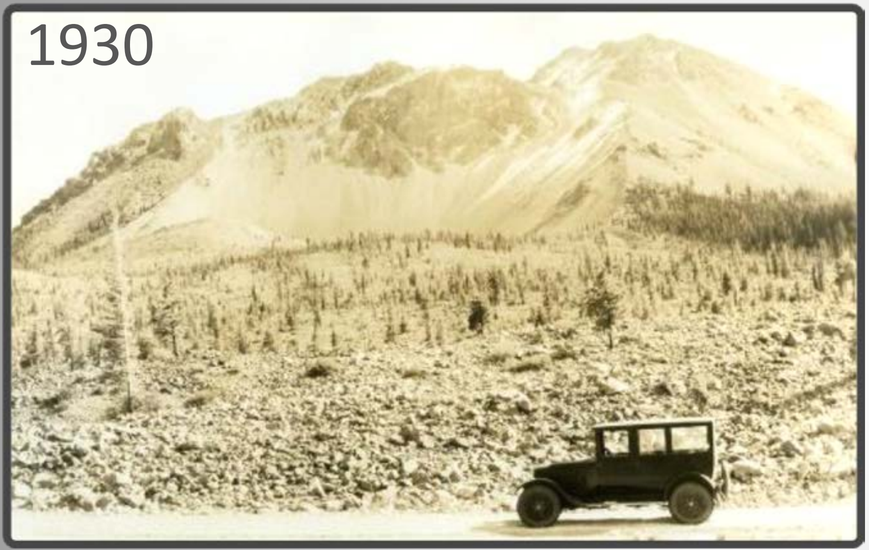
Effects of Recent Climate Change on Terrestrial Vertebrate Ranges in California:

The Grinnell Resurvey Project



Kelly Iknayan & Steve Beissinger

Dept. of Environmental Science, Policy & Management and Museum of Vertebrate Zoology, UC Berkeley

Effects of Recent Climate Change on Terrestrial Vertebrate Ranges in California

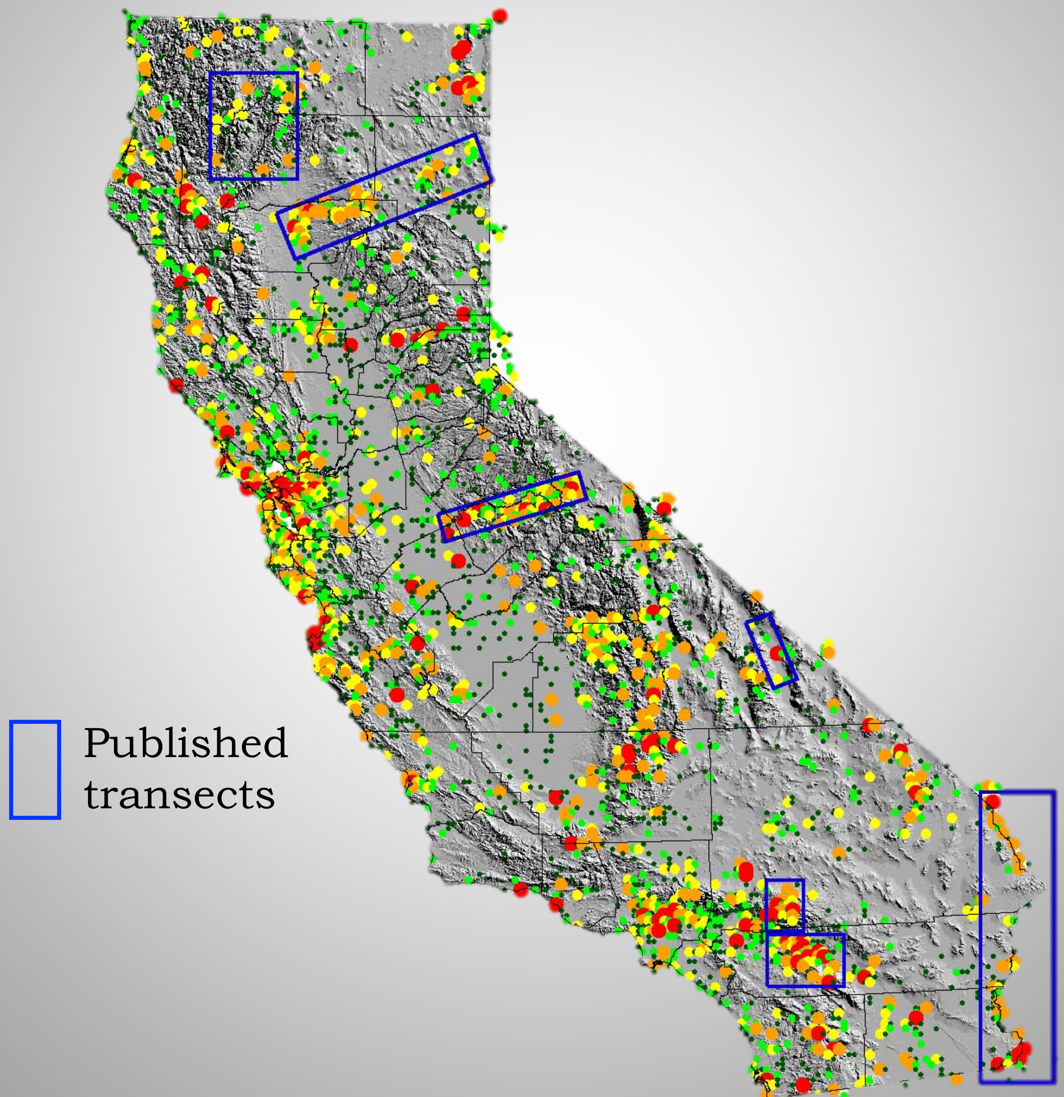
- Vertebrates == Mammals and Birds
- Range == Elevational Range Dynamics
- In California == the Sierra Nevada

THE GRINNELL RESURVEY PROJECT

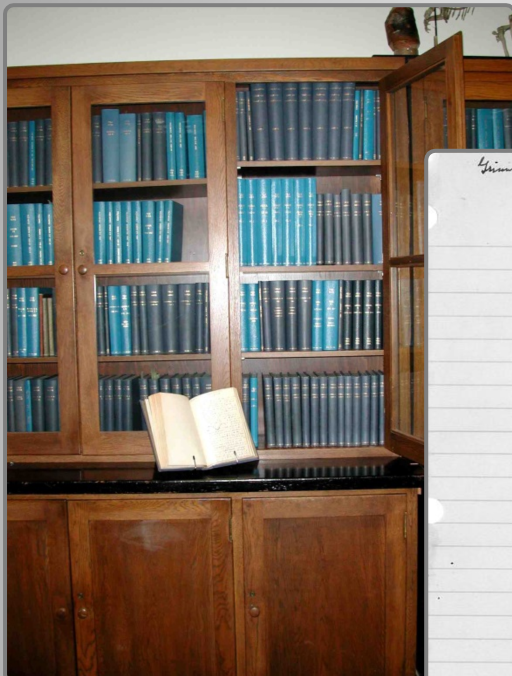
The Grinnell Legacy

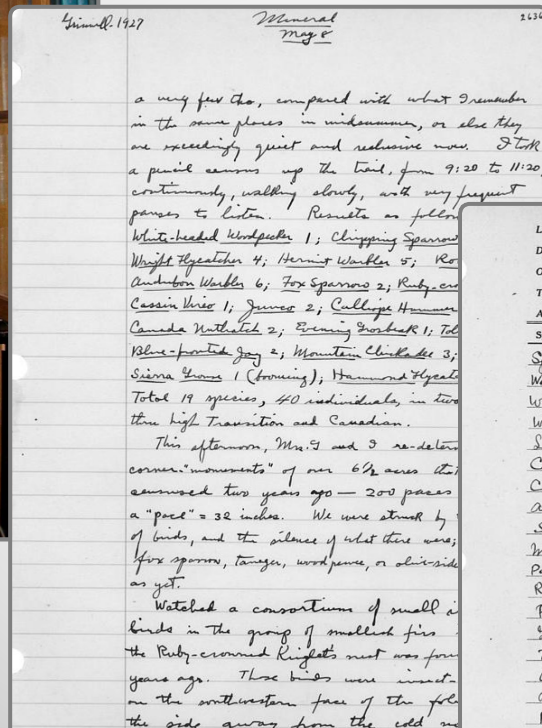
Joseph Grinnell
MVZ Director 1908-39

Pre-1940 MVZ: Specimen Locality Records



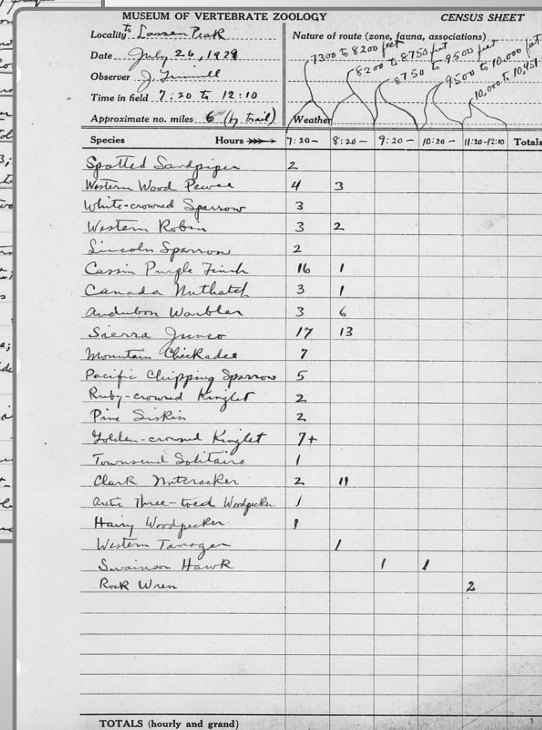
Pre-1940 MVZ: Field Notes





Grinnell 1927 — Mineral — May 8 — 2636

a very few tho, compared with what I remember
in the same places in midsummer, or else they
are exceedingly quiet and reclusive now. I took
a pencil census up the trail, from 9:20 to 11:20,
continuously, walking slowly, with very frequent
pauses to listen. Results as follo
White-headed Woodpecker 1; Chipping Sparrow
Wright Flycatcher 4; Hermit Warbler 5; Ro
Audubon Warbler 6; Fox Sparrow 2; Ruby-cr
Cassin Vireo 1; Junco 2; Calliope Hummi
Canada Nuthatch 2; Evening Grosbeak 1; Tol
Blue-fronted Jay 2; Mountain Chickadee 3;
Sierra Grouse 1 (booming); Hammond Flycat
Total 19 species, 40 individuals, in two
thru high Transition and Canadian.
This afternoon, Mrs. G and I re-determ
corner "monuments" of our 6½ acres tha
censused two years ago — 200 paces
a "pace" = 32 inches. We were struck by
of birds, and the silence of what there were;
fox sparrow, tanager, wood pewee, or olive-side
as yet.
Watched a consortium of small i
birds in the group of smallish firs
the Ruby-crowned Kinglet's nest was foun
years ago. These birds were insect-
on the southwestern face of the fol
the side away from the cold n



