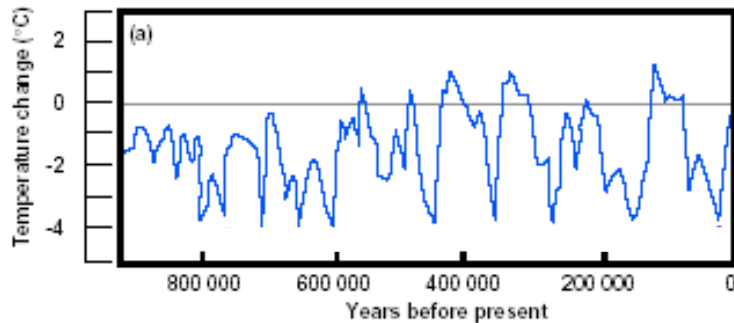
❖ Population size change, range adjustment

Medieval Warm Period



Folland et al. 1990, NOAA data

Quaternary Climate Events



Mid-Pleistocene

❖ Morphologic change

Pleistocene-Holocene Transition

❖ Range adjustment, morphologic change, extinction, community reorganization

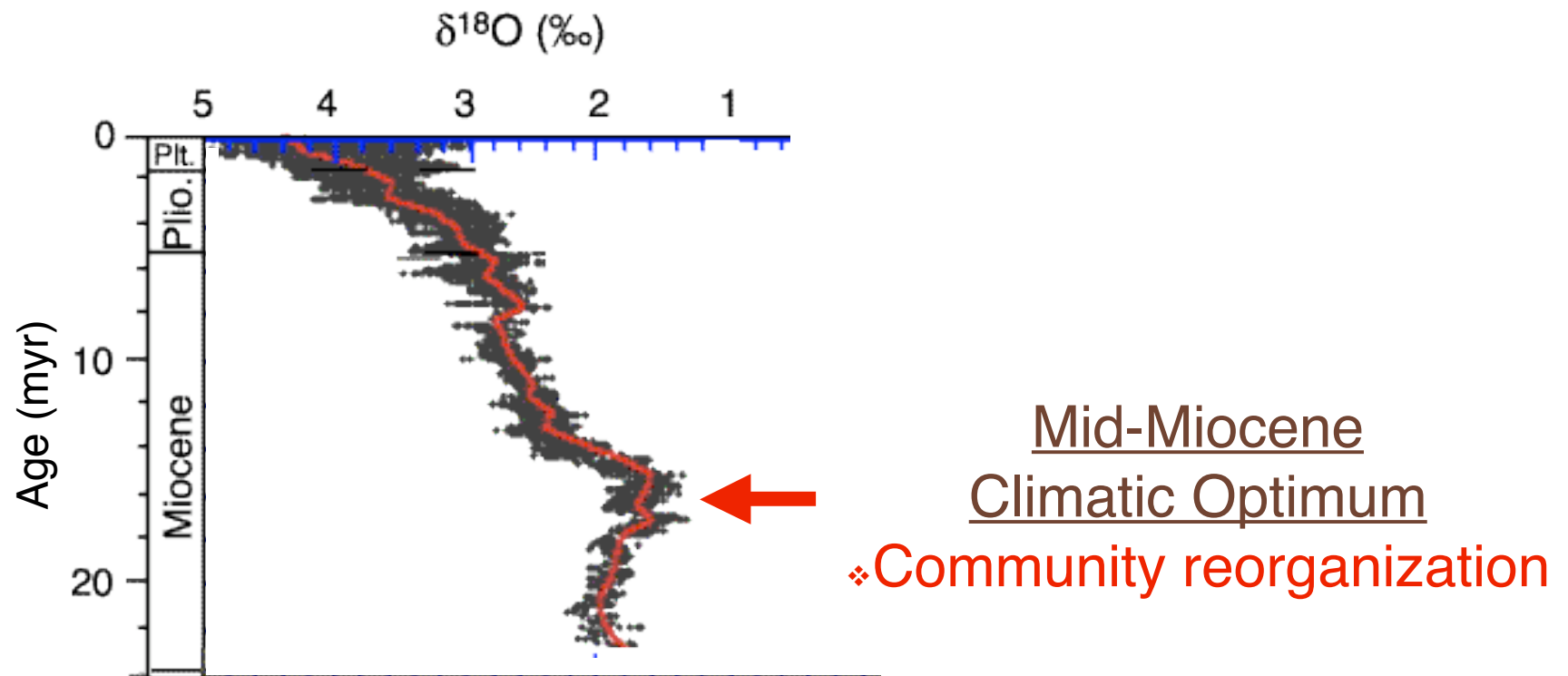
Mid-Holocene

❖ Population size change, range adjustment

Medieval Warm Period

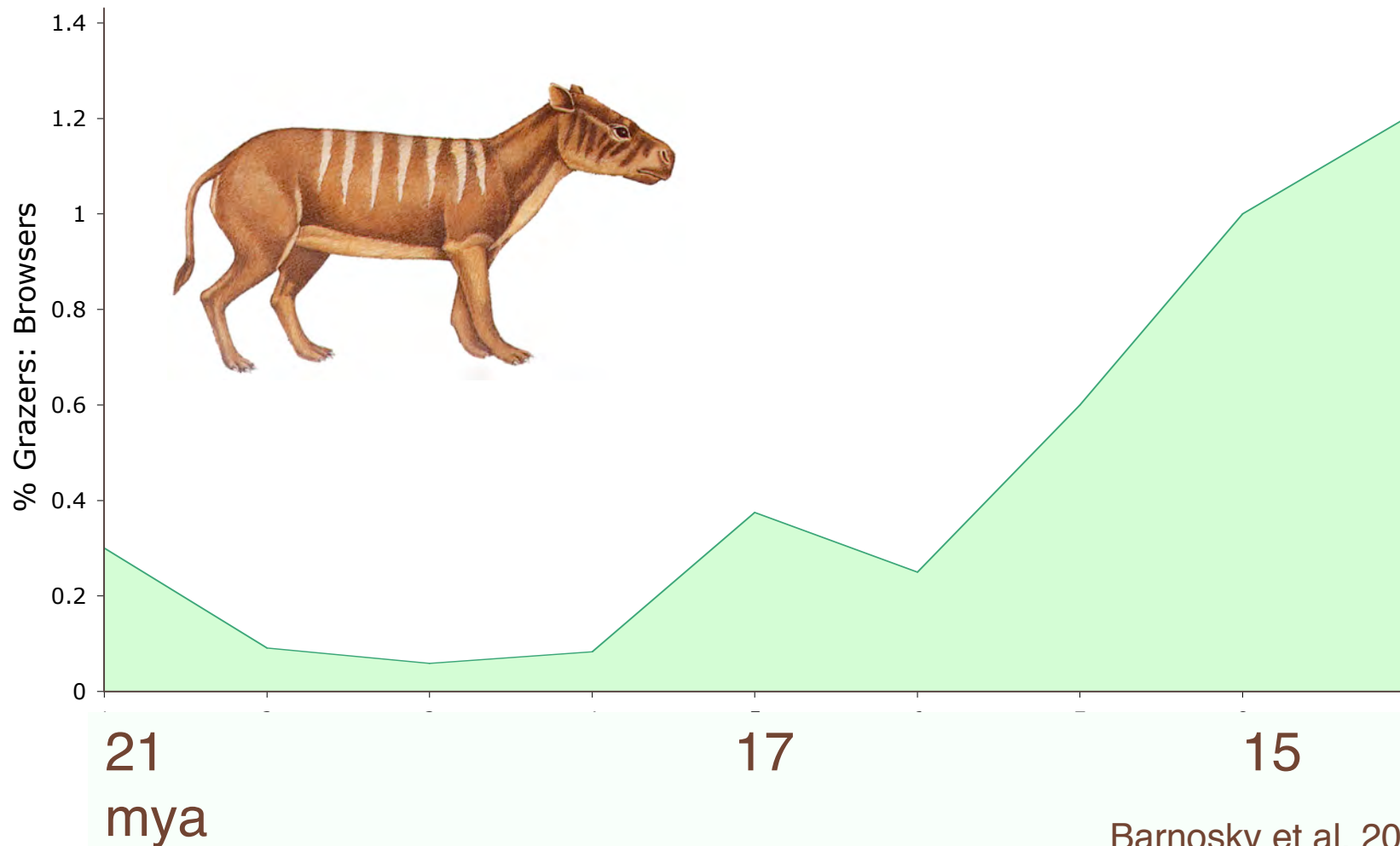
❖ Population size change, morphologic change, genetic change

Global Temperatures- Last 20 Myr



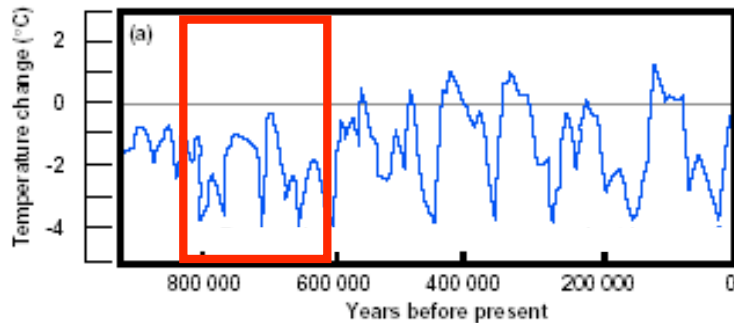
Mid-Miocene Climatic Optimum: Community reorganization

