GIS Applications to Museum Specimens

Joseph Grinnell (1877–1939)

- "At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions in California and the west wherever we now work."
- Founder and First Director of MVZ
- Ecological Niche Concept

Biogeography, niche evolution and changing climates

- Arthur M. Sackler Colloquium of the National Academy of Sciences, held in Irvine, CA, December 11–13, 2008, in celebration of the Centennial of the Museum of Vertebrate Zoology at the University of California at Berkeley.

- PNAS---Vol 106, articles publ Nov 2009

Species distribution models

- based on current ecological niche constraints
- used to project future and past species distributions
- assumptions add uncertainty in model projections
  - structure of the models,
  - algorithms used to translate niche associations into distributional probabilities,
  - quality and quantity of data,
  - mismatches between the scales of modeling and data.

Niche Modeling and statistical phylogeography of the Western Jumping Mouse (*Zapus princeps)* : Testing alternative hypotheses

Jason L. Malaney

The Question

- Assessing past geographical distributions and processes
- Do communities remain intact through time OR do taxa respond to environmental change idiosyncratically?
  - comparative phylogeography across multiple species
  - Signals of introgression in taxa thru glacial cycles?
  - OR did taxa remain in sustained isolation?

Importance of Museums…

- Documentation
  - Provide verifiable evidence of who, what, when, where, how, why
  - Data can then be used to ask interesting questions over evolutionary time
    - Where did organisms potentially occur in the past?
    - Where will organisms go with changes in climate?

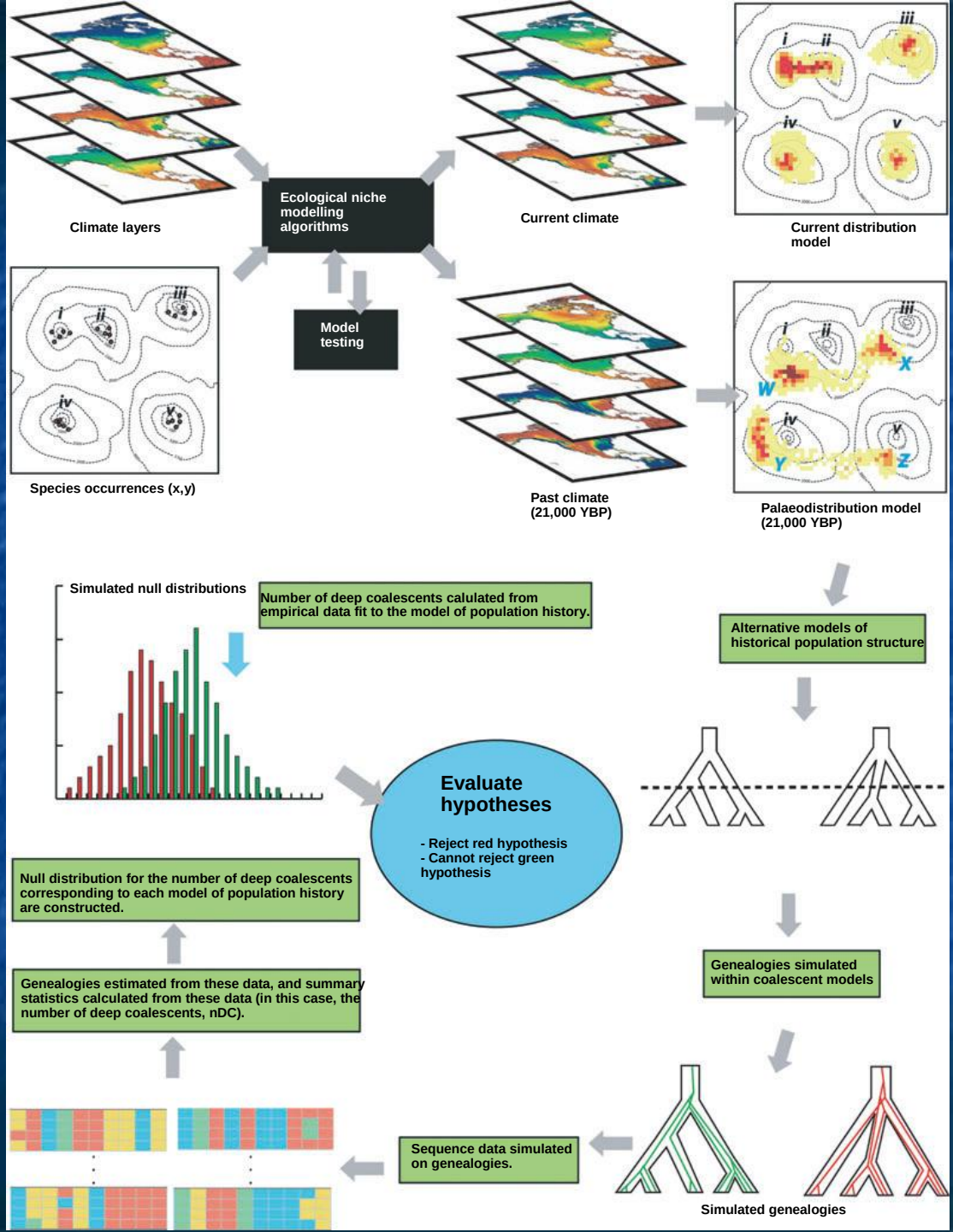
Where did organisms potentially occur in the past?

- Calculate current distribution model
- Project to past - Paleoclimate distribution
- Propose alternative hypotheses of demography of organisms
  - Test hypotheses empirically with multi-locus DNA data
    - Effective population sizes – Ne
    - relatedness of lineages – clades & trees
    - Divergence dates - when splits between lineages occurred
  - Relate these back to paleo-distributions and contemporary distributions
- Very strong story of **history** of organisms
  - Natural history museums are fundamental…

Where will organisms go with changes in climate?