MUSEUM OF VERTEBRATE ZOOLOGY — CENSUS SHEET

Locality: to Lassen Peak
Date: July 26, 1929
Observer: J. Grinnell
Time in field: 7:20 to 12:10
Approximate no. miles: 6 (by trail)
Nature of route (zone, fauna, associations): 7300 to 8200 feet; 8200 to 8750 feet; 8750 to 9500 feet; 9500 to 10,000 feet; 10,000 to 10,451
Weather

Species	7:20–	8:20–	9:20–	10:20–	11:20–12:10	Totals
Spotted Sandpiper	2					
Western Wood Pewee	4	3				
White-crowned Sparrow	3					
Western Robin	3	2				
Lincoln Sparrow	2					
Cassin Purple Finch	16	1				
Canada Nuthatch	3	1				
Audubon Warbler	3	6				
Sierra Junco	17	13				
Mountain Chickadee	7					
Pacific Chipping Sparrow	5					
Ruby-crowned Kinglet	2					
Pine Siskin	2					
Golden-crowned Kinglet	7+					
Townsend Solitaire	1					
Clark Nutcracker	2	11				
Arctic Three-toed Woodpecker	1					
Hairy Woodpecker	1					
Western Tanager		1				
Swainson Hawk			1	1		
Rock Wren					2	
TOTALS (hourly and grand)						

The Grinnell Legacy

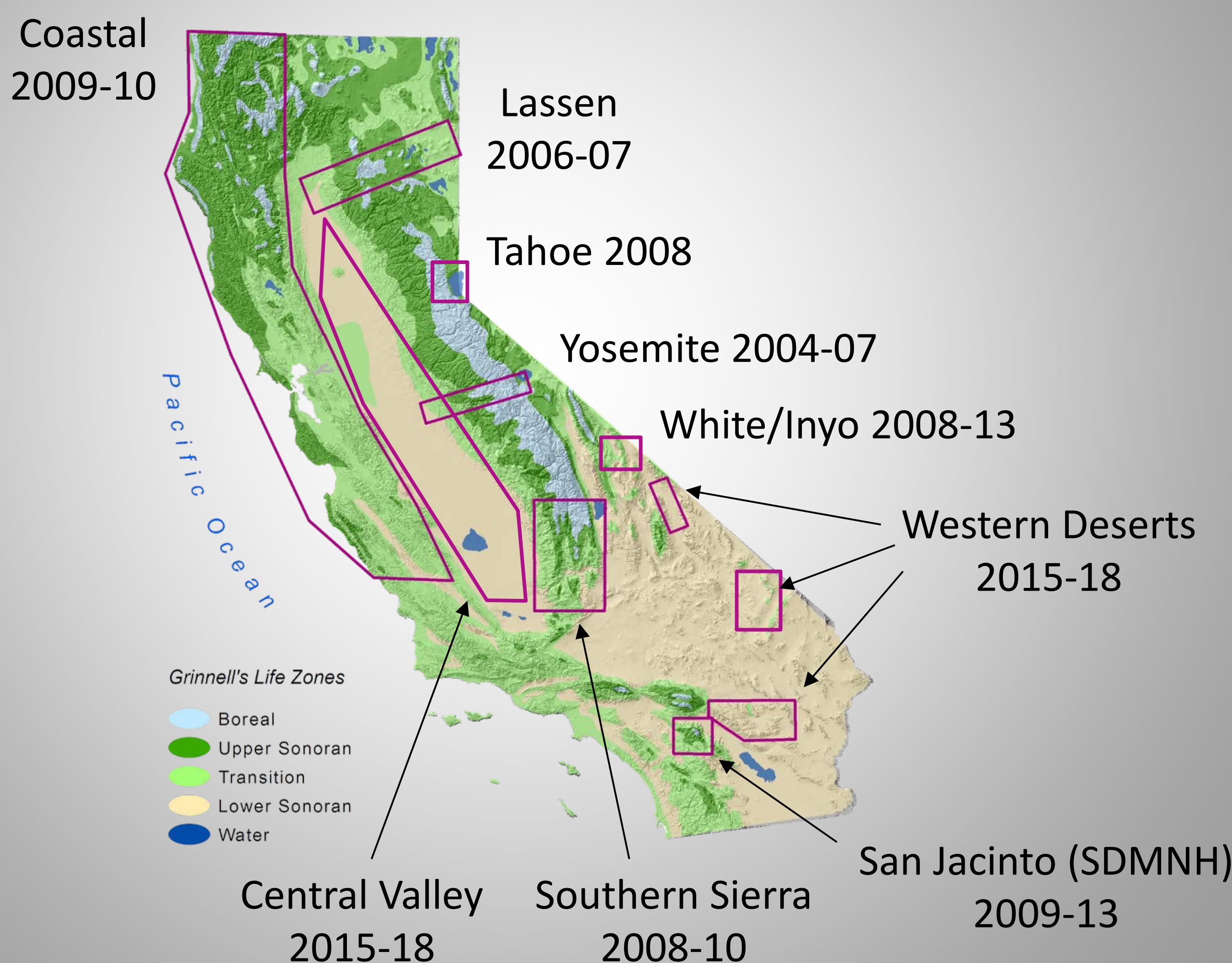
"… the greatest purpose of our museum … will not, however, be realized until the lapse of many years, possibly a century…. And this is that the student of the future will have access to the original record of faunal conditions in California and the west…"

-Grinnell, 1910

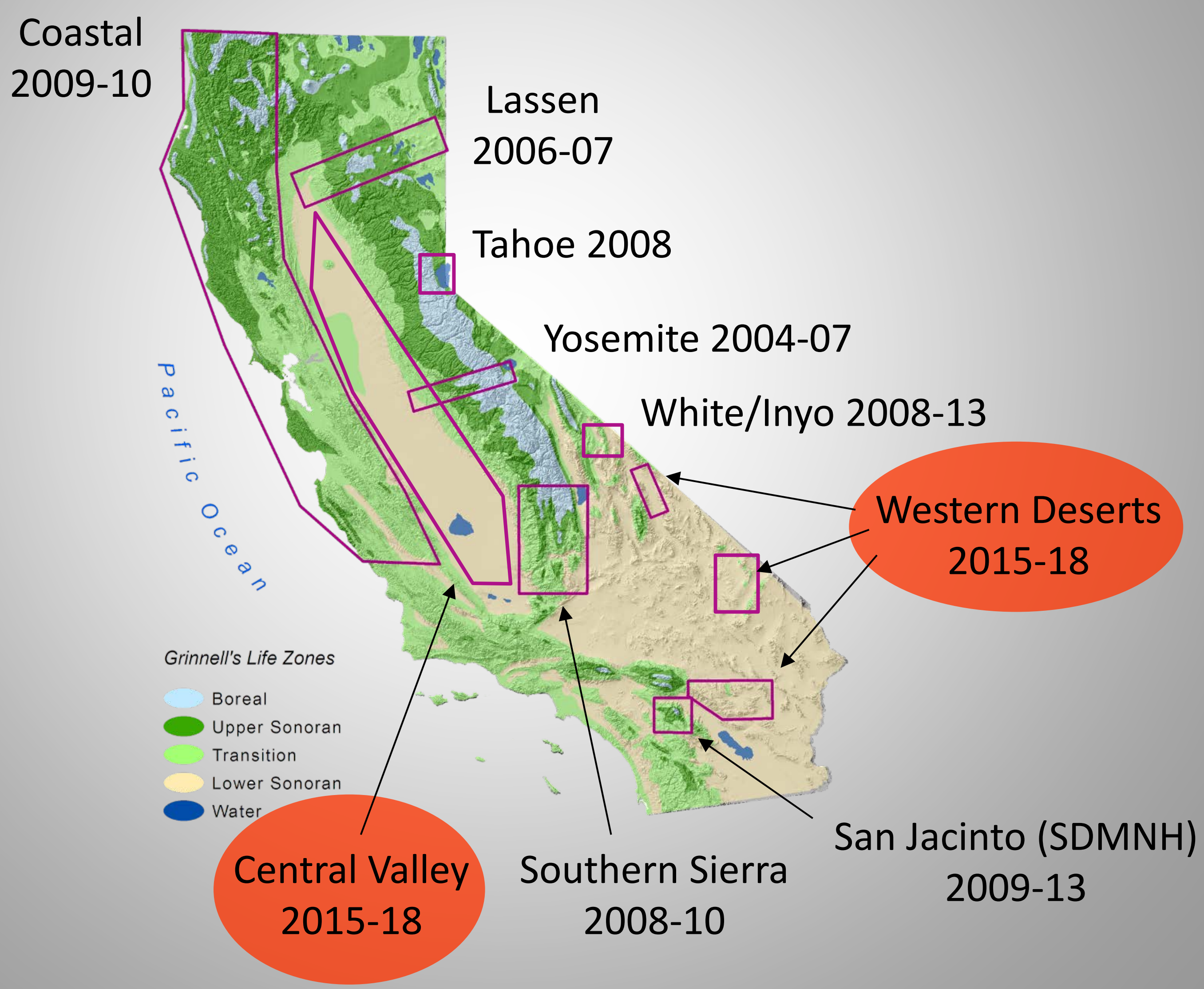
Joseph Grinnell
MVZ Director 1908-39

The Grinnell Resurvey Project

(*2004 - Present*)