Mid-Miocene Climatic Optimum: Community reorganization



Barnosky et al. 2003

Quaternary Climate Events



Mid-Pleistocene

❖ Morphologic change

Pleistocene-Holocene Transition

- ❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

- ❖ Population size change, range adjustment

Medieval Warm Period

- ❖ Population size change, morphologic change, genetic change

Mid-Pleistocene: Morphologic Change

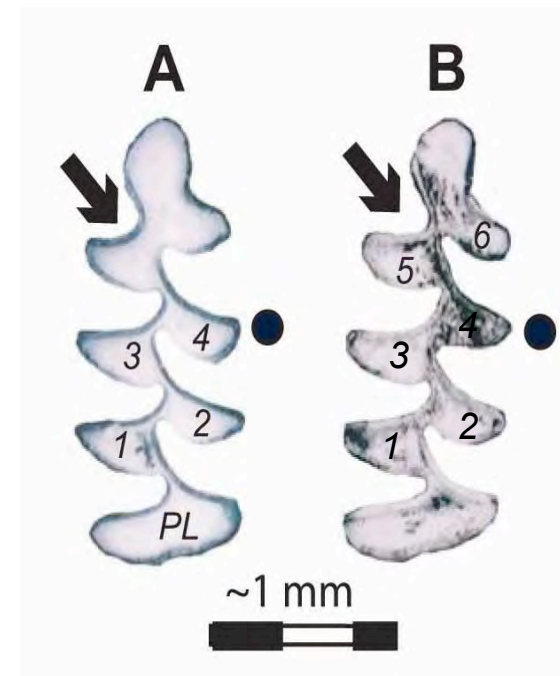


Sagebrush vole

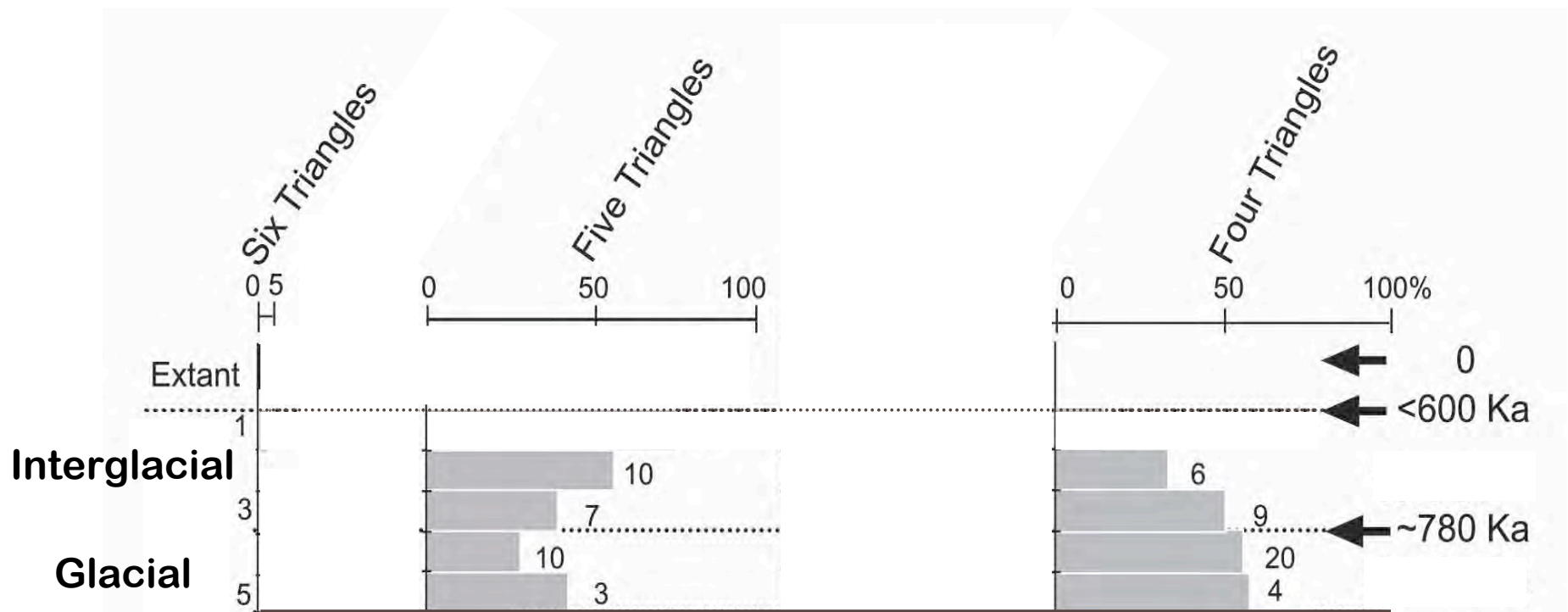
Mid-Pleistocene: Morphologic Change



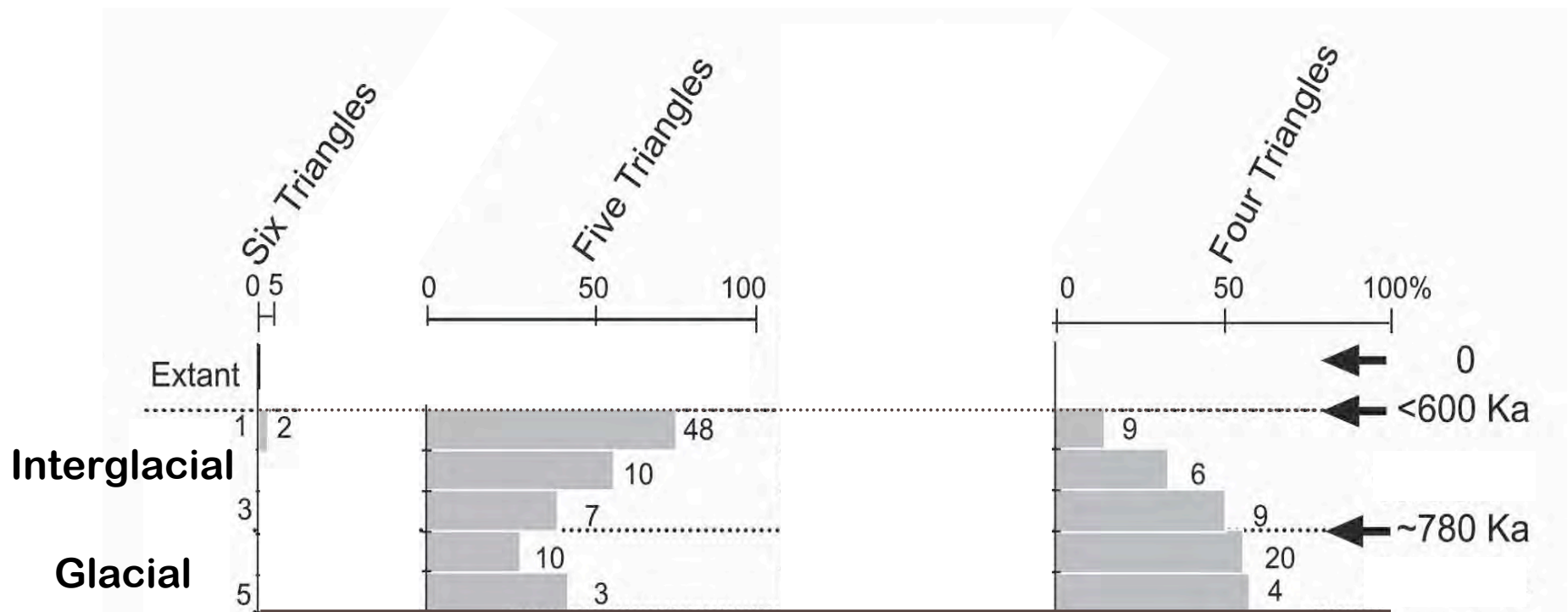
Sagebrush vole



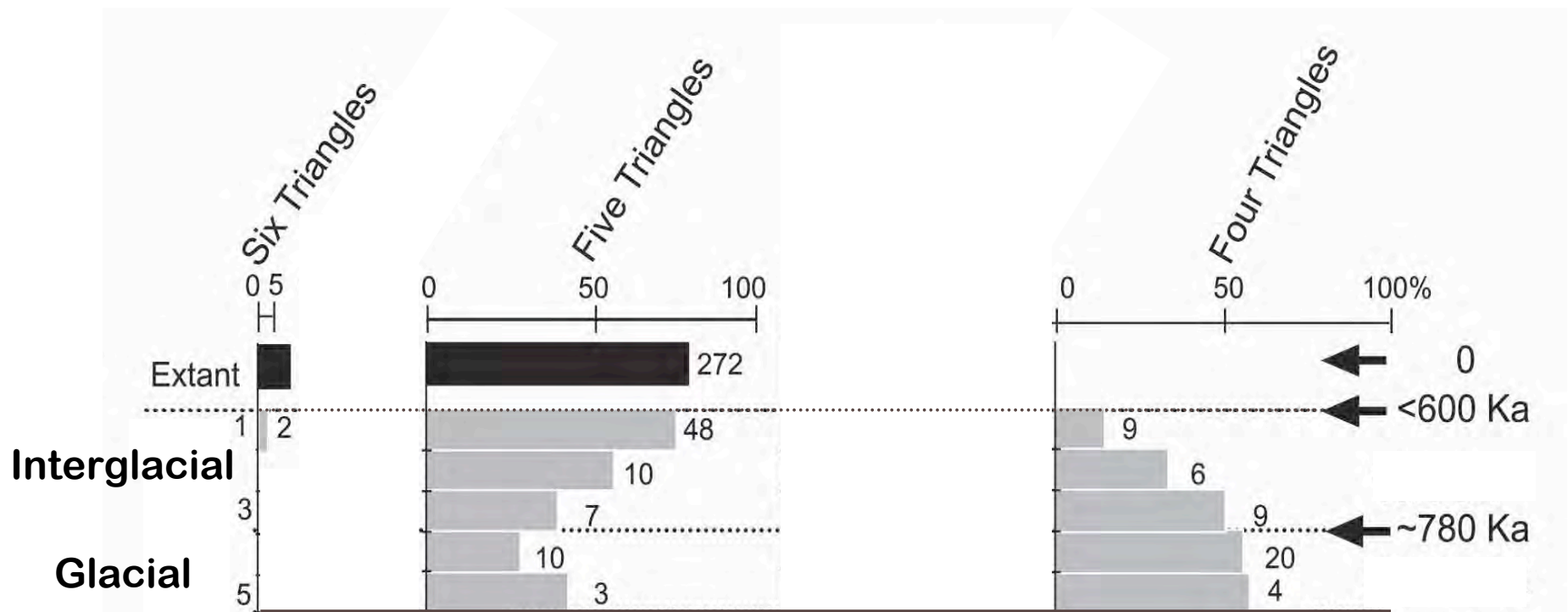
Mid-Pleistocene: Morphologic Change



Mid-Pleistocene: Morphologic Change



Mid-Pleistocene: Morphologic Change



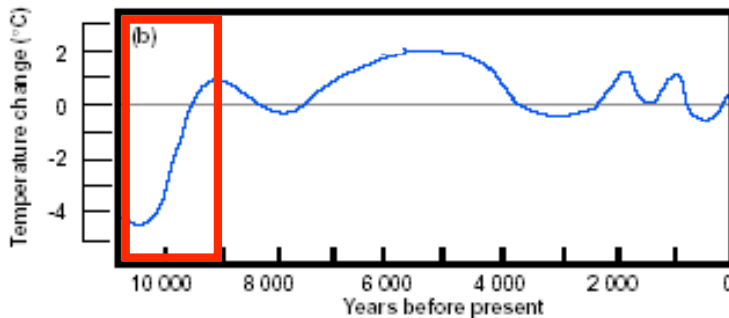
Quaternary Climate Events

Mid-Pleistocene

- ❖ Morphologic change

Pleistocene-Holocene Transition

- ❖ Range adjustment, morphologic change, extinction, community reorganization



Mid-Holocene

- ❖ Population size change, range adjustment

Medieval Warm Period

- ❖ Population size change, morphologic change, genetic change

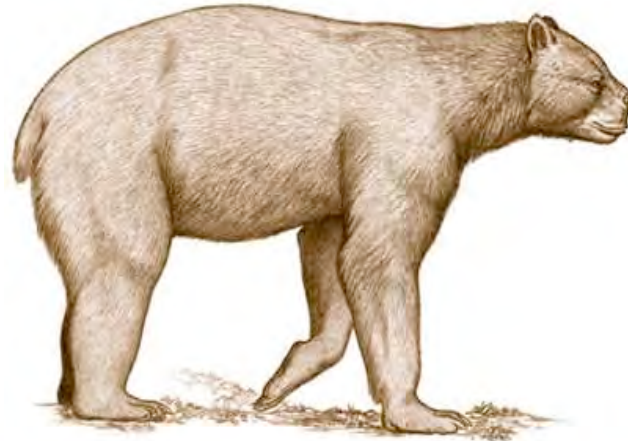
Pleistocene/Holocene Transition



Western camel



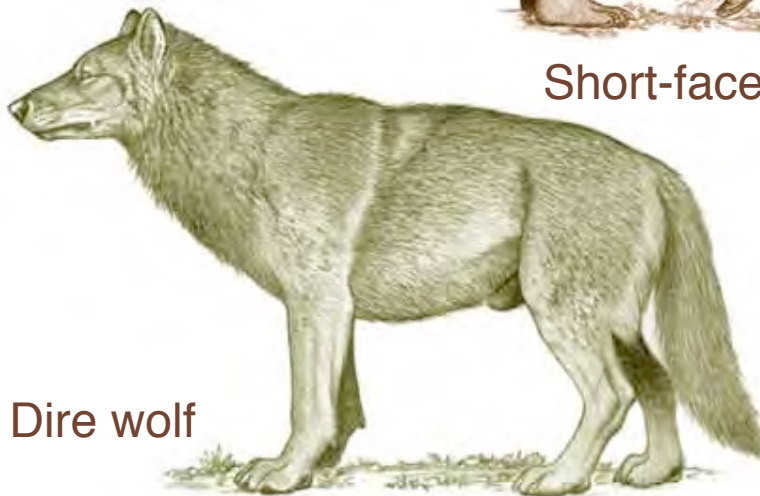
Columbian mammoth



Short-faced bear



Shasta ground sloth