- Calculate current distribution model
- Project to future - future distribution
  - Helps with making decisions about conservation of lineages → areas
  - Helps to project if current activities may have future repercussions
- Very strong story of **future** of organisms
  - Natural history museums are fundamental…

- Strengths of phylogeography & coalescent modeling
  - Statistical inference – Parametric Bootstrap
  - GIS technologies – ecological niche models
  - Multiple independent markers
  - Multiple species



Richards et al. 2007

Empirical Example

- Are distributions of western North American mammals ephemeral or persistent historically?

- Single Ancestor

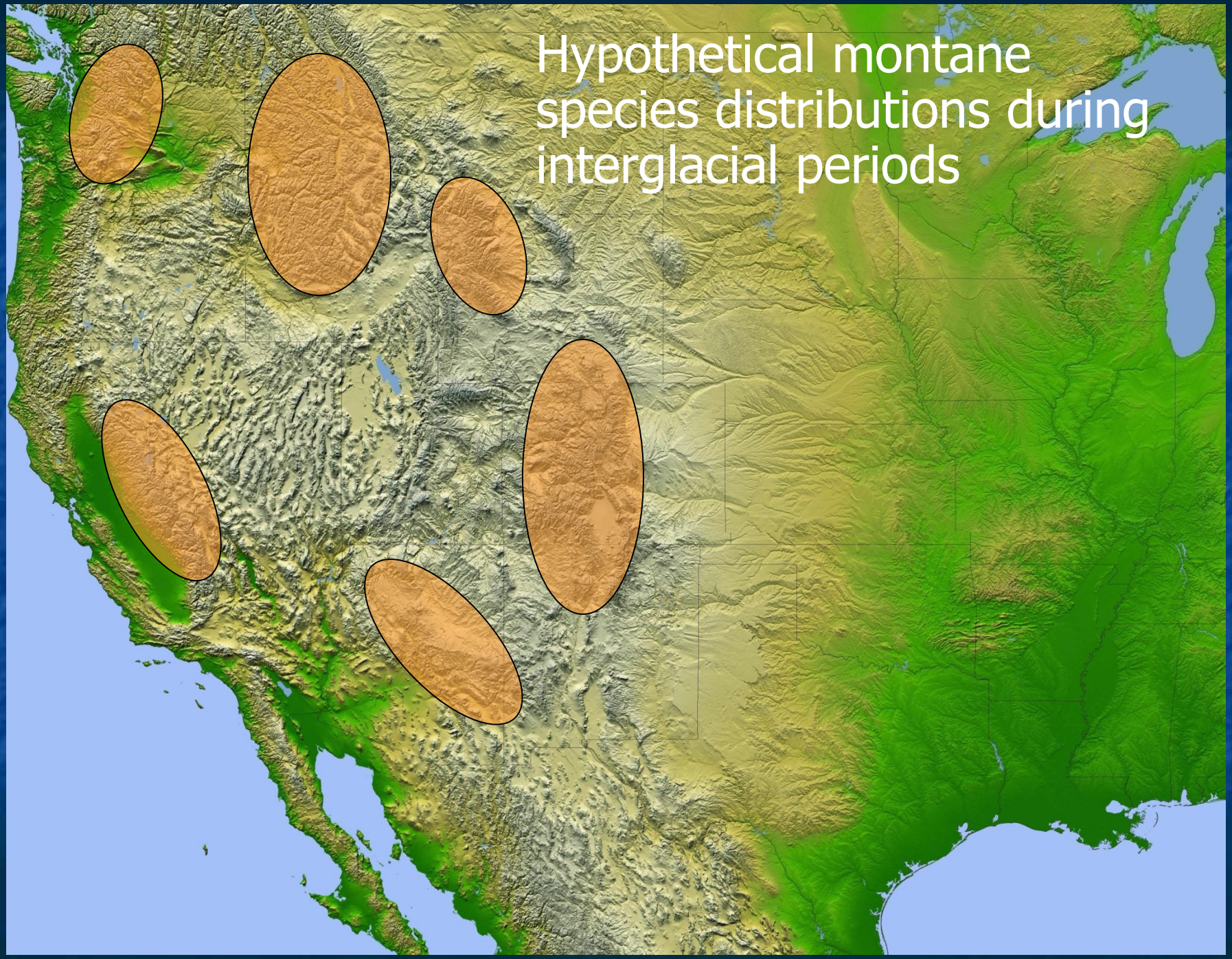
- Populations have recently fragmented from a common ancestor

- Independent Refuge

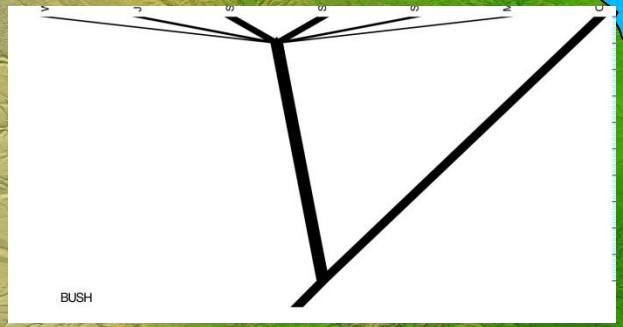
- Populations were disjunct, persisting in isolated pockets throughout glacial cycles

- Admixture

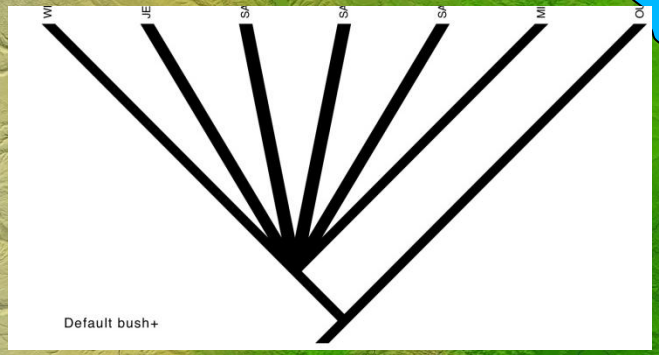
- No isolation during glaciations - populations repeatedly introgress
- Habitats coalesced and became less isolated


Hypothetical montane species distributions during interglacial periods

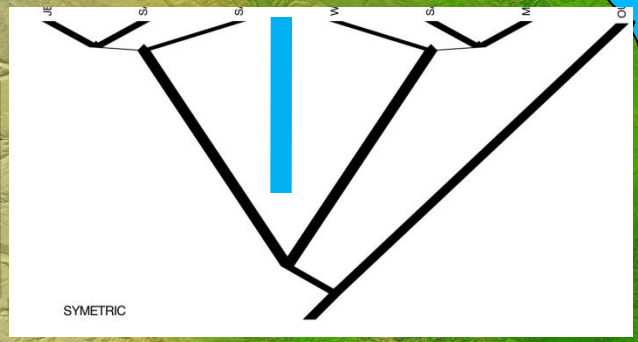
Single ancestor during glacial periods?