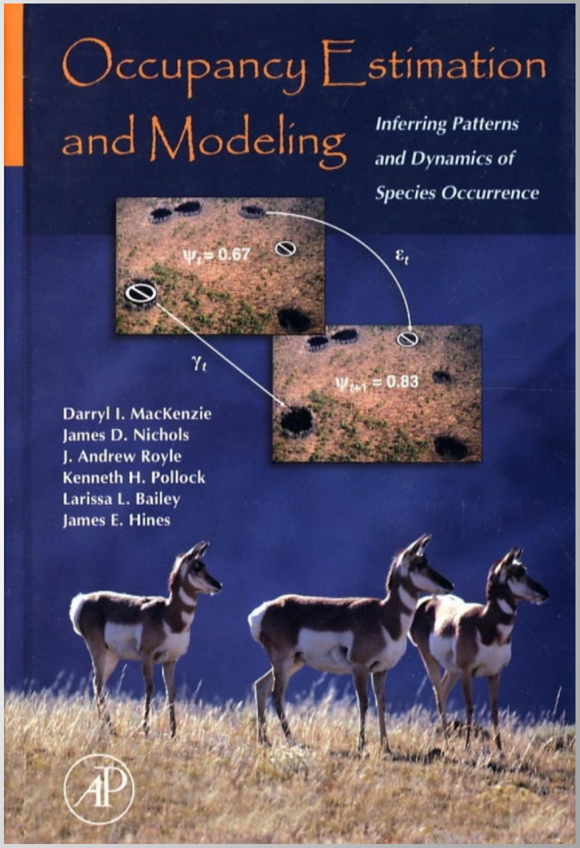
The Grinnell Resurvey Project



Linking Historic to Modern: Occupancy Models

- Depend on repeated, within-era temporal surveys
- **Probability of a false absence(P_{fa}):**
  - Estimates likelihood an observed absence is a true absence and not a lack of detection
  - Across sites (m) based on repeat (n) surveys:

$$P_{fa} = \prod_{j=1}^{m} \prod_{i=1}^{n} \left(1 - p_{ij}\right)$$



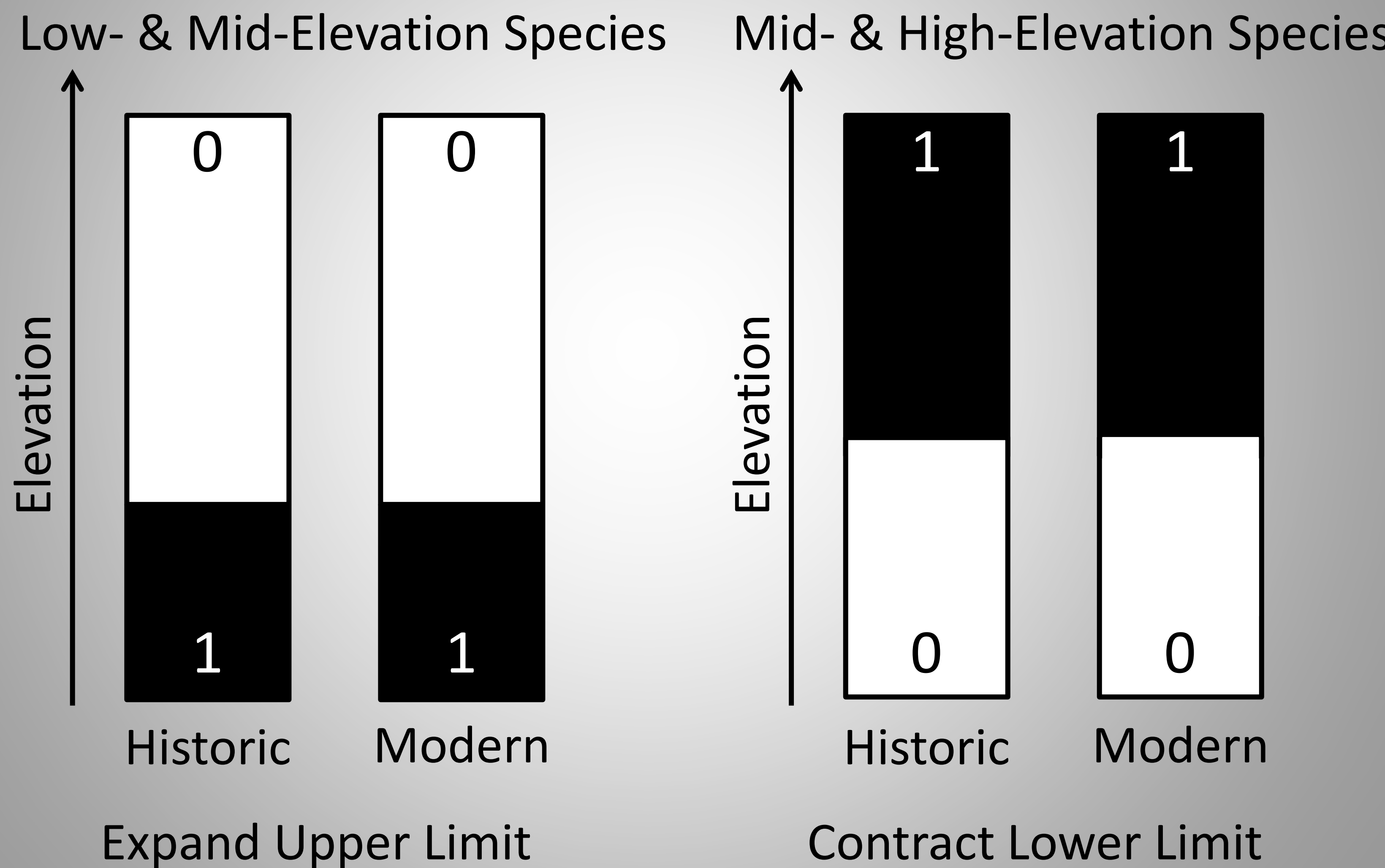
MacKenzie et al. Ecology 2002, 2004; book in 2006

EFFECTS OF CLIMATE CHANGE ON TERRESTRIAL VERTEBRATE RANGES

Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?

Naïve Range Limit Predictions

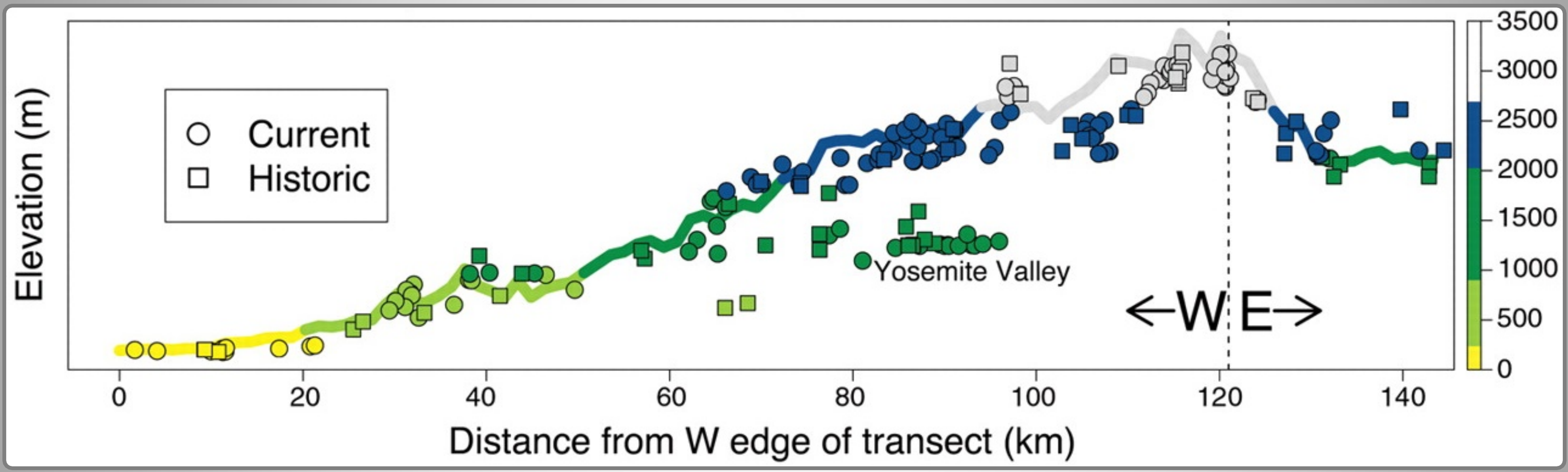


Globally Coherent Fingerprint: Poleward and Upslope

"Mega" Meta-analyses:

- Parmesan and Yohe 2003. Science:
  - N = 434 species (latitude)
- Chen et al. 2011. Science:
  - N = 764 (latitude)
  - N = 1367 (elevation)