Dire wolf



Sabertooth

Pleistocene/Holocene Transition: Extinction



Giant ground sloth

Barnosky et al 2004

Pleistocene/Holocene Transition: Extinction



Giant ground sloth

❖ 90 genera
worldwide

Barnosky et al 2004

Pleistocene/Holocene Transition: Extinction



Giant ground sloth

❖ 90 genera
worldwide

❖ Body size bias
>44kg

Pleistocene/Holocene Transition: Extinction



Giant ground sloth

- ❖ 90 genera worldwide
- ❖ Body size bias >44kg
- ❖ Role for climatic change

Pleistocene/Holocene Transition: Extinction



Barnosky et al 2004

Pleistocene/Holocene Transition: Extinction



❖ **Humans implicated as catalysts**

Pleistocene/Holocene Transition: Range adjustment



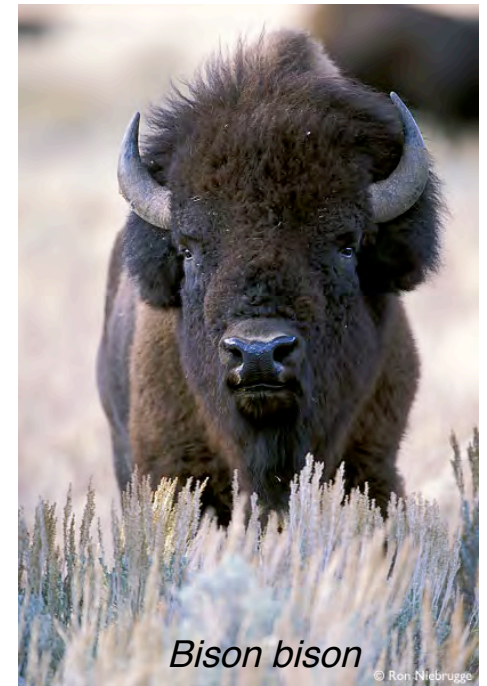
Northern bog lemming



Pleistocene/Holocene Transition: Morphologic change



Bison latifrons



Bison bison

© Ron Niebrugge

Pleistocene/Holocene Transition: Morphologic change



Bison latifrons



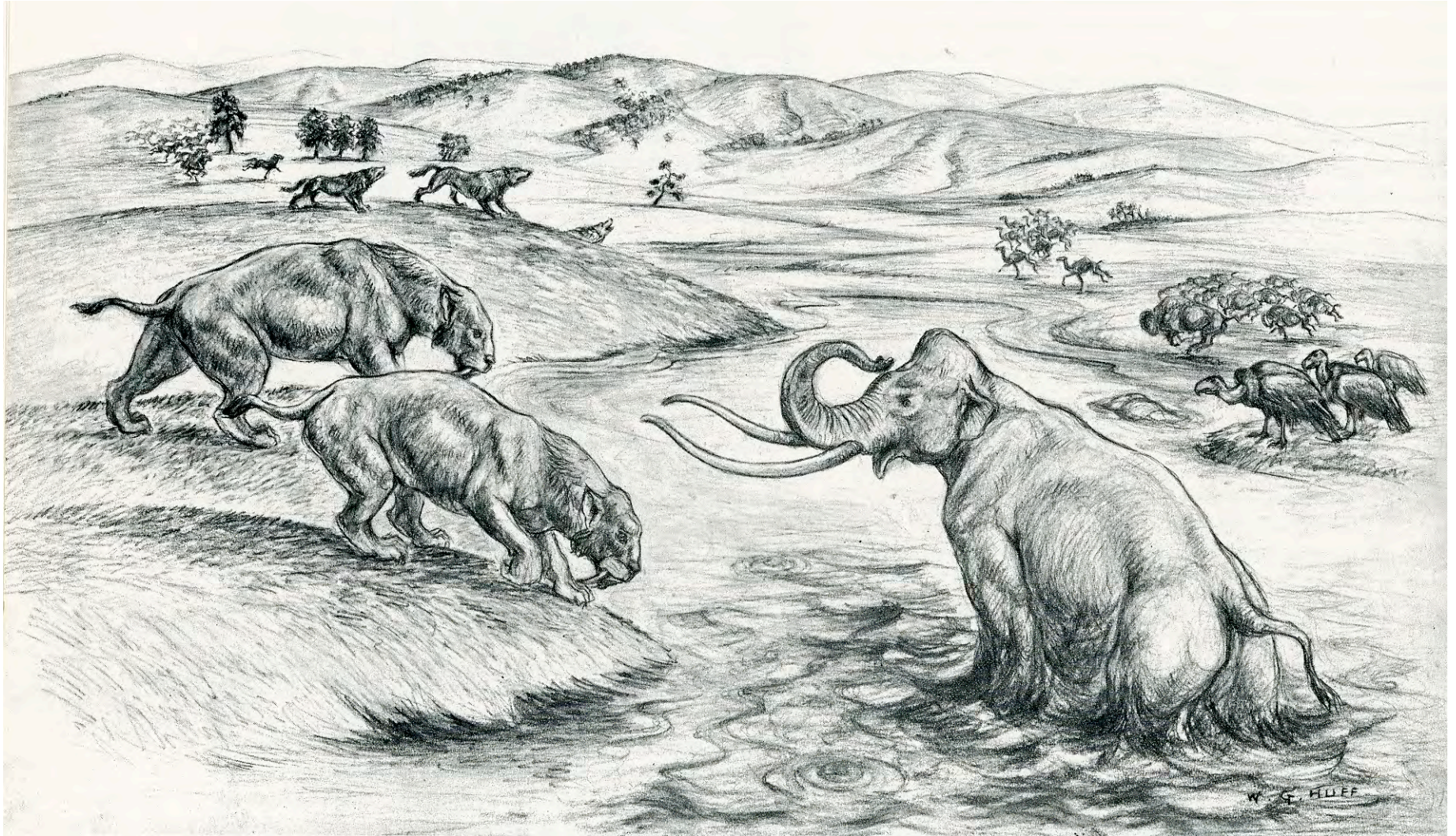
*Many species show
a decrease
in body size with warming*



Bison bison

© Ron Niebrugge

Pleistocene/Holocene Transition: Community reorganization



Quaternary Climate Events

Mid-Pleistocene

- ❖ Morphologic change

Pleistocene-Holocene Transition

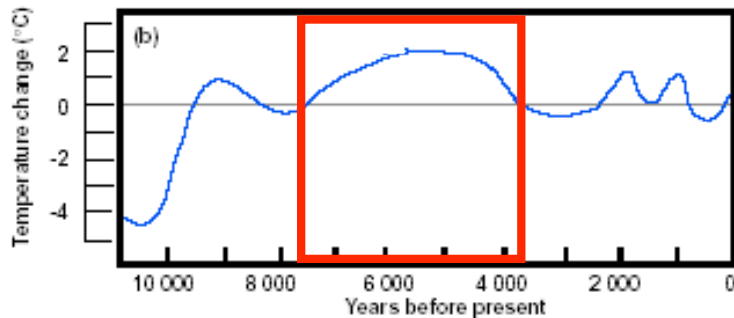
- ❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