Admixture during glacial periods?

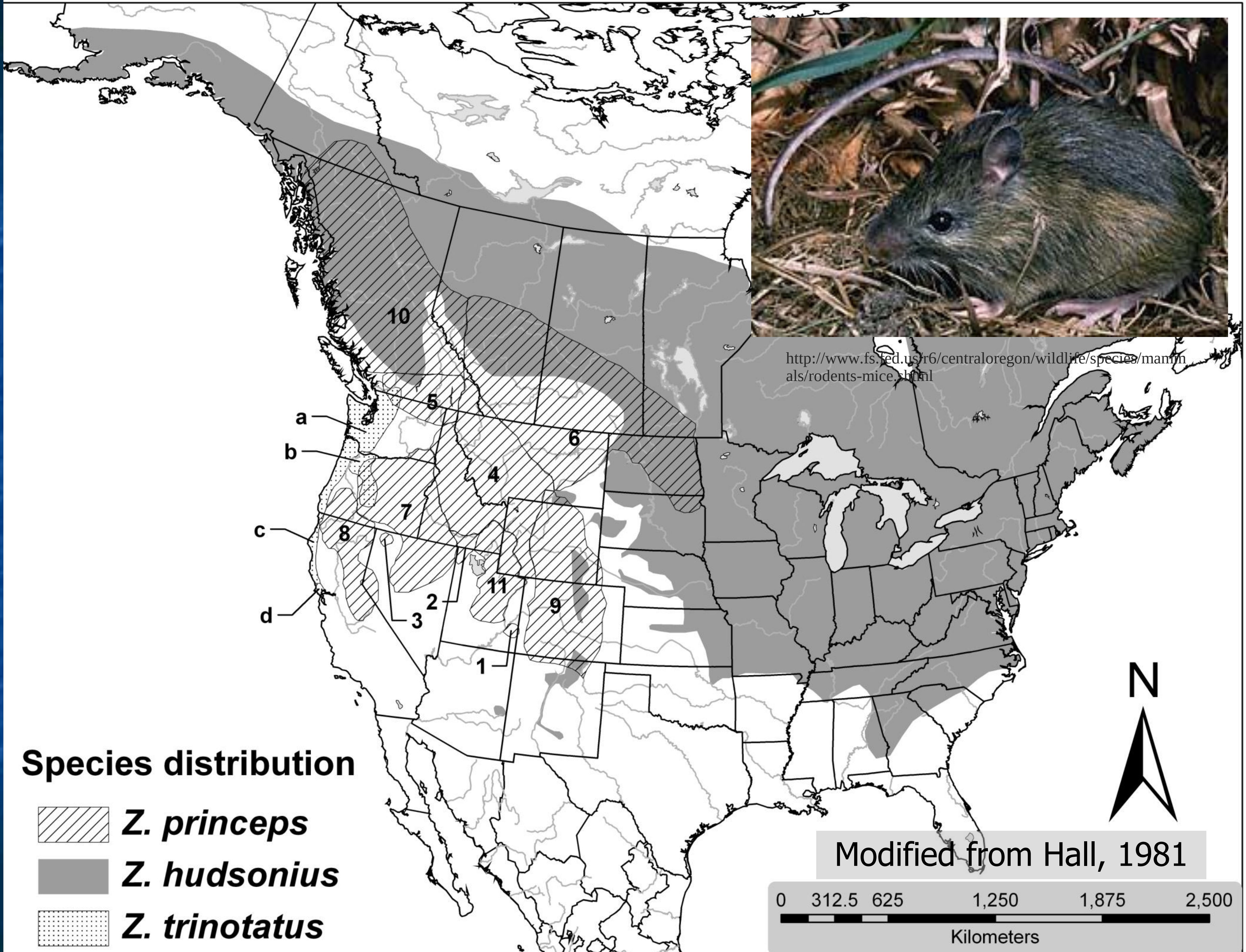


Independent refuge during glacial periods?



Zapus princeps

- One of 3 species of *Zapus*
  - Family Dipodidae
- Range: Western North America
  - New Mexico to southern Yukon
- Habitat: Generally willow and aspen thickets along riparian zones
  - Dense vegetation, highly fragmented in SW
- Biology: active 3-4 months, low natality, long generations, low densities