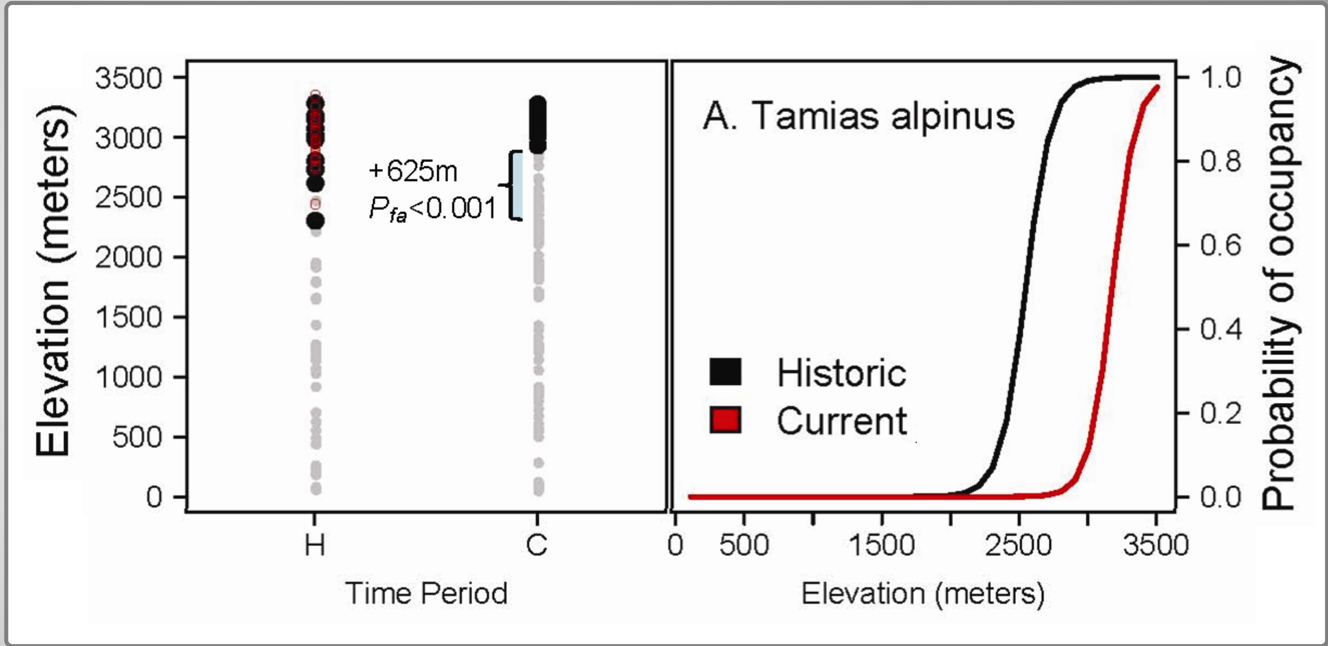
The Grinnell Resurvey Project: Yosemite Transect, Small Mammals



Moritz et al. 2008. Science 322: 261-264

Mammal Trapping Data and Occupancy Profiles

Alpine chipmunk
Tamias alpinus



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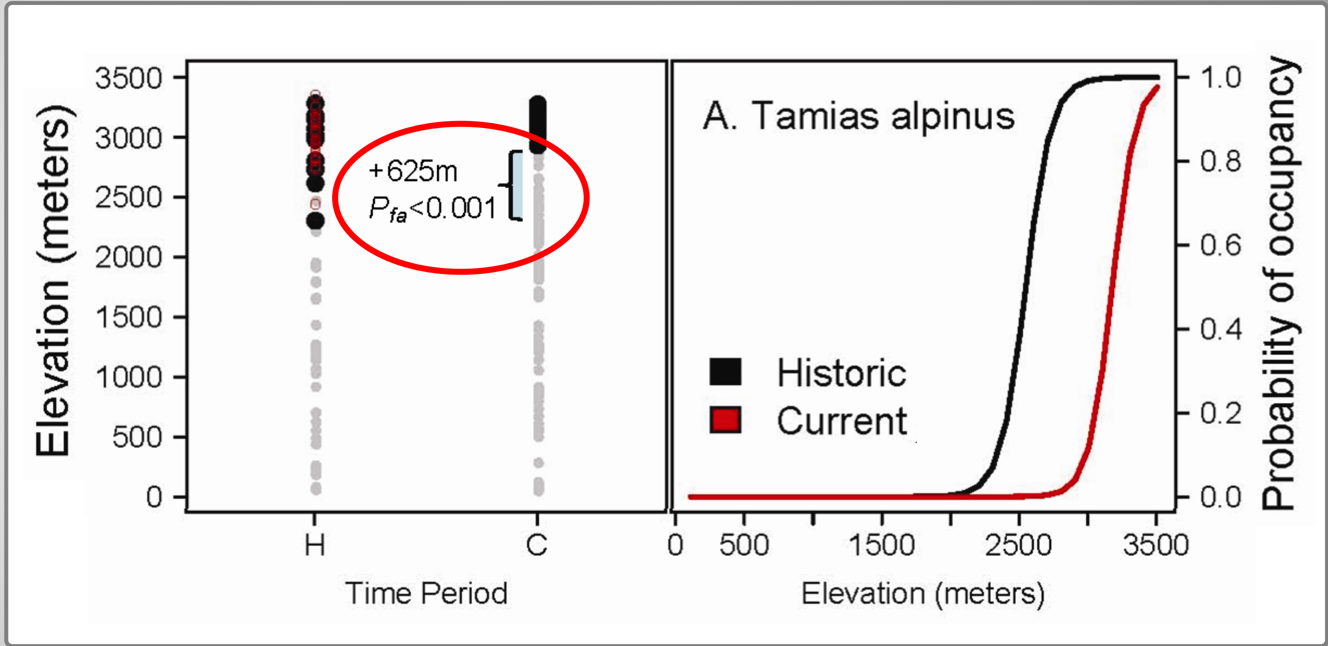

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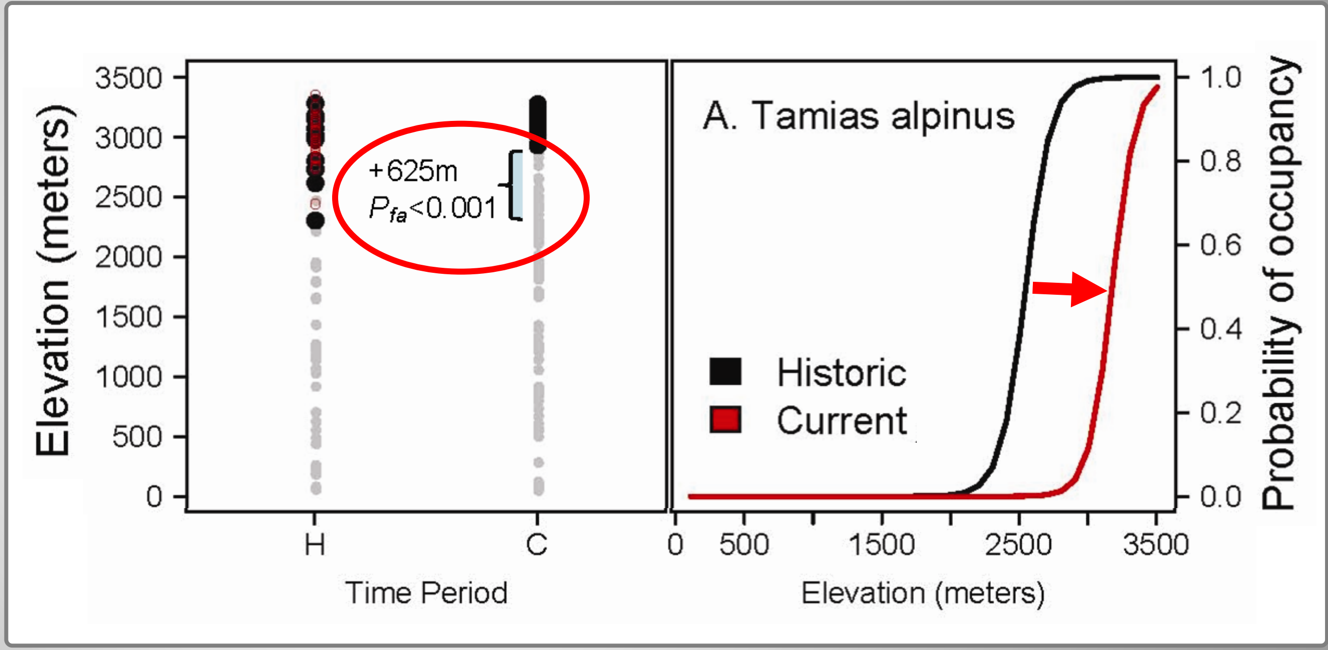
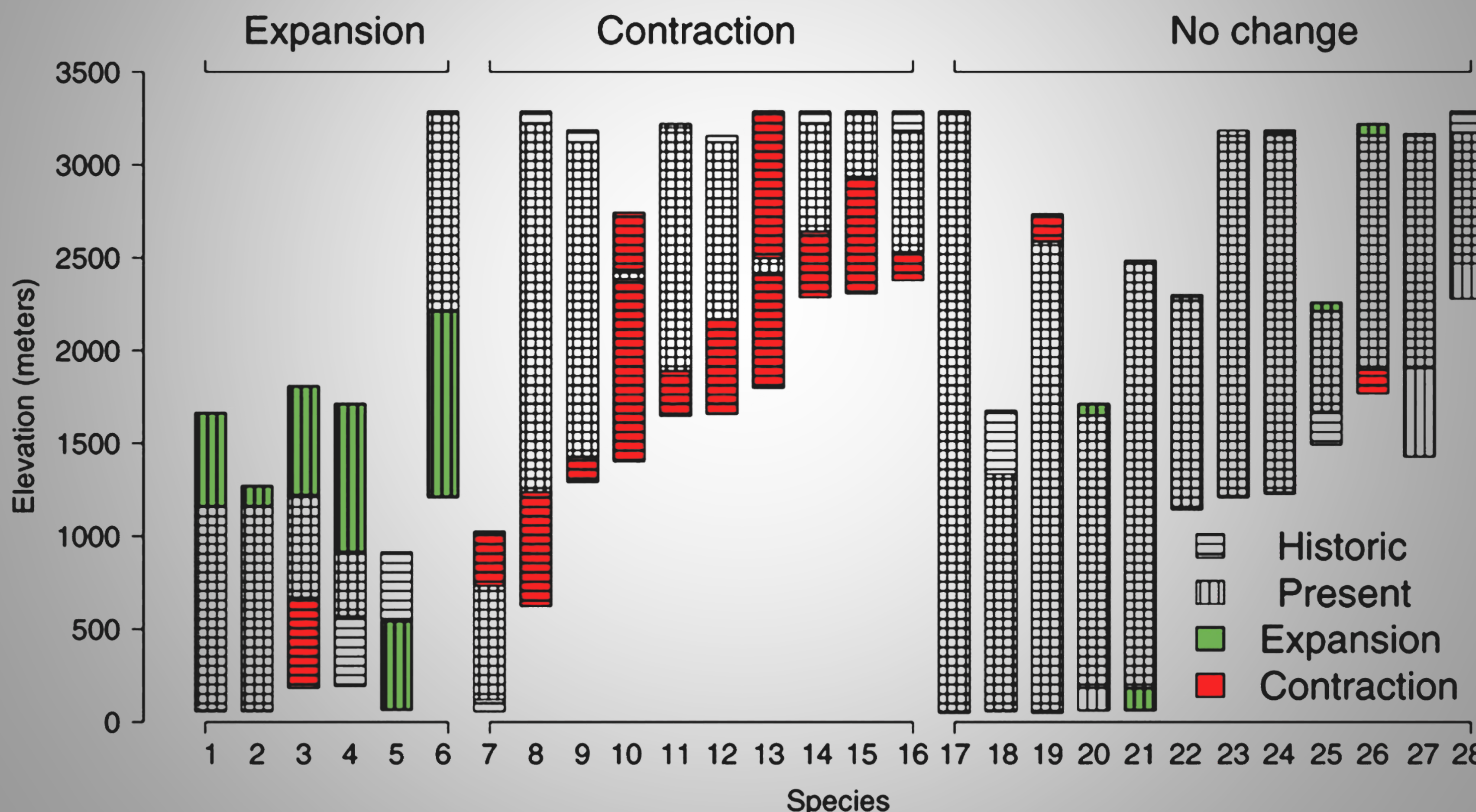