- ❖ **Population size change, range adjustment**

Medieval Warm Period

- ❖ Population size change, morphologic change, genetic change

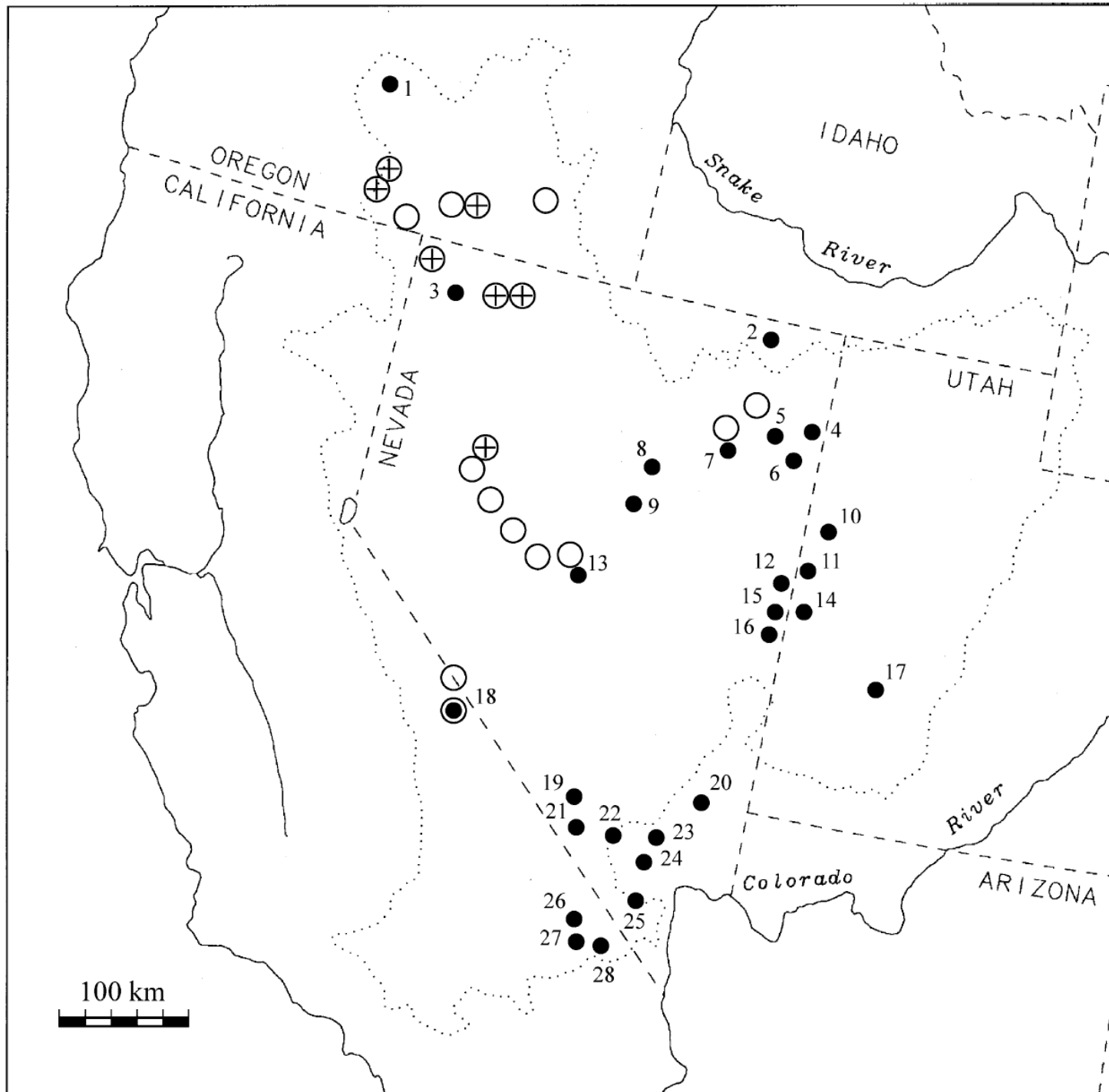


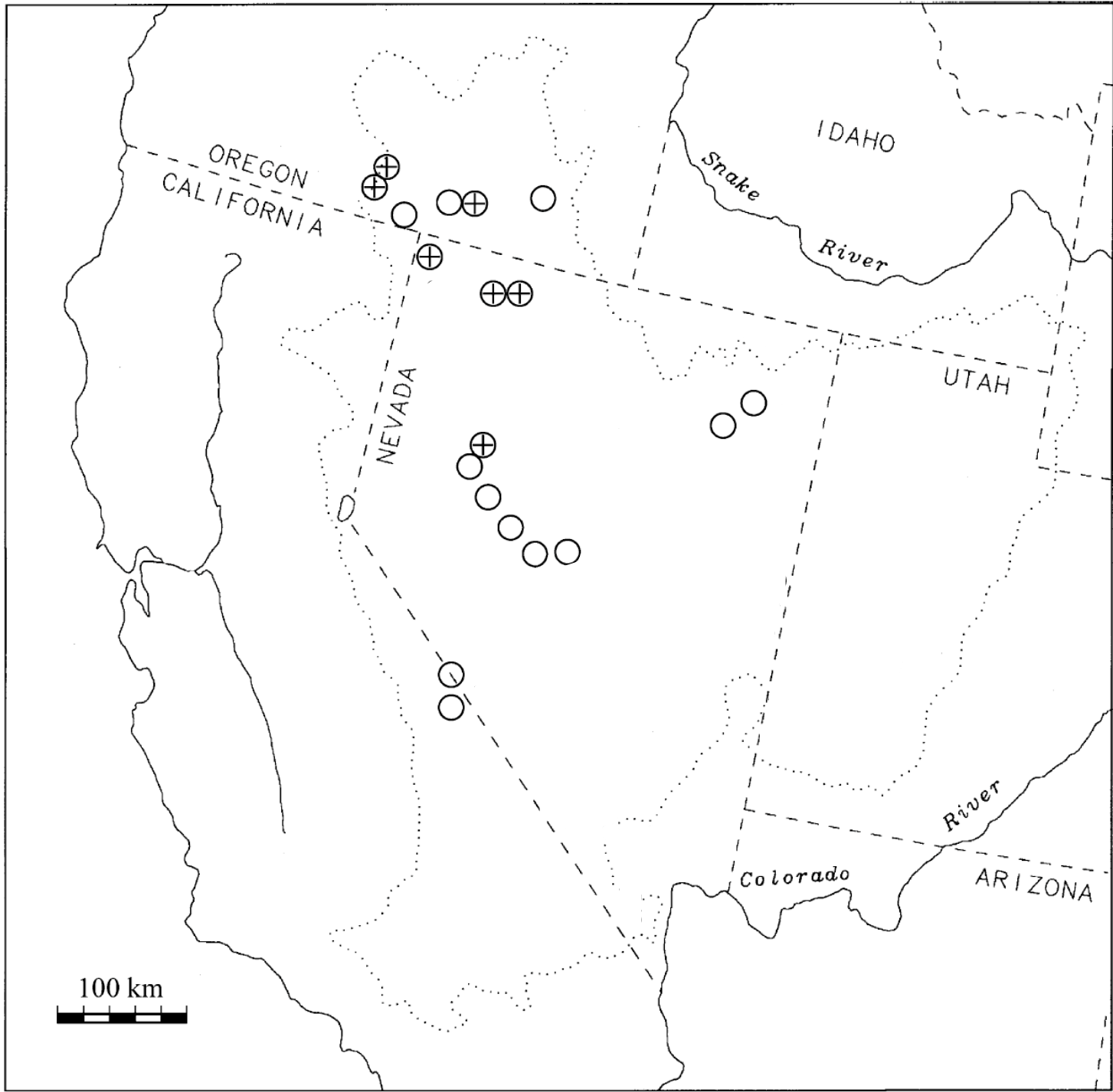
Mid-Holocene: Population size change



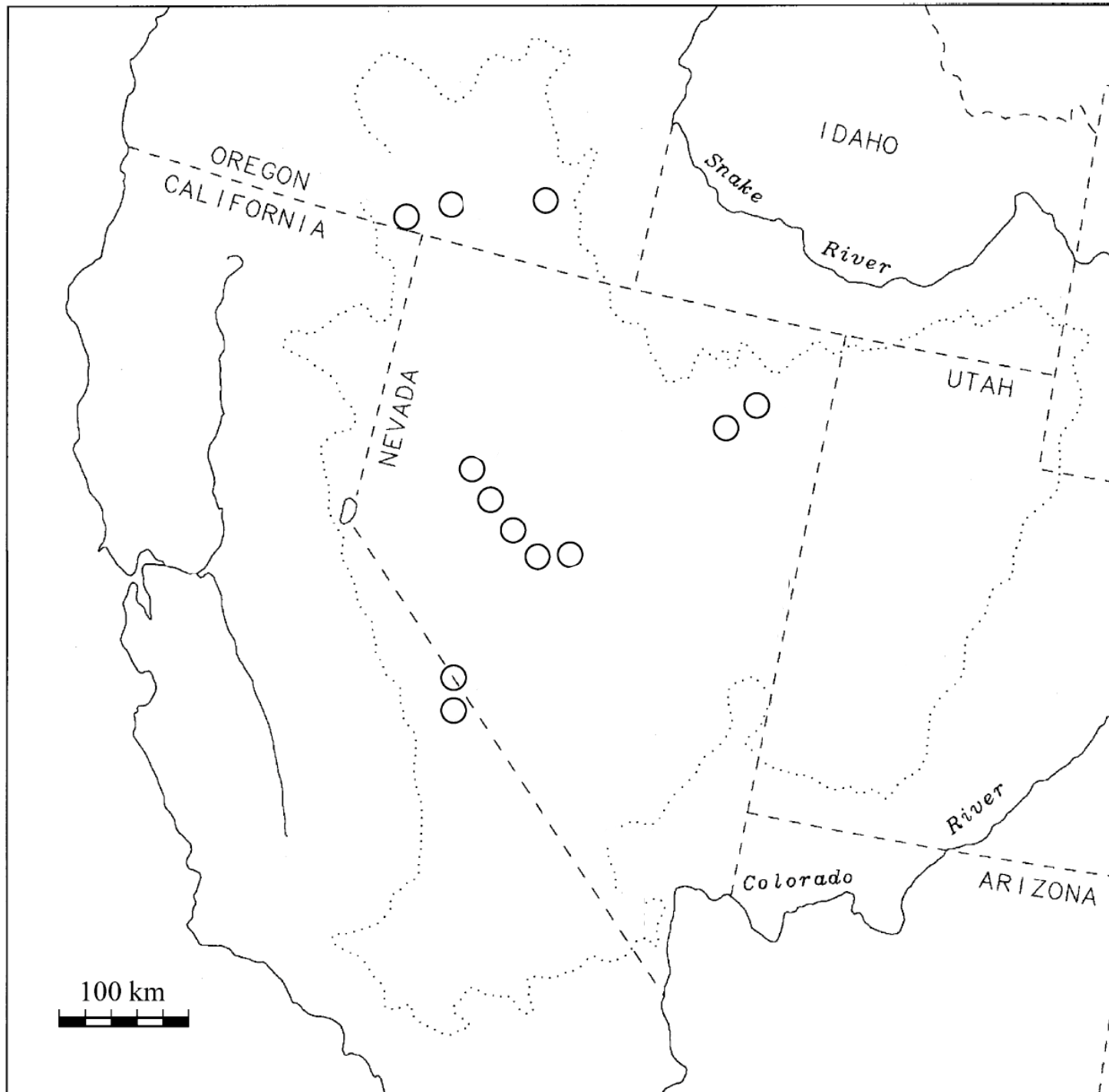
pika







Grayson
2005



Grayson
2005

Quaternary Climate Events

Mid-Pleistocene

- ❖ Morphologic change

Pleistocene-Holocene Transition

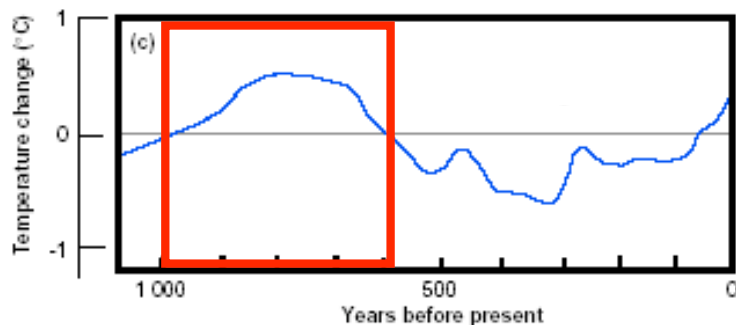
- ❖ Range adjustment, morphologic change, extinction, community reorganization