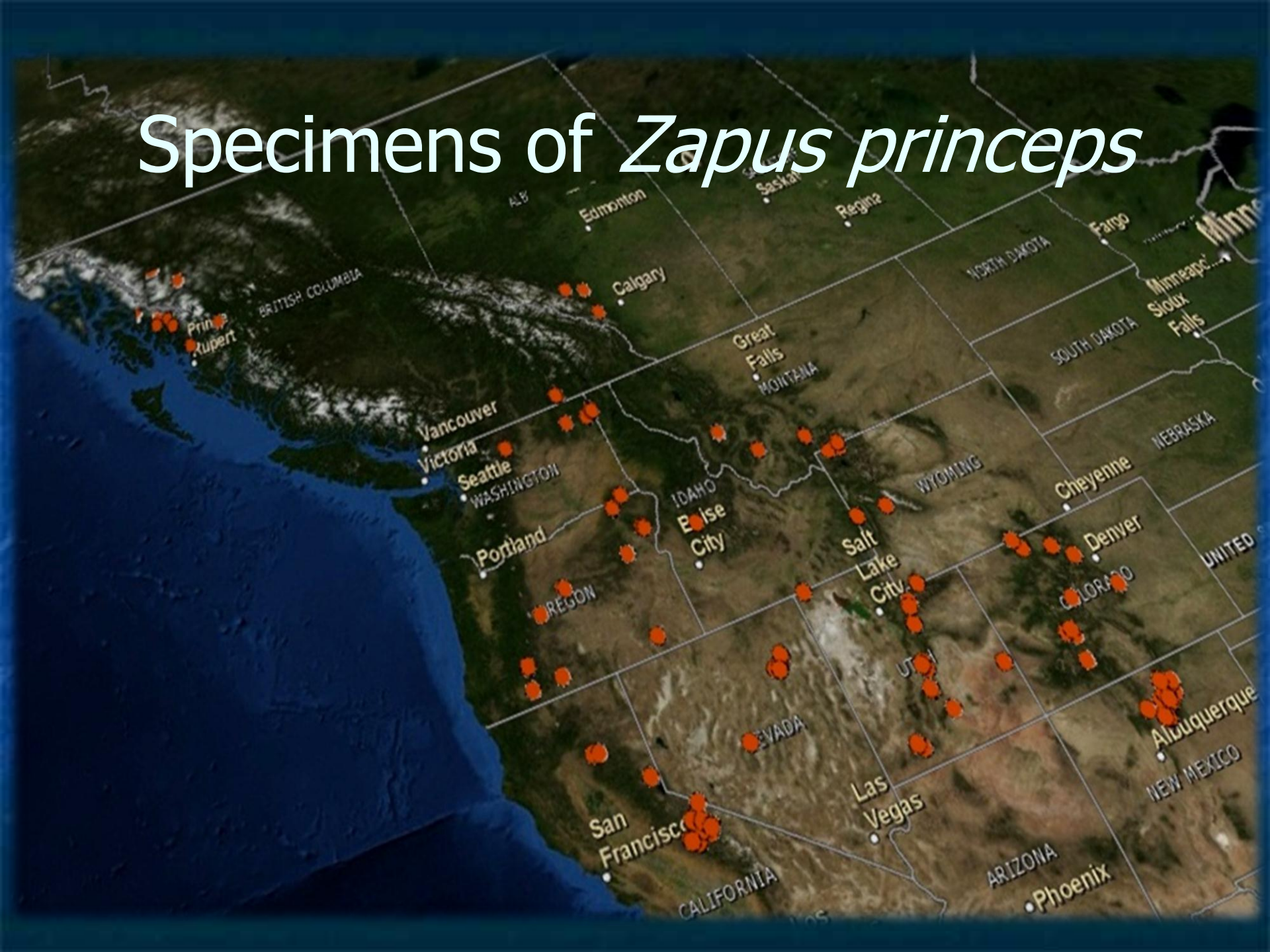


http://www.fs.fed.us/r6/centraloregon/wildlife/species/mammals/rodents-mice.shtml

Methods

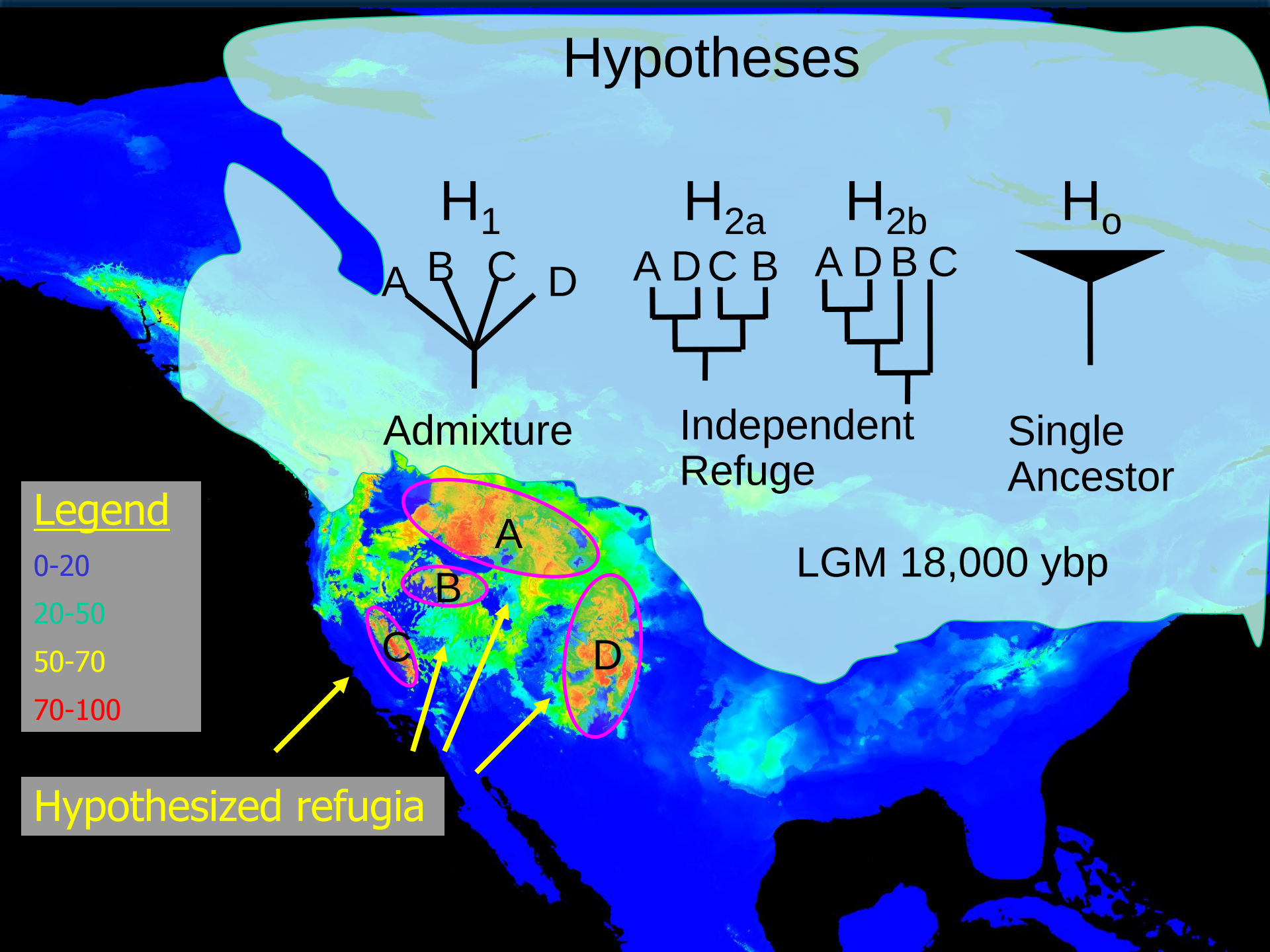
- Tissues obtained from natural history collections
  - DMNS, FMNH, MSB, MVZ, UAM, UMNH, and UWBM
- MtDNA
  - 1140 base pairs of Cytochrome *b* gene
  - 295 Total specimens: 292 sequenced (28 from Patton and Conroy), 3 from GenBank
    - 221 *Zapus princeps,* 65 *Z. hudsonius,* 8 *Z. trinotatus,* 1 *Napaeozapus insignius*
- Nuclear DNA – 5 genes
  - APOB – 367bp, BCRA – 919bp, EFG – 573, GBA – 528bp, MYH2 – 266bp
  - 63 specimens representing major mtDNA clades
- Total: 3793bp