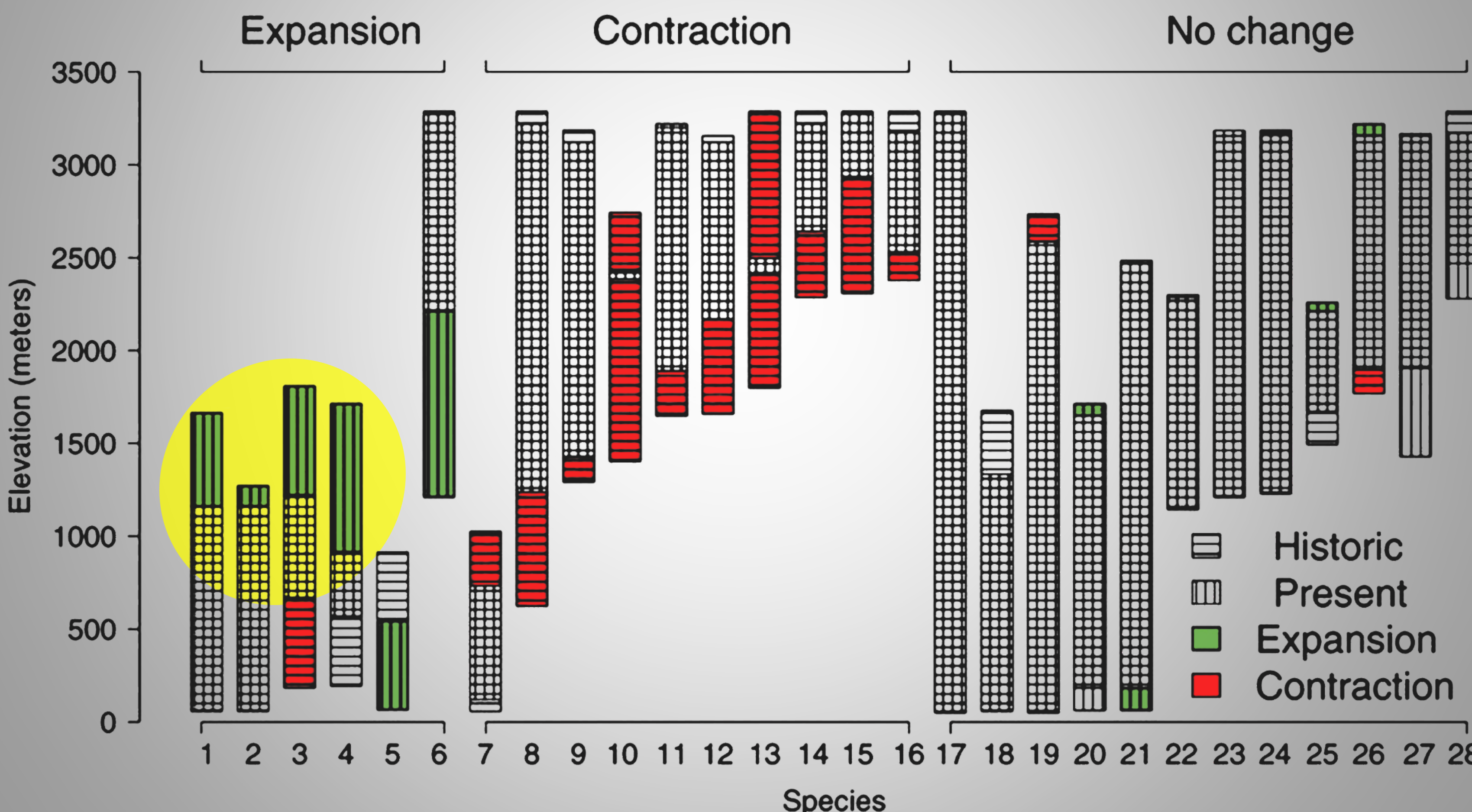
Moritz et al. 2008. Science 322: 261-264

Elevational Range Change: 28 Yosemite Small Mammal Species



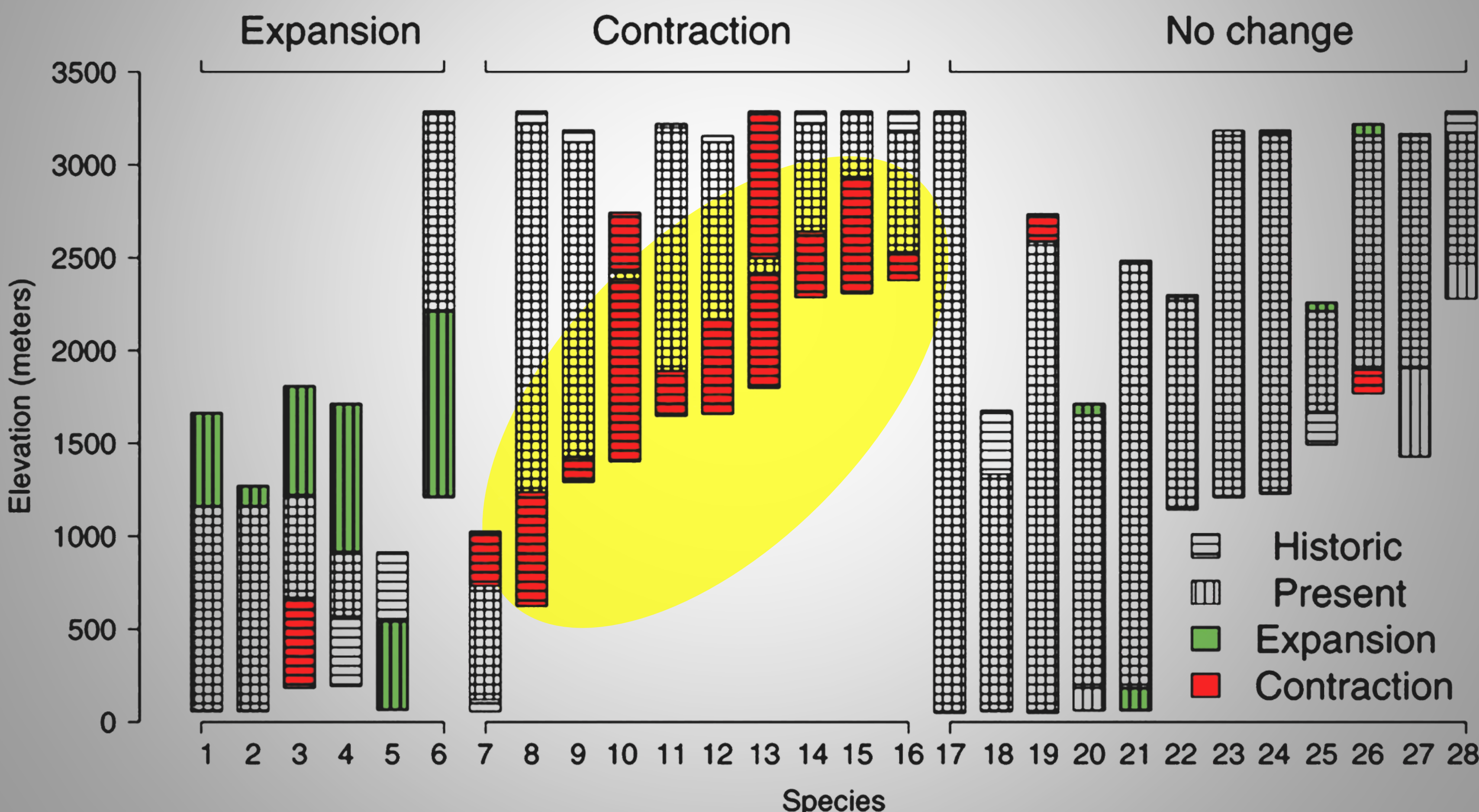
Moritz et al. 2008. Science 322: 261-264