Mid-Holocene

- ❖ Population size change, range adjustment

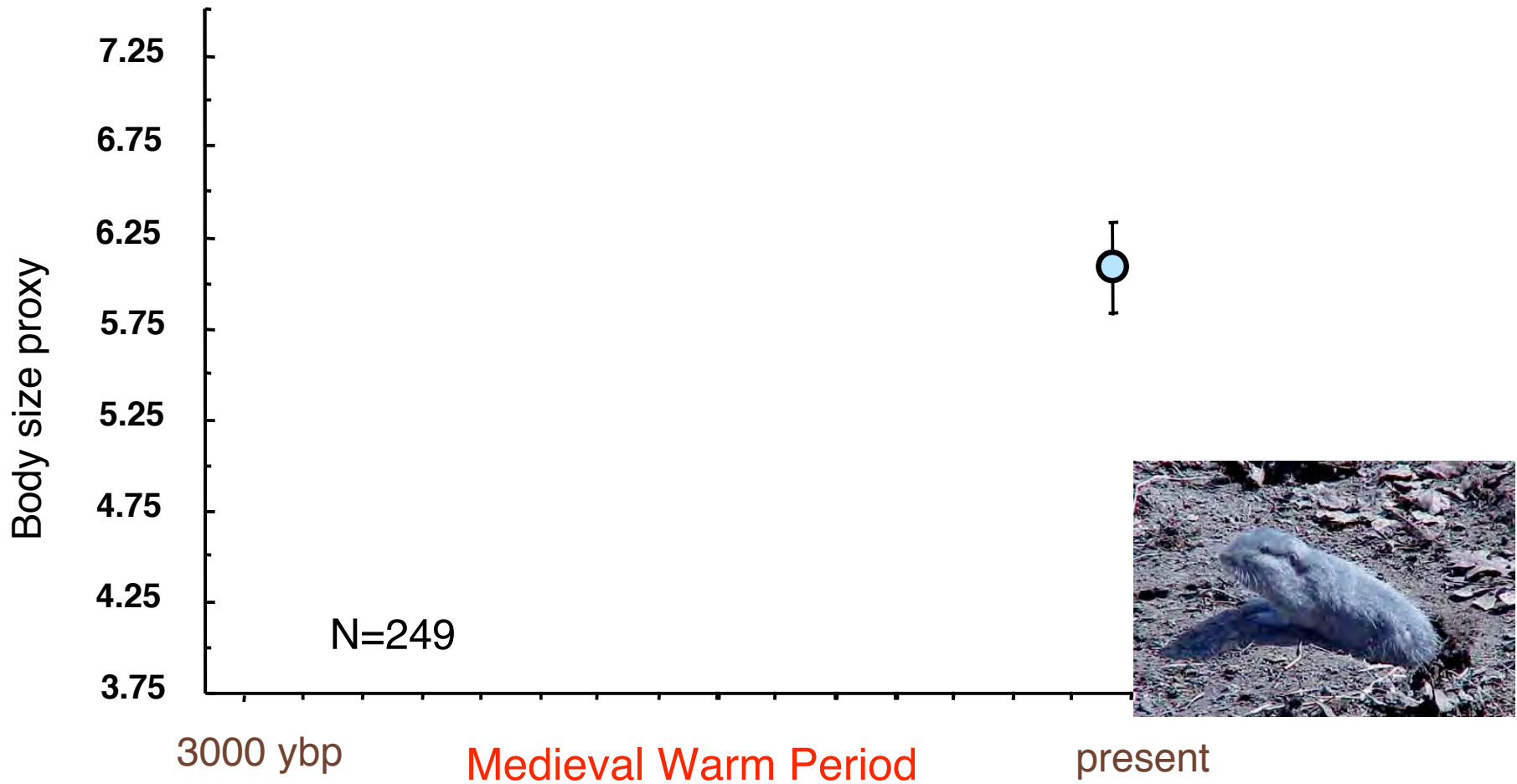
Medieval Warm Period

- ❖ **Population size change, morphologic change, genetic change**

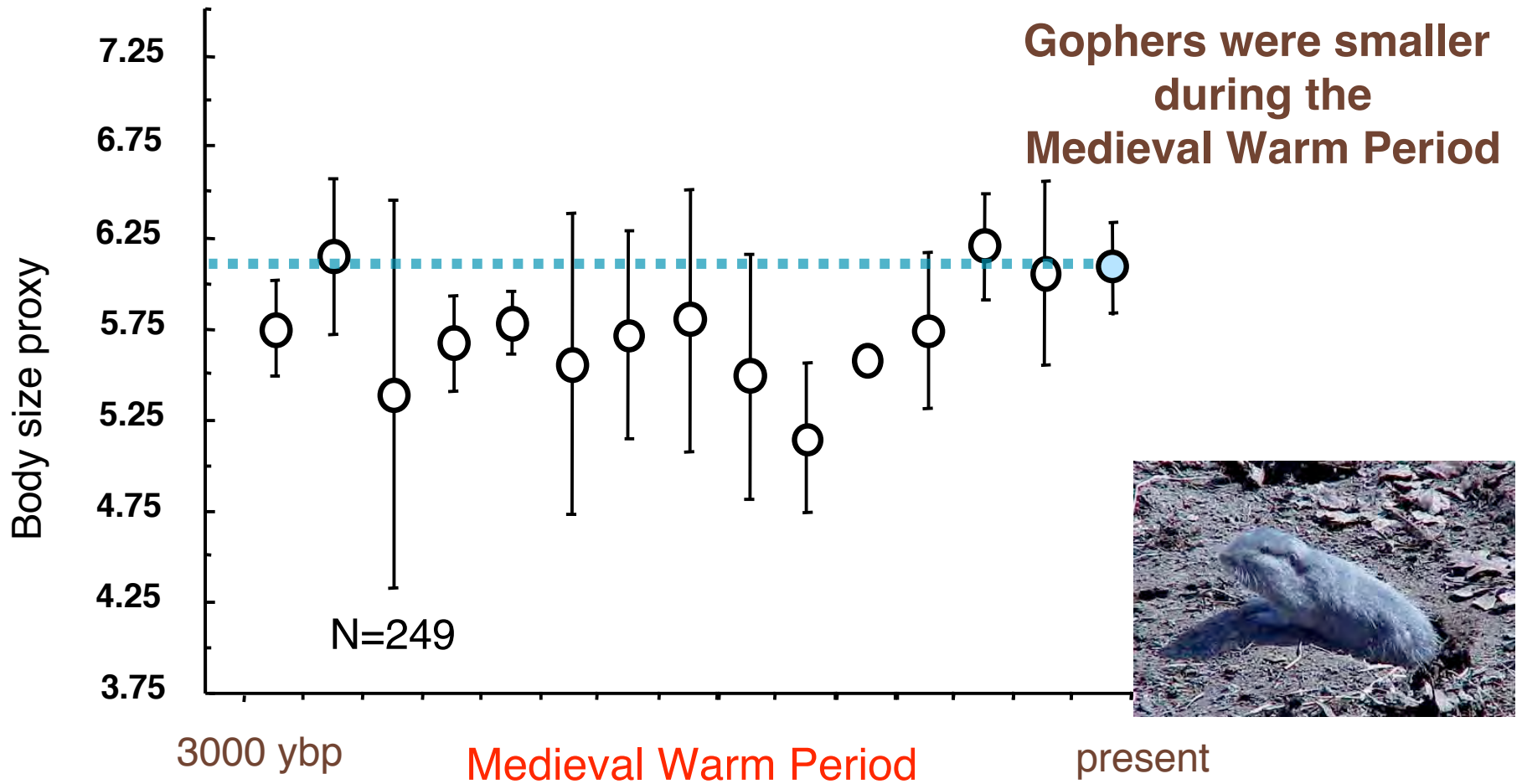


Folland et al. 1990, NOAA data

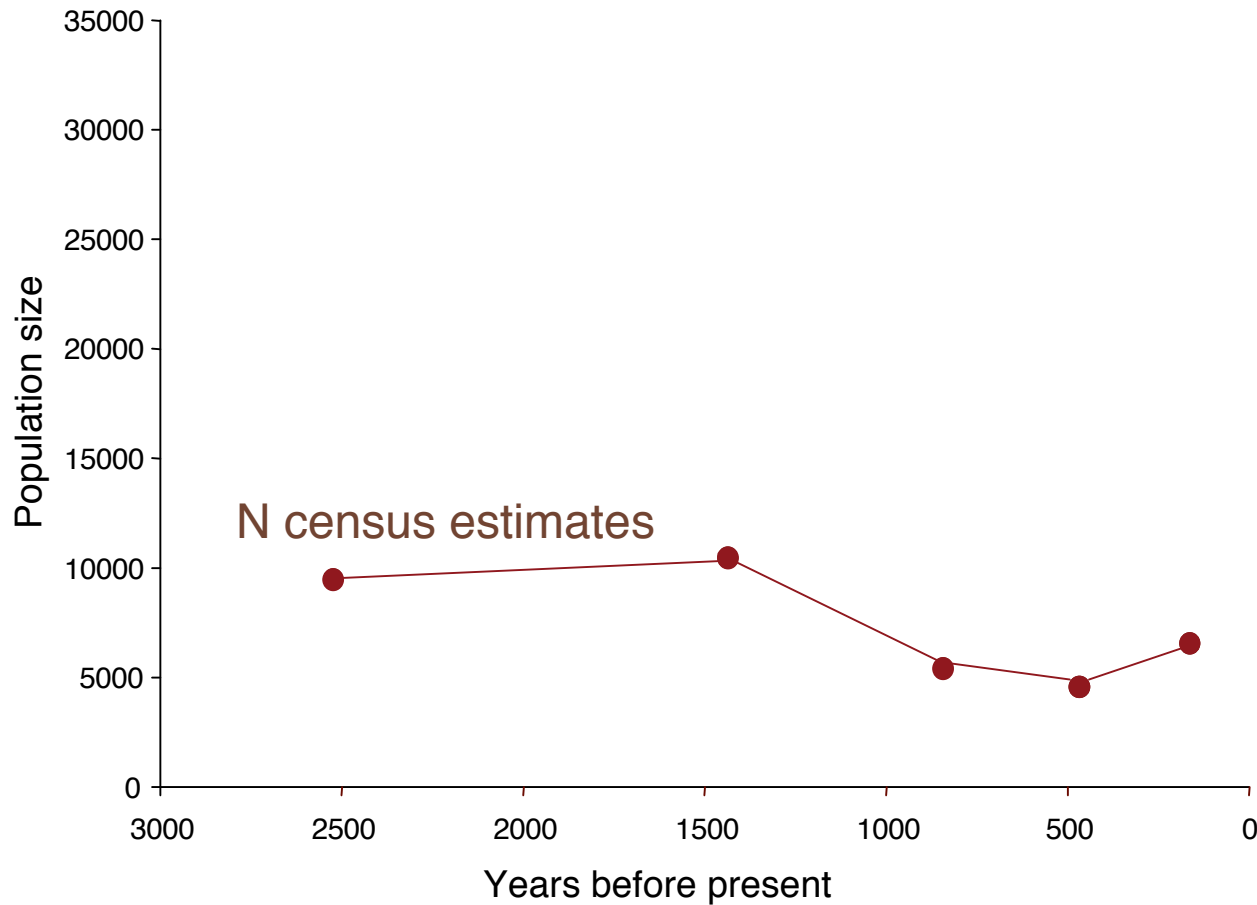
Mid-Holocene: Morphologic change



Mid-Holocene: Morphologic change