Specimens of *Zapus princeps*



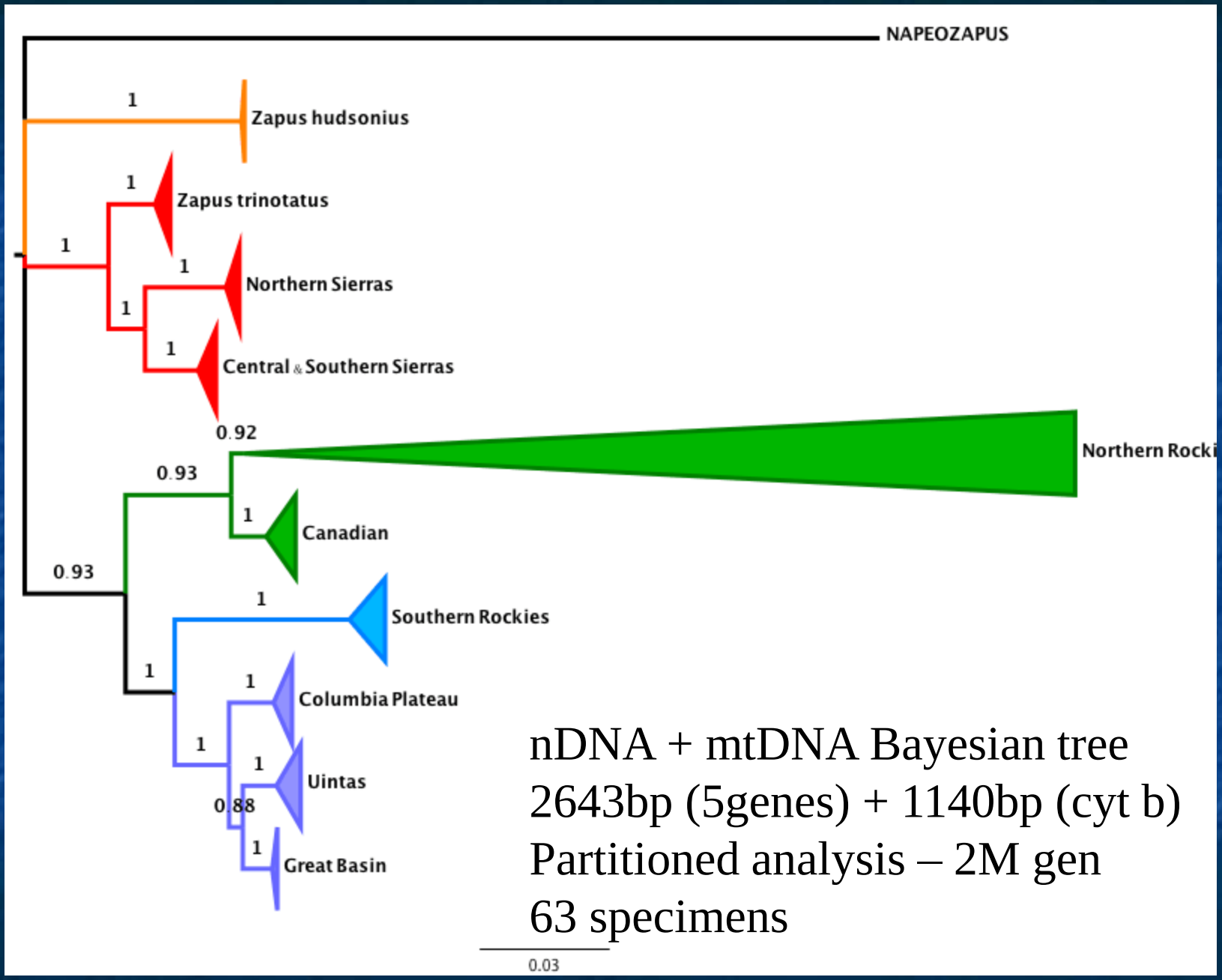
Niche Models & Parameters

- Set the stage for specific hypotheses
- Identify and calculate specific parameters which influence hypotheses – Empirical
  - Phylogeny & Model of Evolution
  - Effective Population Size – Ne
    - Total and lineage
  - Divergence Time - coalescent