Elevational Range Change: Range Expansion



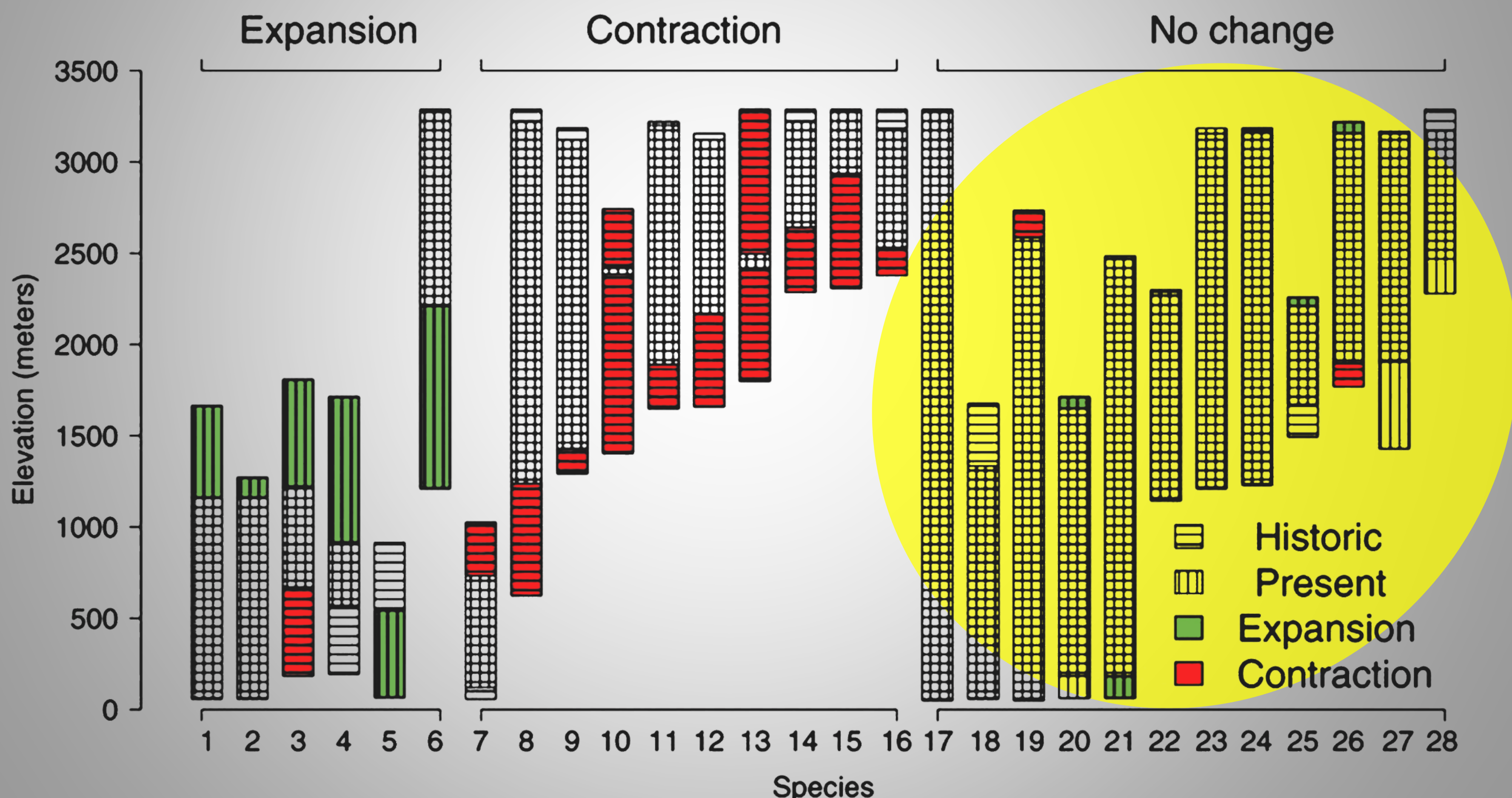
Moritz et al. 2008. Science 322: 261-264

Elevational Range Change: Range Contraction



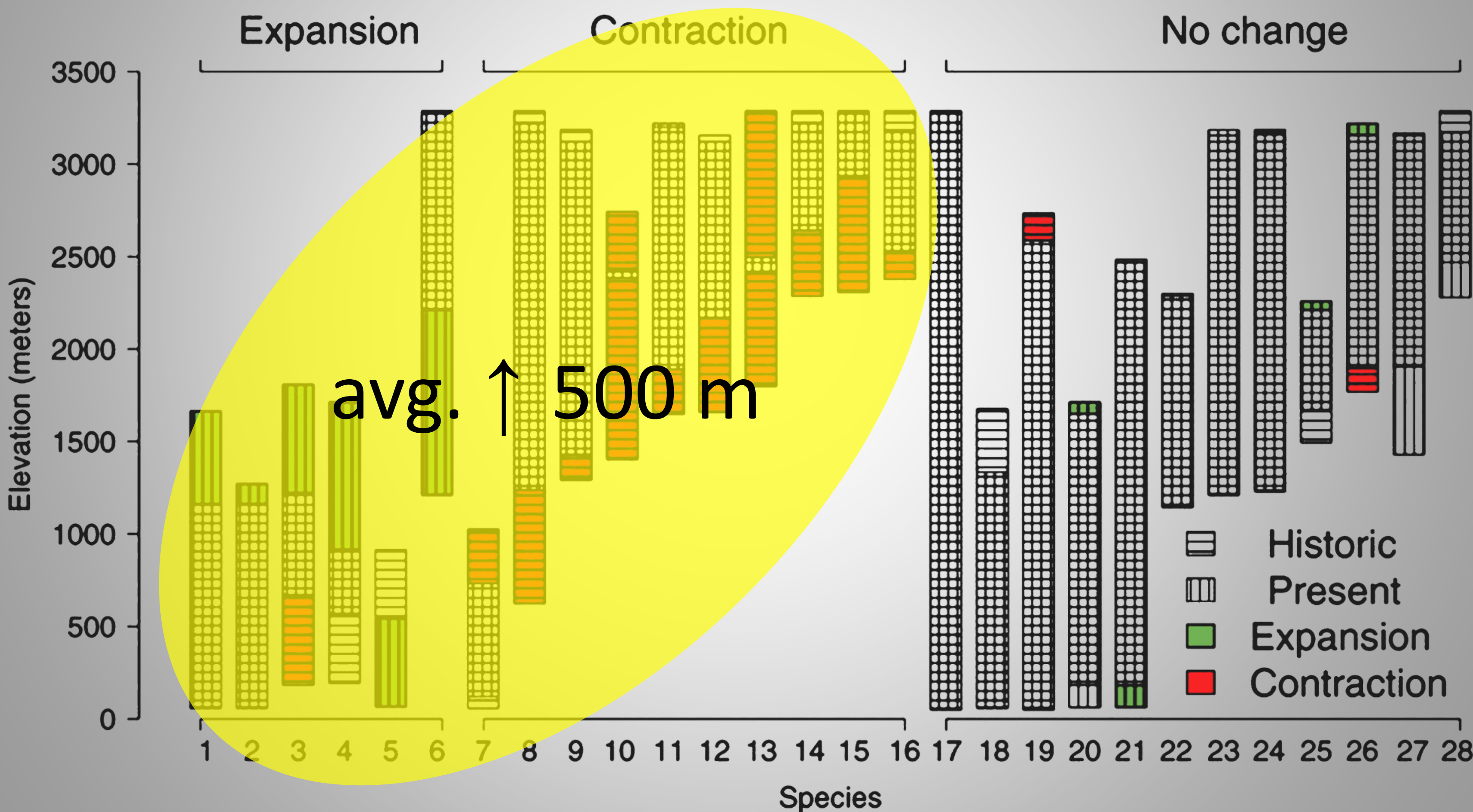
Moritz et al. 2008. Science 322: 261-264

Elevational Range Change: No Change



Moritz et al. 2008. Science 322: 261-264

Elevational Range Change



Moritz et al. 2008. Science 322: 261-264

Range Change Predictors

- Strong:
  - Original elevational range:
    - Low: expand upper limit
    - High: contract lower limit