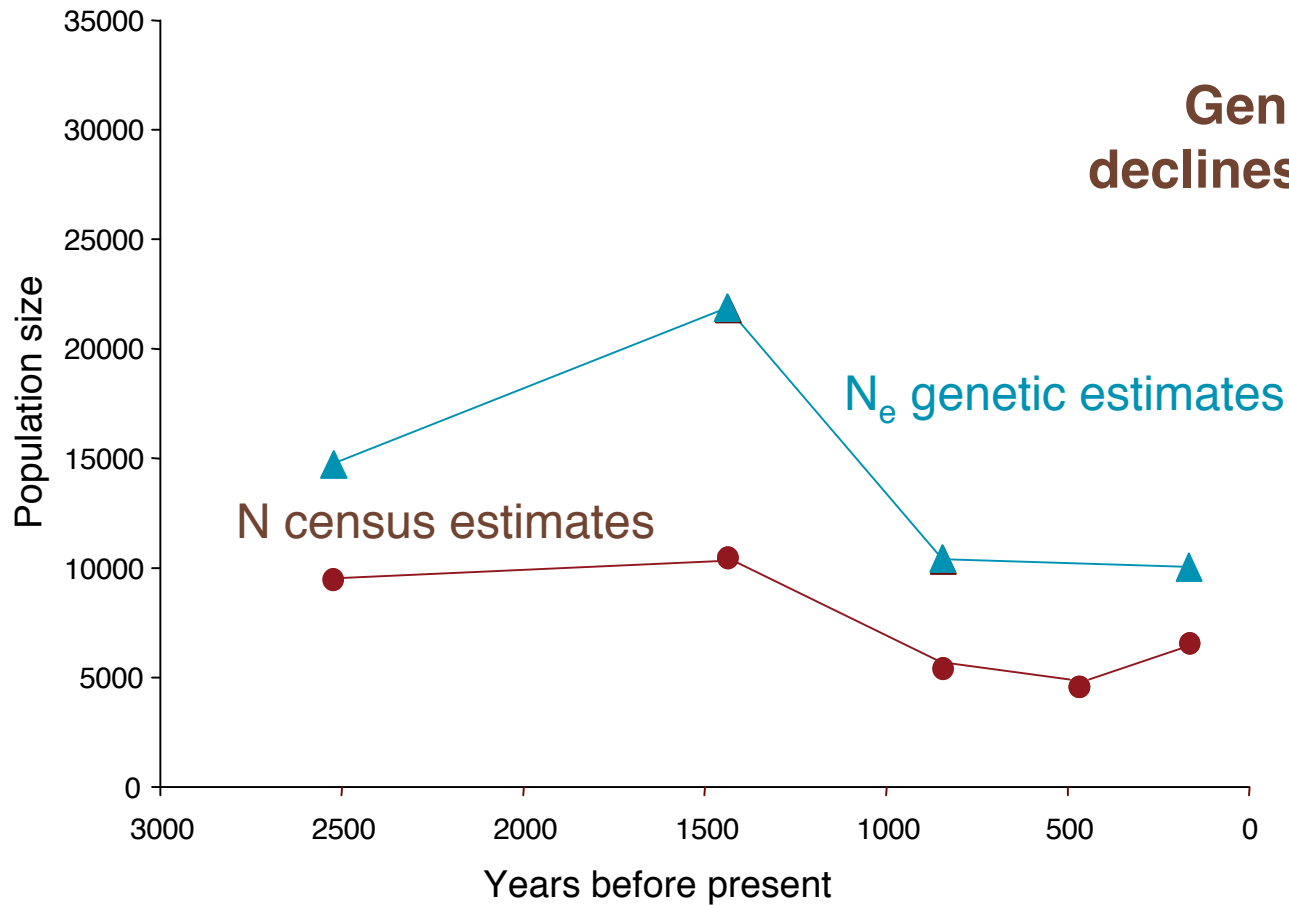
Mid-Holocene: Population size change



Northern pocket gopher

Hadly *et al.* 2004

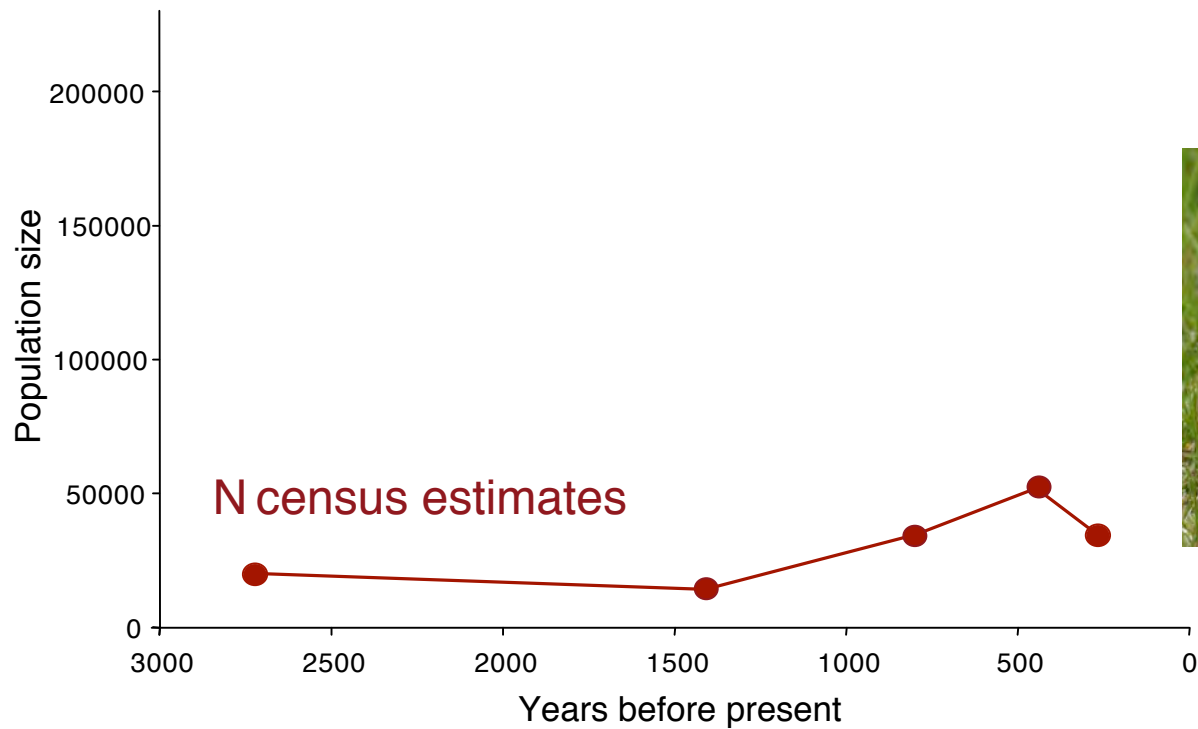
Mid-Holocene: Genetic change



Northern pocket gopher

Hadly *et al.* 2004

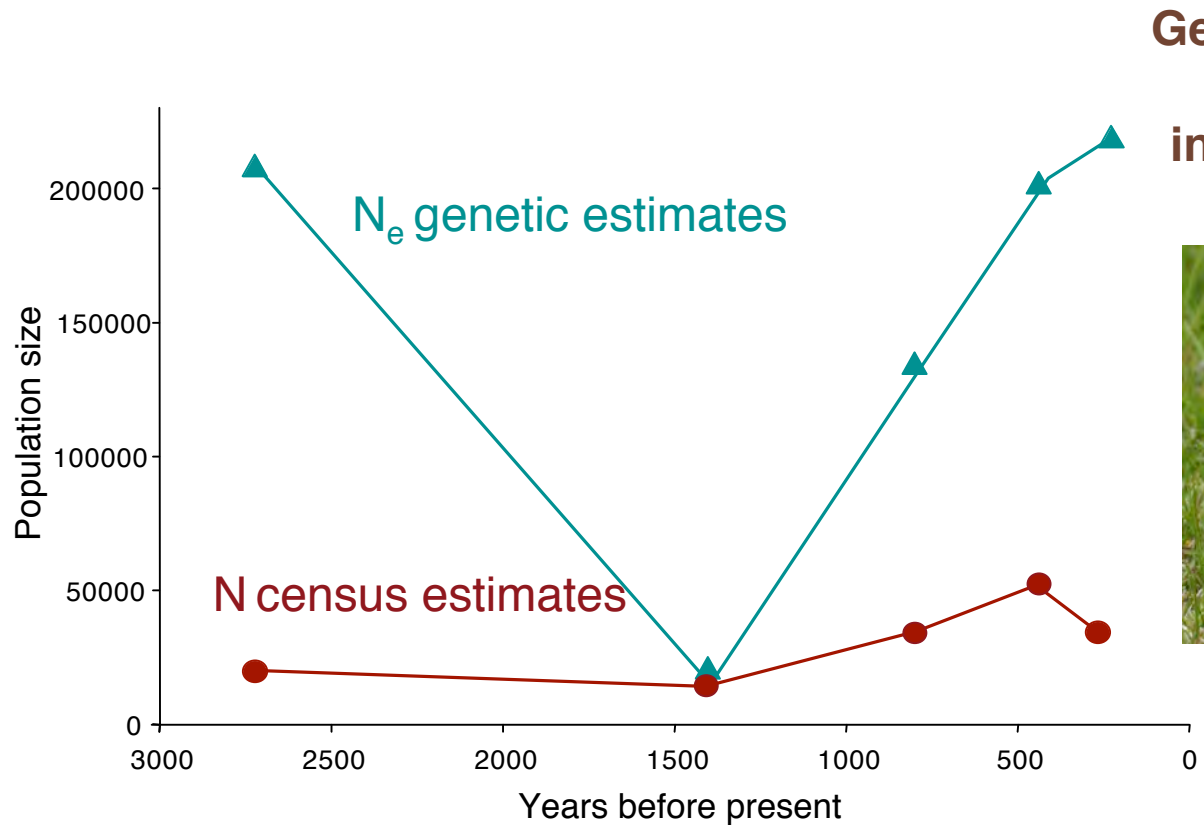
Mid-Holocene: Population size change



Uinta ground squirrel

O'Keefe *et al.* submitted