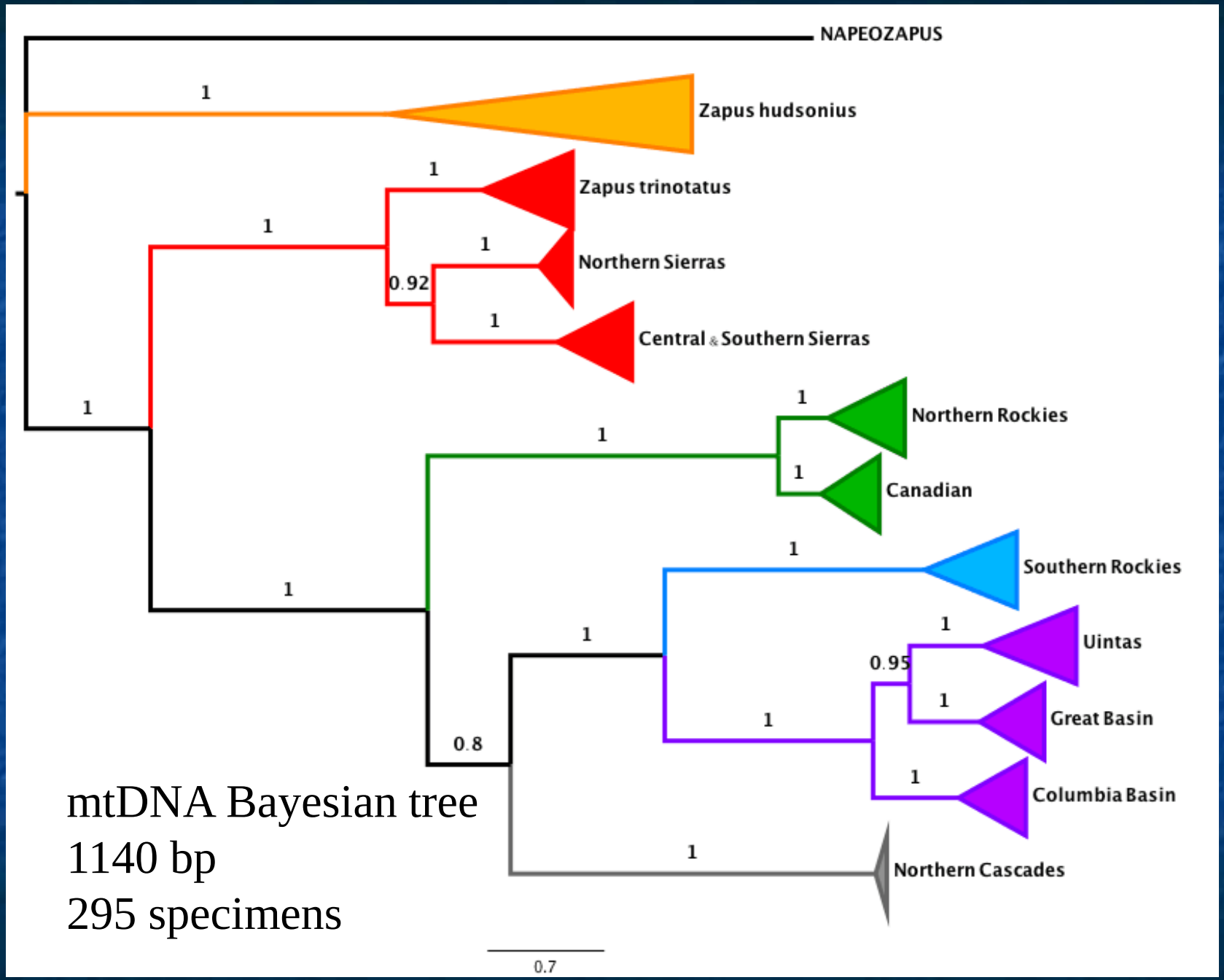

Hypotheses
H1
A B C D
H2a
A D C B
H2b
A D B C
Ho
Admixture
Independent Refuge
Single Ancestor
LGM 18,000 ybp
Legend
0-20
20-50
50-70
70-100
A
B
C
D
Hypothesized refugia

Methods

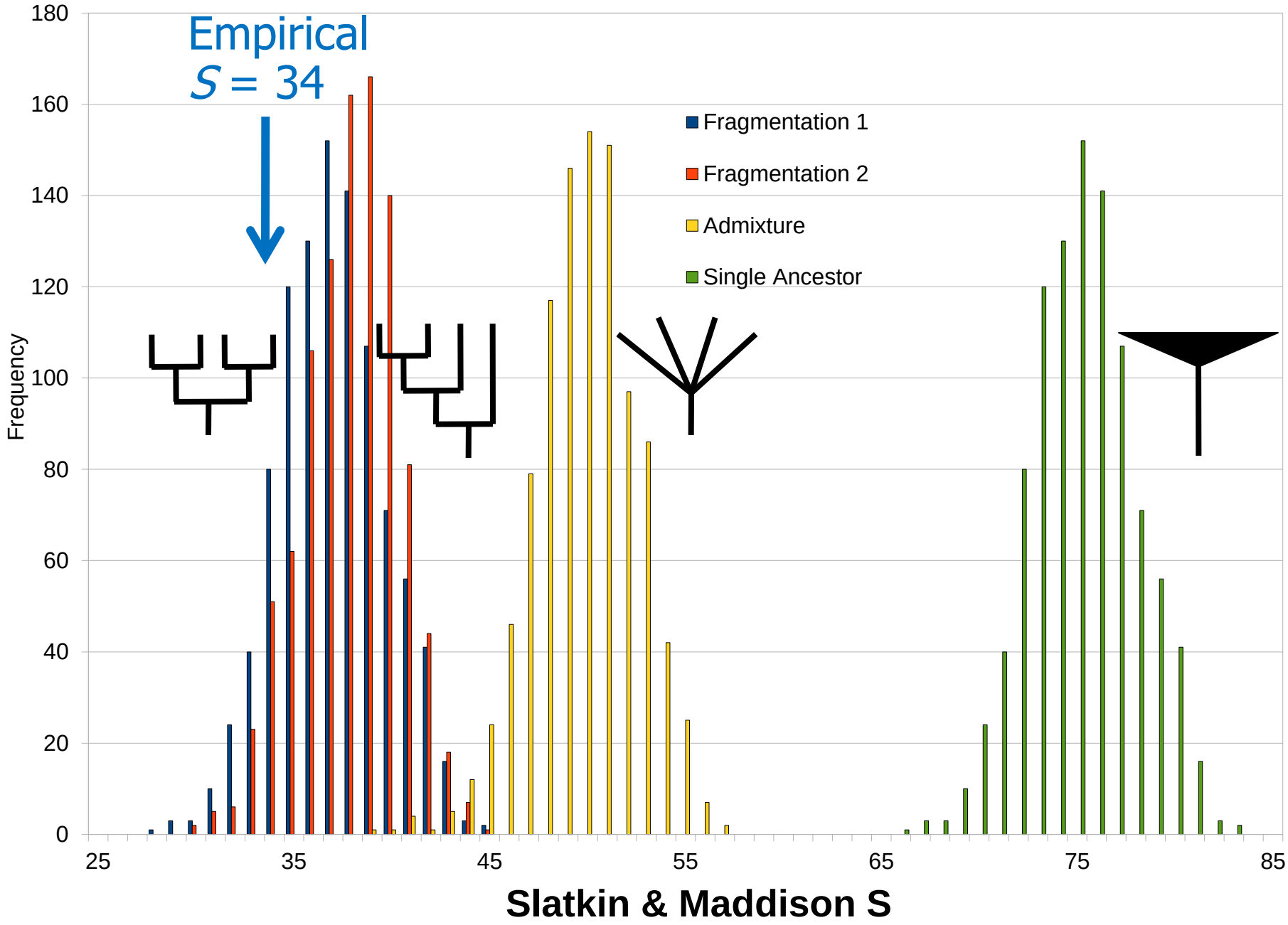
- Statistical phylogeography of *Z. princeps*
  - Test alternative hypotheses of historical demography
- Model based coalescent techniques
  - parametric bootstrap - MESQUITE
    - Simulate genealogies & sequences – probability distribution
      - GTR + I + Γ
    - Metric - *s* of Slatkin and Maddison
    - Compare empirical value to those generated randomly