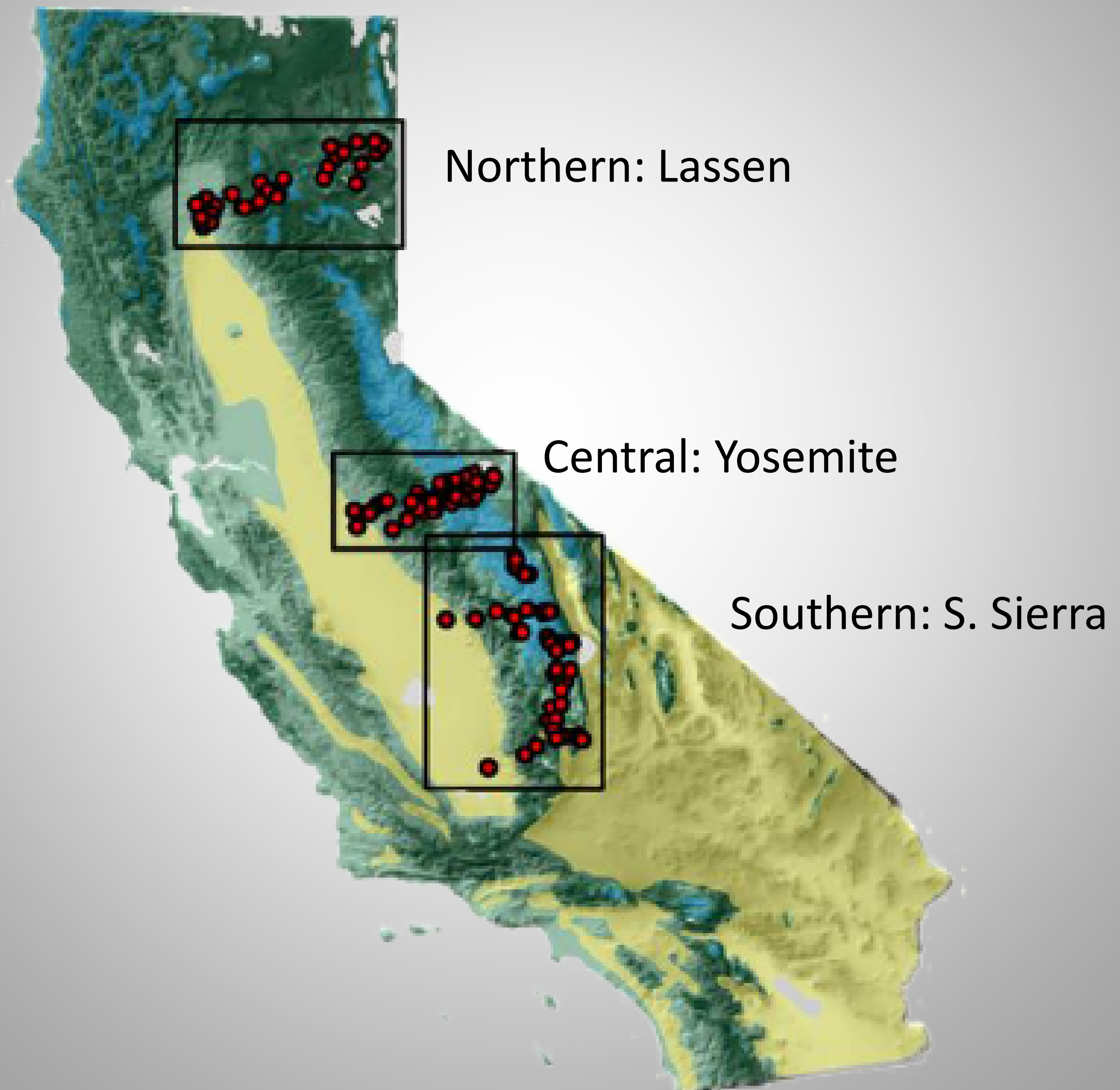
  Consistent with naïve expectations
- Weak:
  - Life history and ecological traits, specifically:
    - Longevity (life span in years): longer, ↓ probability of shift
    - Litters per year: more, ↑ probability of shift

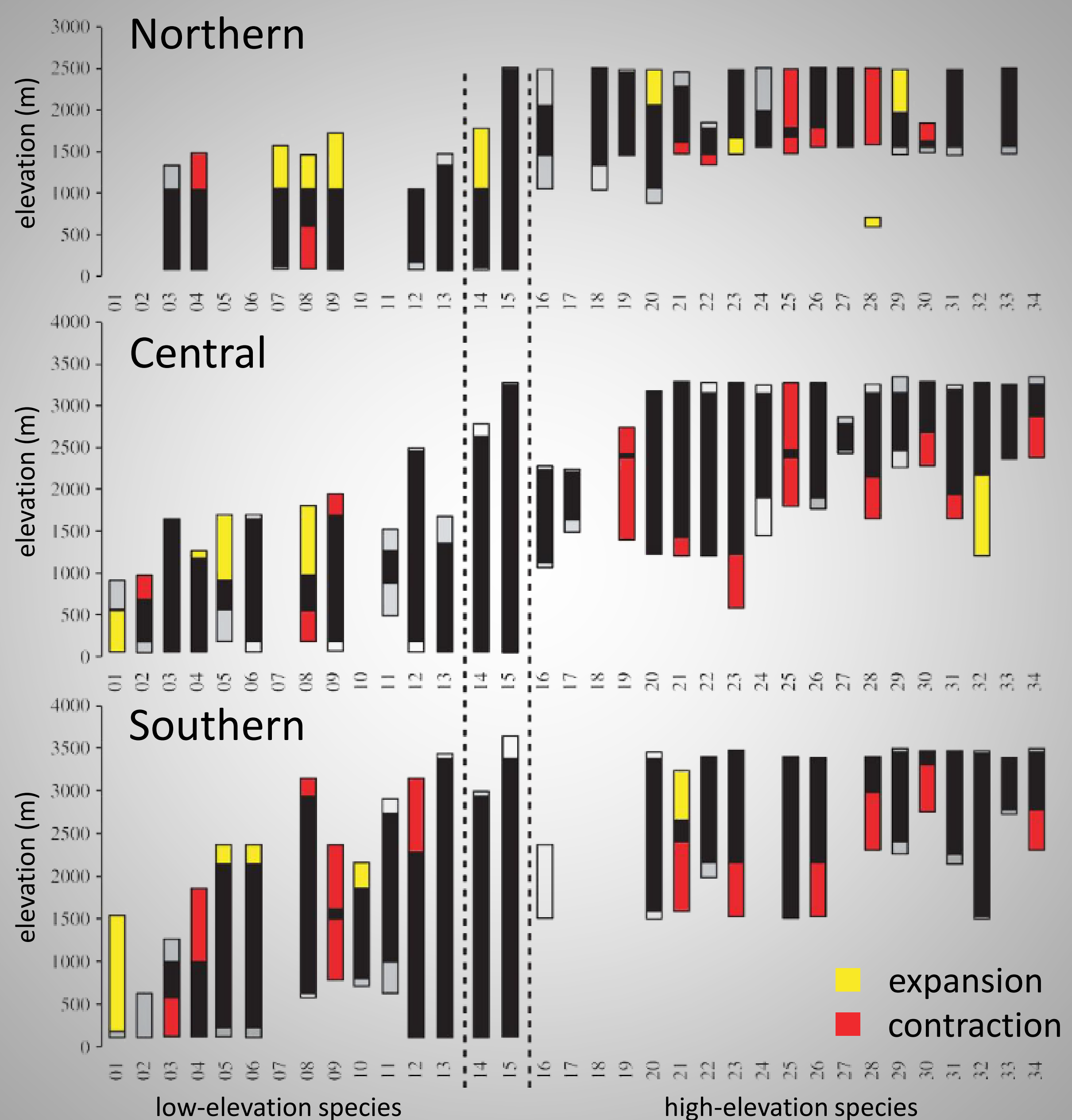
Moritz et al. 2008. Science 322: 261-264

Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent

Dynamics at a Broader Spatial Extent

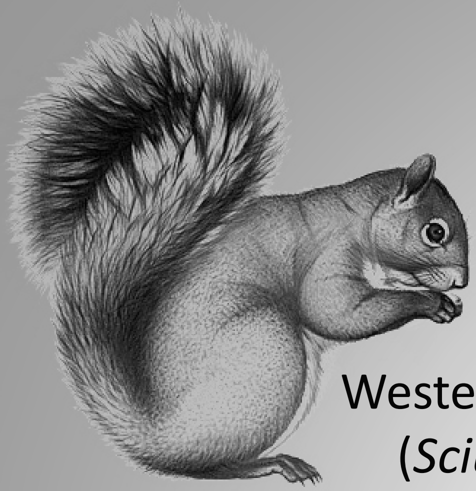




Rowe et al. 2015 Proc Royal Soc B 282: 20141857

Bushy-tailed woodrat
(*Neotoma cinerea*)