Mid-Holocene: Genetic change



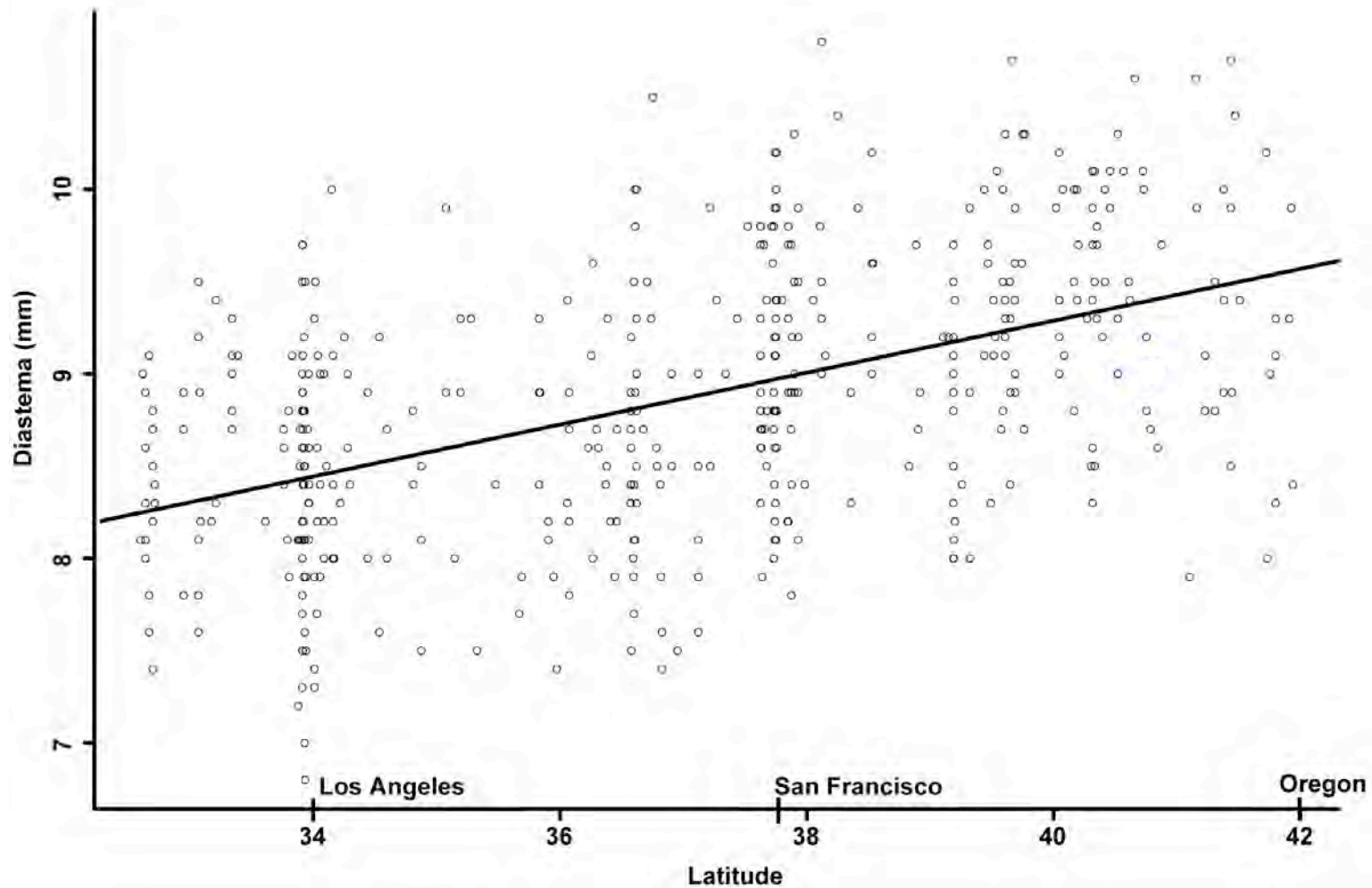
Genetic diversity *increases* with population size increase because of gene flow



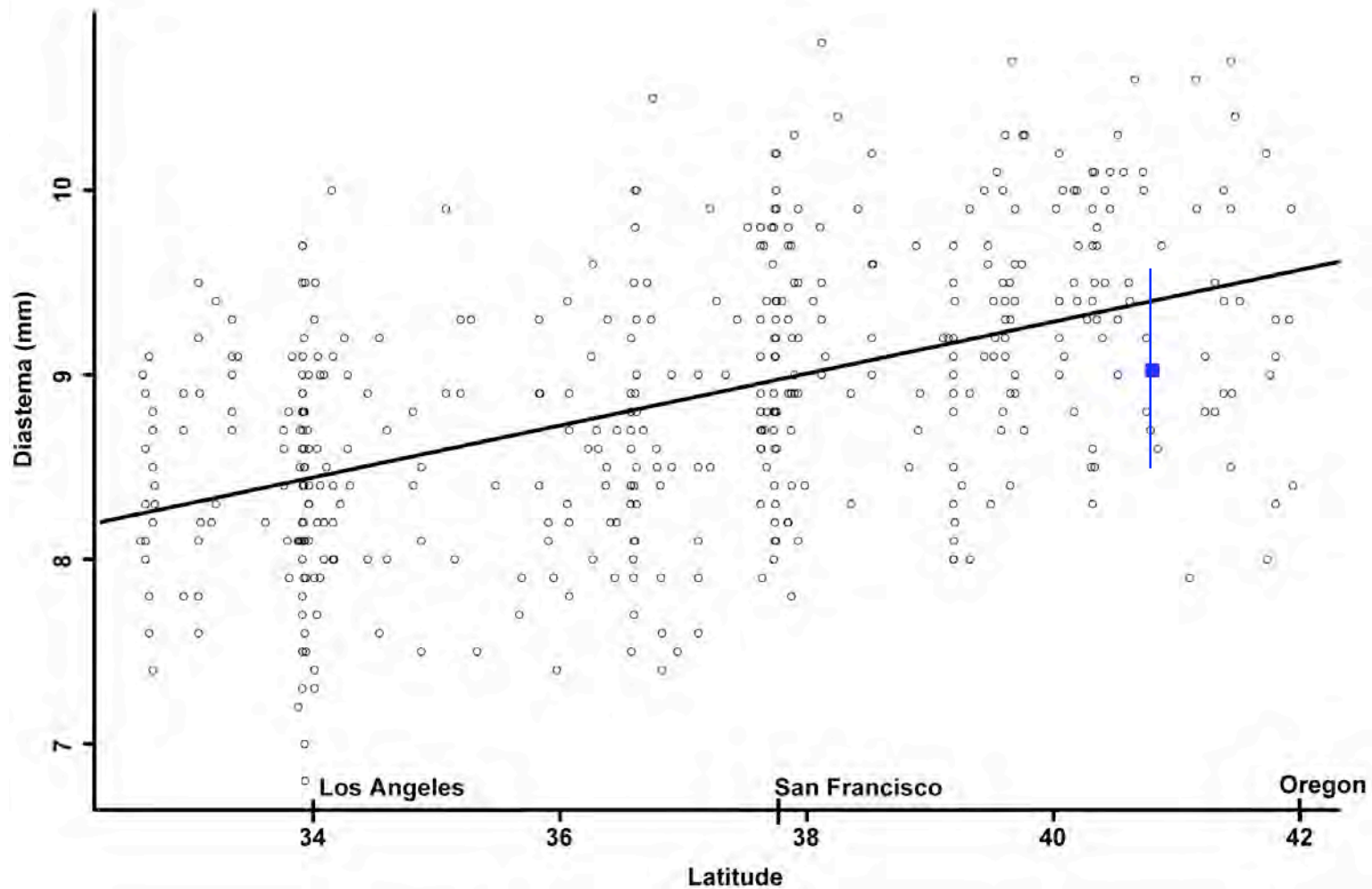
Uinta ground squirrel

Integrating past and present: California ground squirrels

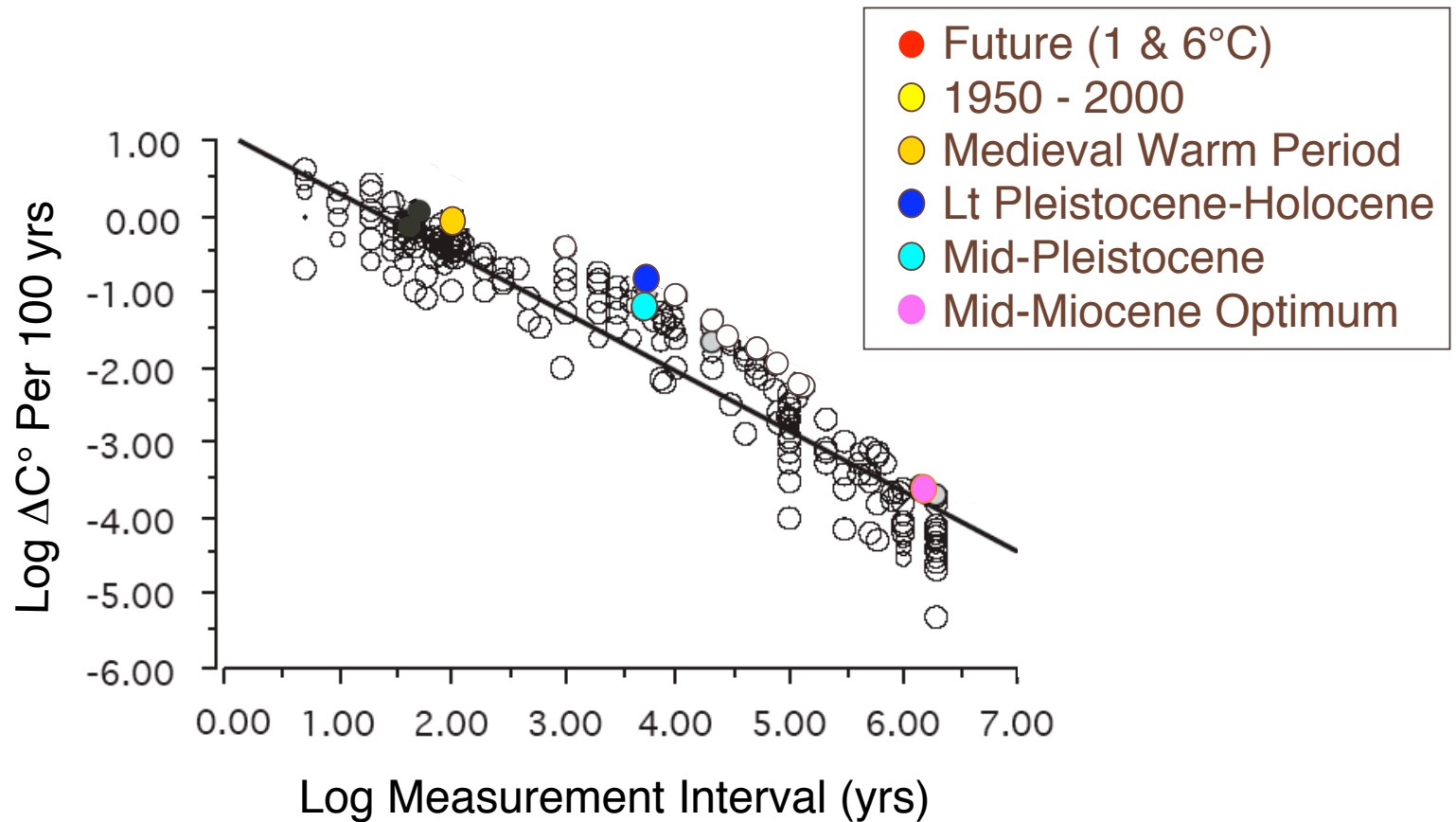
Integrating past and present: California ground squirrels