nDNA + mtDNA Bayesian tree
2643bp (5genes) + 1140bp (cyt b)
Partitioned analysis – 2M gen
63 specimens



mtDNA Bayesian tree
1140 bp
295 specimens

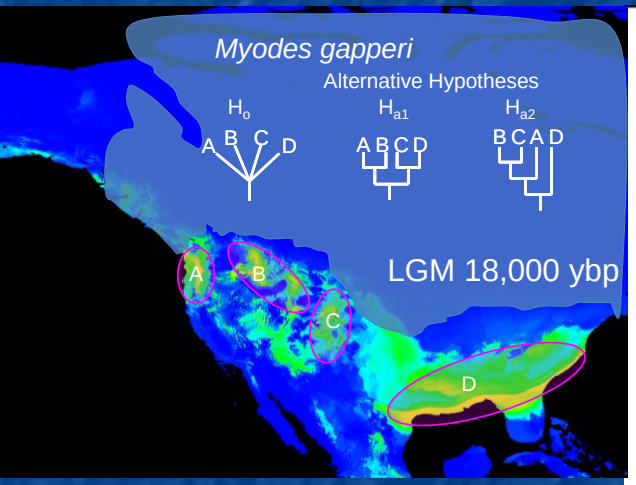

Empirical
S = 34
Fragmentation 1
Fragmentation 2
Admixture
Single Ancestor
Frequency
0
20
40
60
80
100
120
140
160
180
25
35
45
55
65
75
85
Slatkin & Maddison S