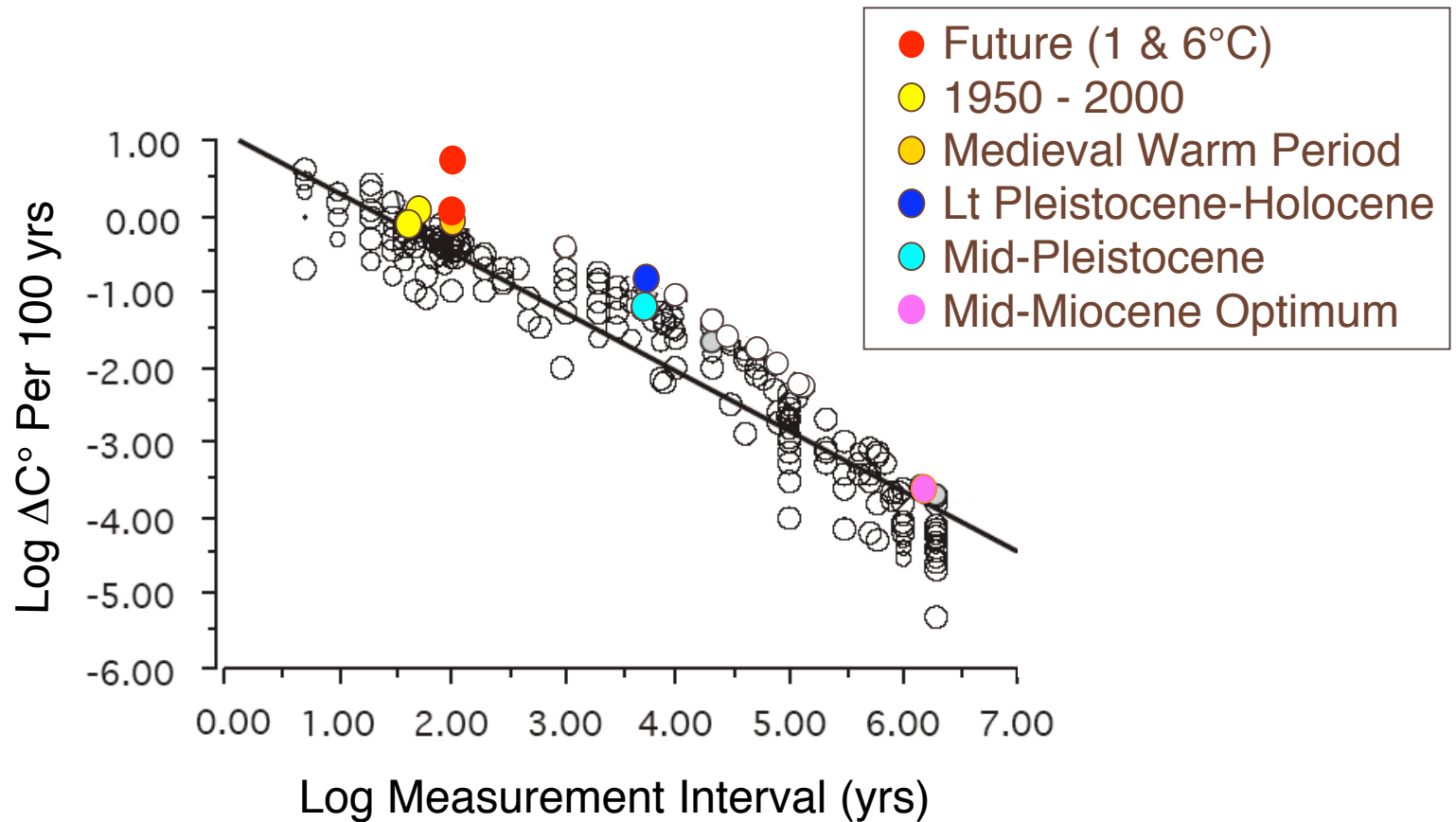
Integrating past and present: California ground squirrels



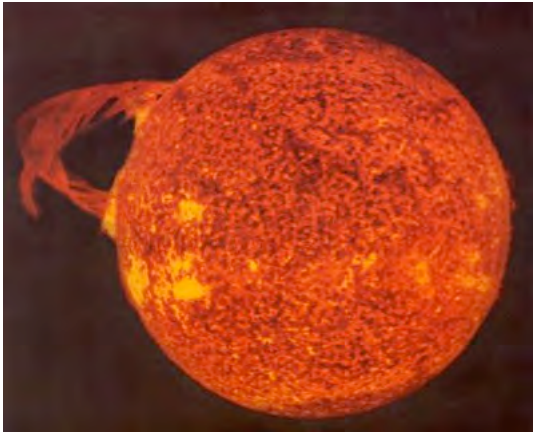
Does Rate of Warming Matter?



Does Rate of Warming Matter?



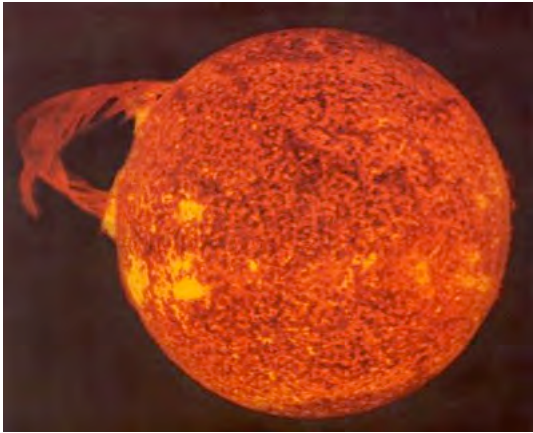
How Do Mammals Respond to Warming?



Community reorganization
Morphologic change
Extinction
Population size change
Range adjustment
Gene flow

Mid-Miocene
Mid-Pleistocene
Pleistocene/Holocene
Transition
Mid-Holocene
Medieval Warm Period

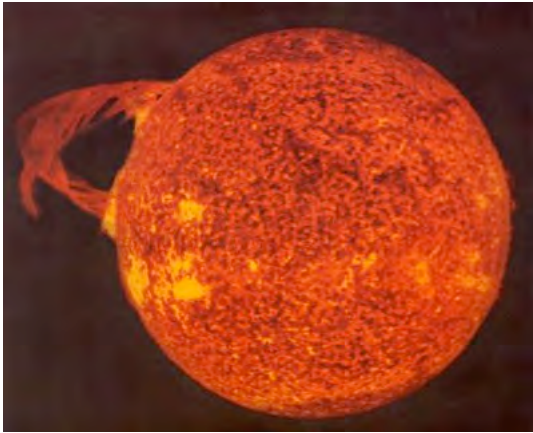
How Do Mammals Respond to Warming?



Community reorganization
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Range adjustment
Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change					
Extinction					
Population size change					
Range adjustment					
Gene flow					

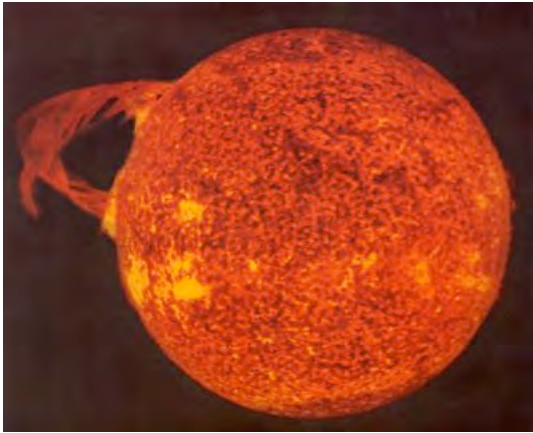
How Do Mammals Respond to Warming?



Community reorganization
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 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change		×	×		×
Extinction					
Population size change					
Range adjustment					
Gene flow					

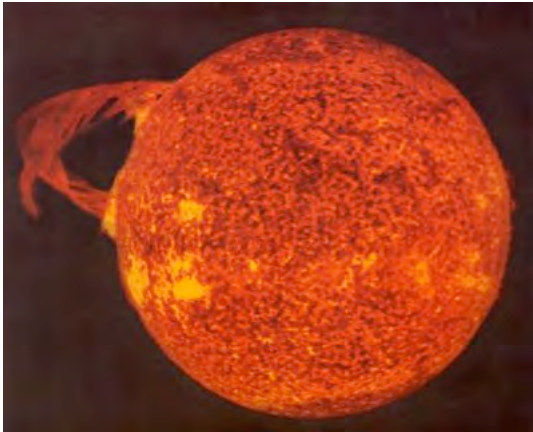
How Do Mammals Respond to Warming?



Community reorganization
 Morphologic change
 Extinction
 Population size change
 Range adjustment
 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change		×	×		×
Extinction			×		
Population size change					
Range adjustment					
Gene flow					

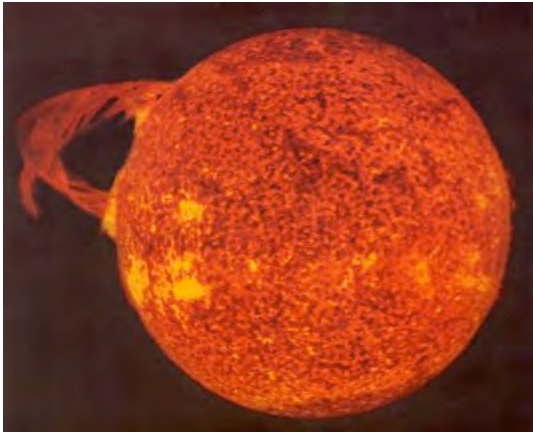
How Do Mammals Respond to Warming?



Community reorganization
 Morphologic change
 Extinction
 Population size change
 Range adjustment
 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change		×	×		×
Extinction			×		
Population size change				×	×
Range adjustment					
Gene flow					

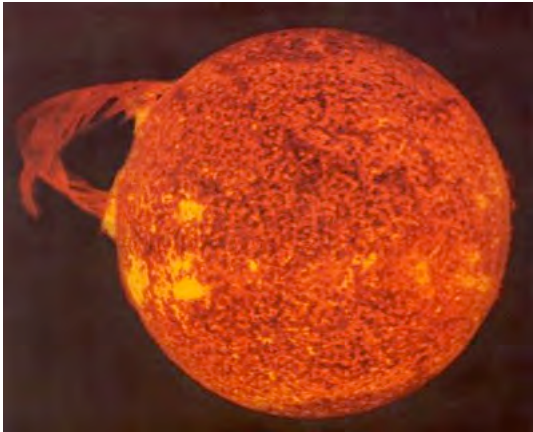
How Do Mammals Respond to Warming?



Community reorganization
 Morphologic change
 Extinction
 Population size change
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 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change		×	×		×
Extinction			×		
Population size change				×	×
Range adjustment			×	×	
Gene flow					

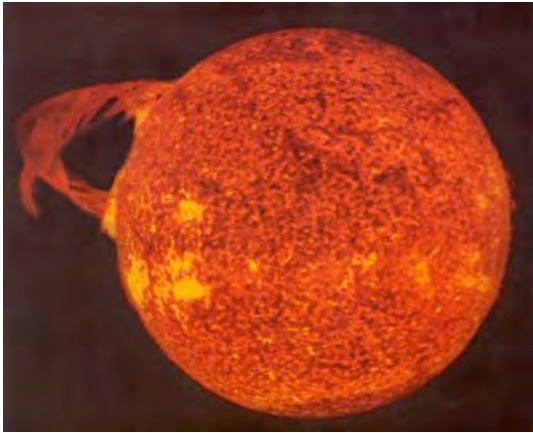
How Do Mammals Respond to Warming?



Community reorganization
 Morphologic change
 Extinction
 Population size change
 Range adjustment
 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period
Community reorganization	×		×		
Morphologic change		×	×		×
Extinction			×		
Population size change				×	×
Range adjustment			×	×	
Gene flow					×

How Do Mammals Respond to Warming?



Community reorganization
 Morphologic change
 Extinction
 Population size change
 Range adjustment
 Gene flow

	Mid-Miocene	Mid-Pleistocene	Pleistocene/Holocene Transition	Mid-Holocene	Medieval Warm Period	Future
Community reorganization	×		×			?
Morphologic change		×	×		×	?
Extinction			×			?
Population size change				×	×	?
Range adjustment		×	×			?
Gene flow					×	?

Acknowledgements



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