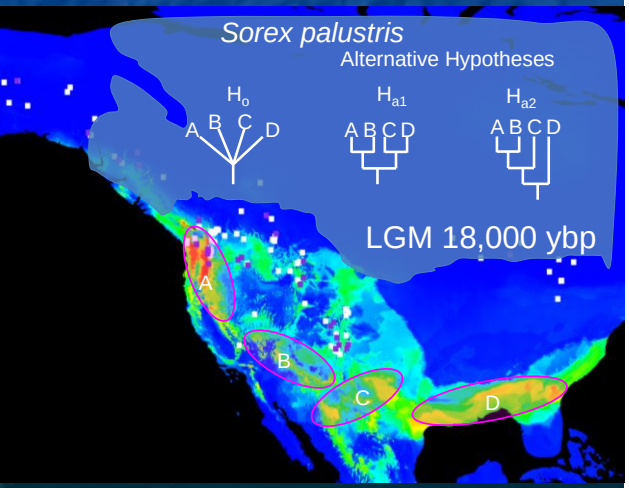
Summary

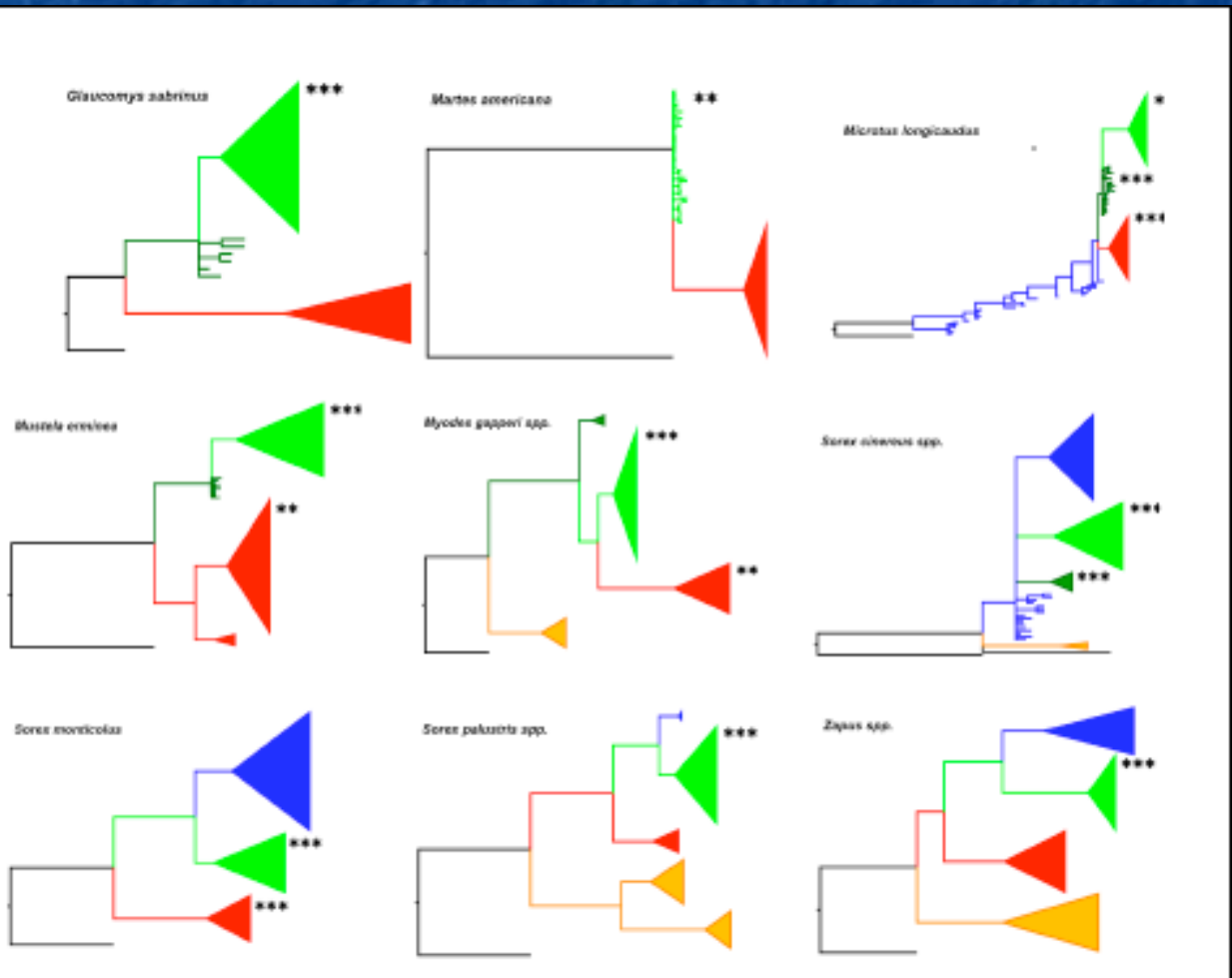
- Highly divergent *Zapus princeps* lineages
  - 4 distinct, monophyletic, and novel lineages
    - Multiple markers
  - structured lineages that exhibit high levels of deep historical differentiation
    - May warrant taxonomic revisions
    - Morphology
- Jumping mice in western NA appear to have undergone sustained fragmentation
  - Can not reject the independent refuge hypotheses
  - Challenge is to disentangle alternative models
    - more specific parameterization within fragmentation model

Other montane species?

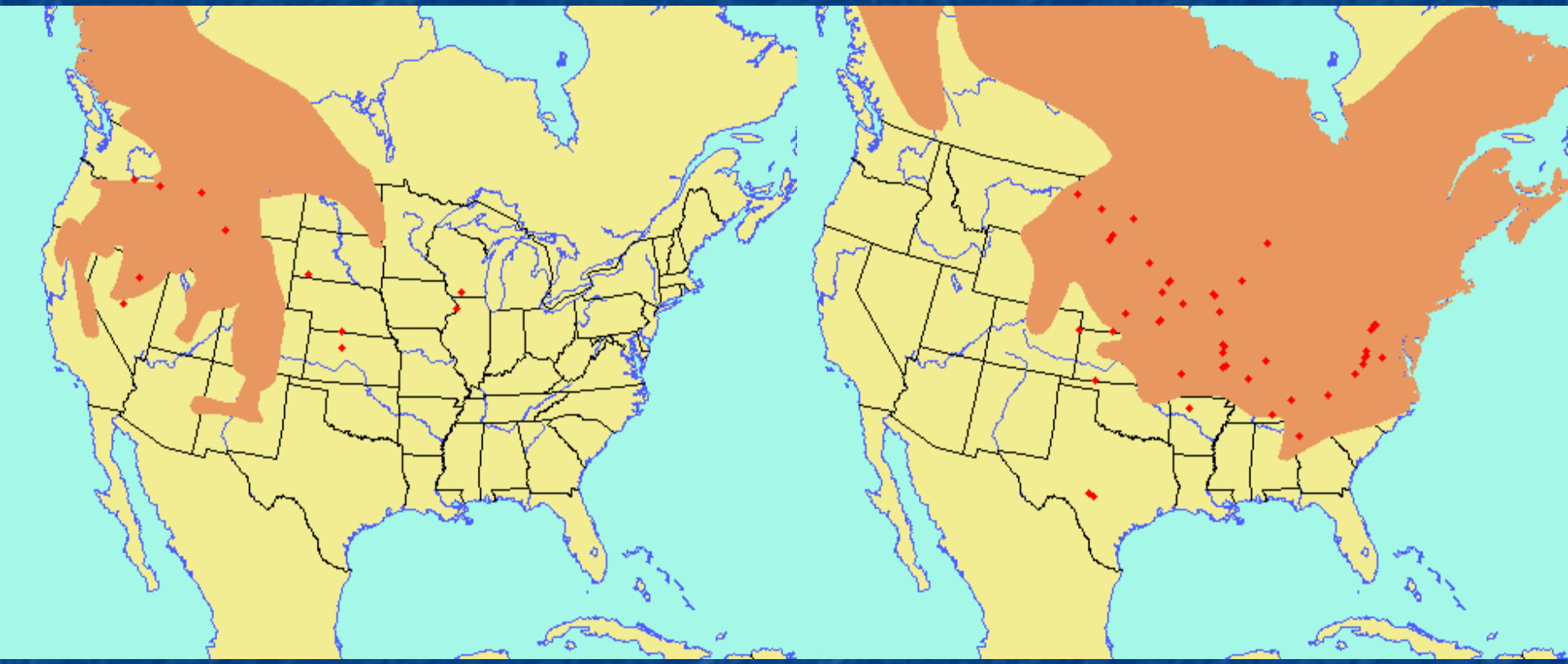
- Comparative Phylogeography
  - Do communities remain intact through time OR do taxa respond to environmental change idiosyncratically?







Fossil Record



Zapus princeps ***Zapus hudsonius***