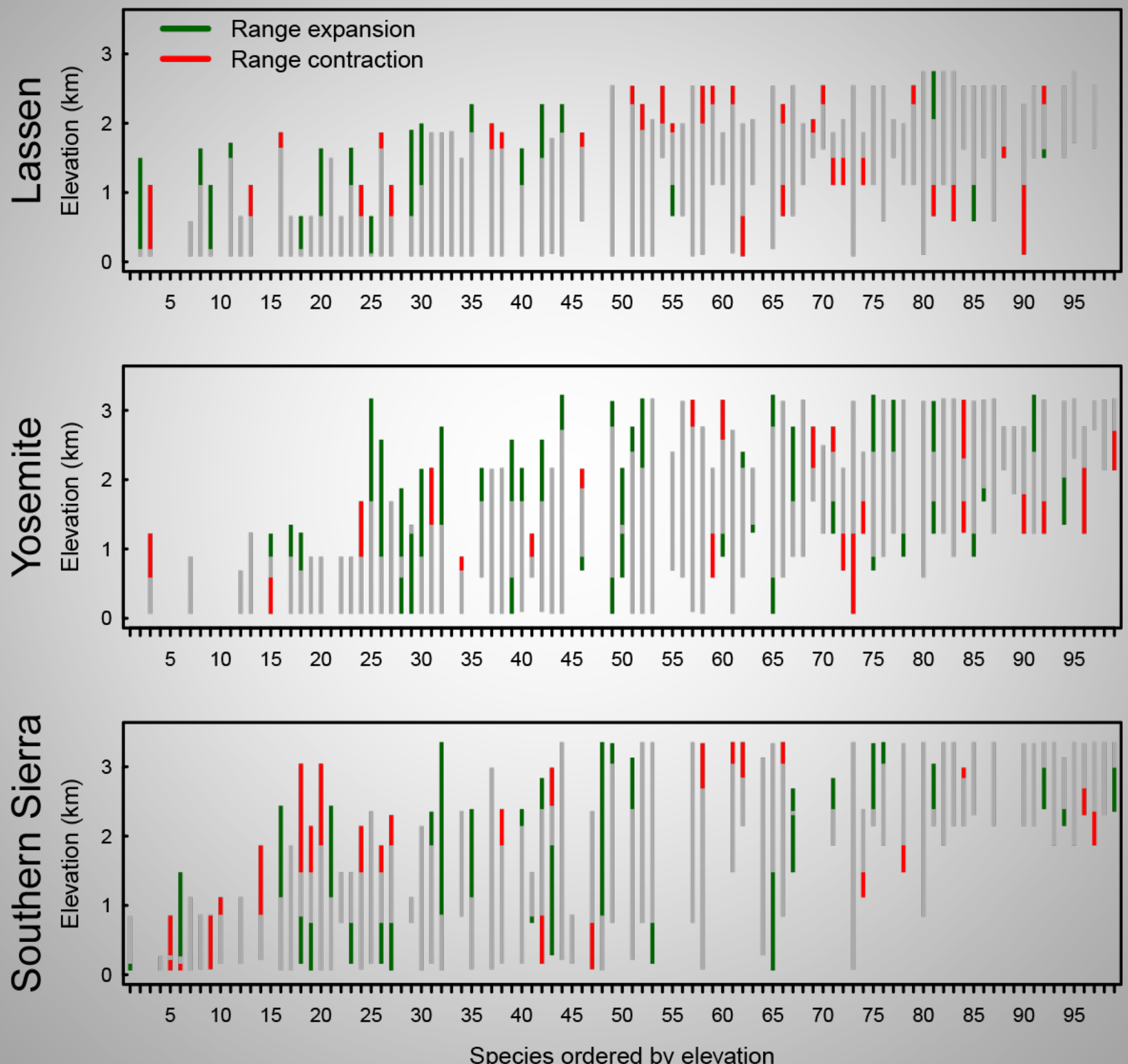
Rowe et al. 2015 Proc Royal Soc B 282: 20141857



Western gray squirrel
(*Sciurus griseus*)

Rowe et al. 2015 Proc Royal Soc B 282: 20141857

Avian Elevational Range Response



Tingley et al. 2012 Glob Change Biol 18: 3279-3290

Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
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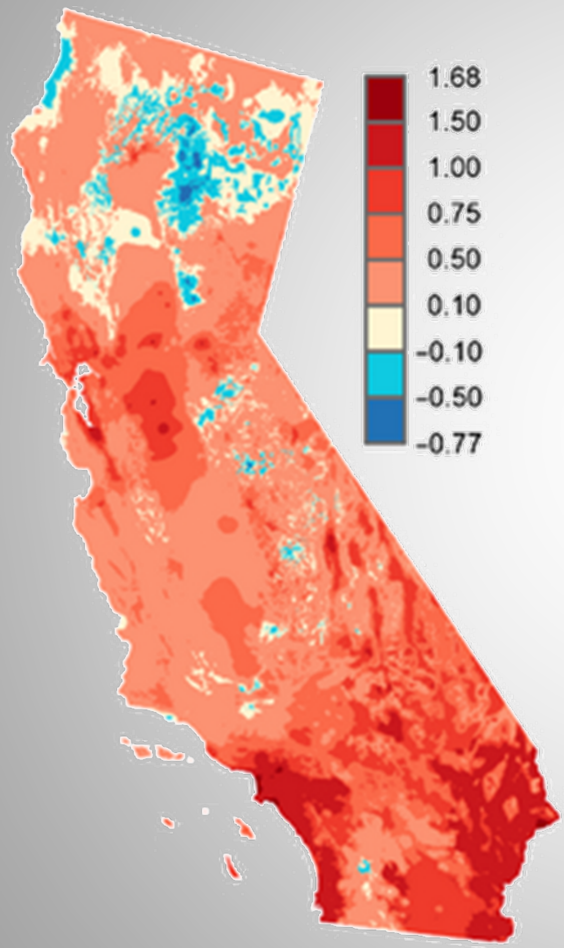
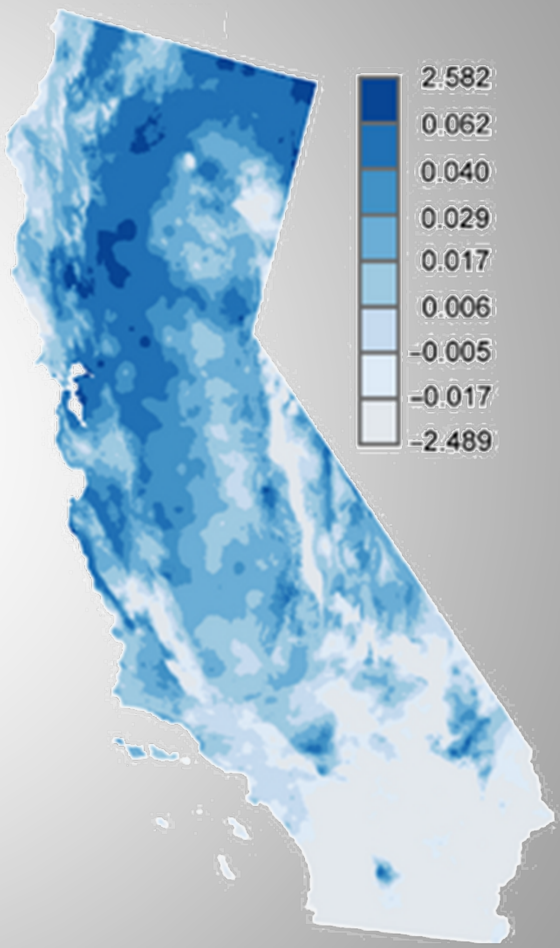
  - The shortcomings of the naïve approach

Climate Change Since Grinnell: Substantial and Highly Variable



Δ mean temp. (°C)

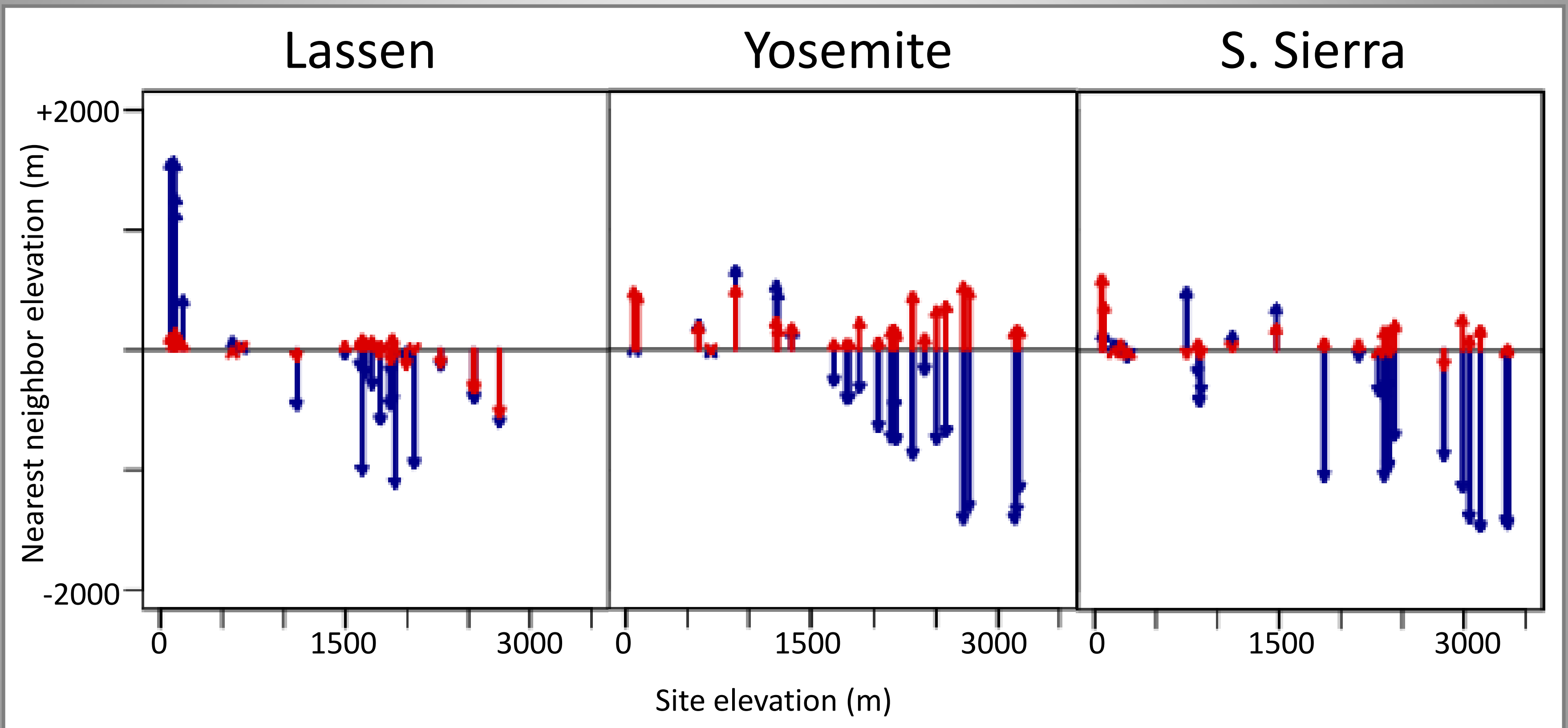


Δ total precip (mm)

Rapacciuolo et al. 2014 Glob Change Bio 20:2841-2855

The Elevational Push and Pull of Climate Change:

Nearest Climatic Neighbor (Temperature and Precipitation)



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Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
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- Predictors of Range Change

Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
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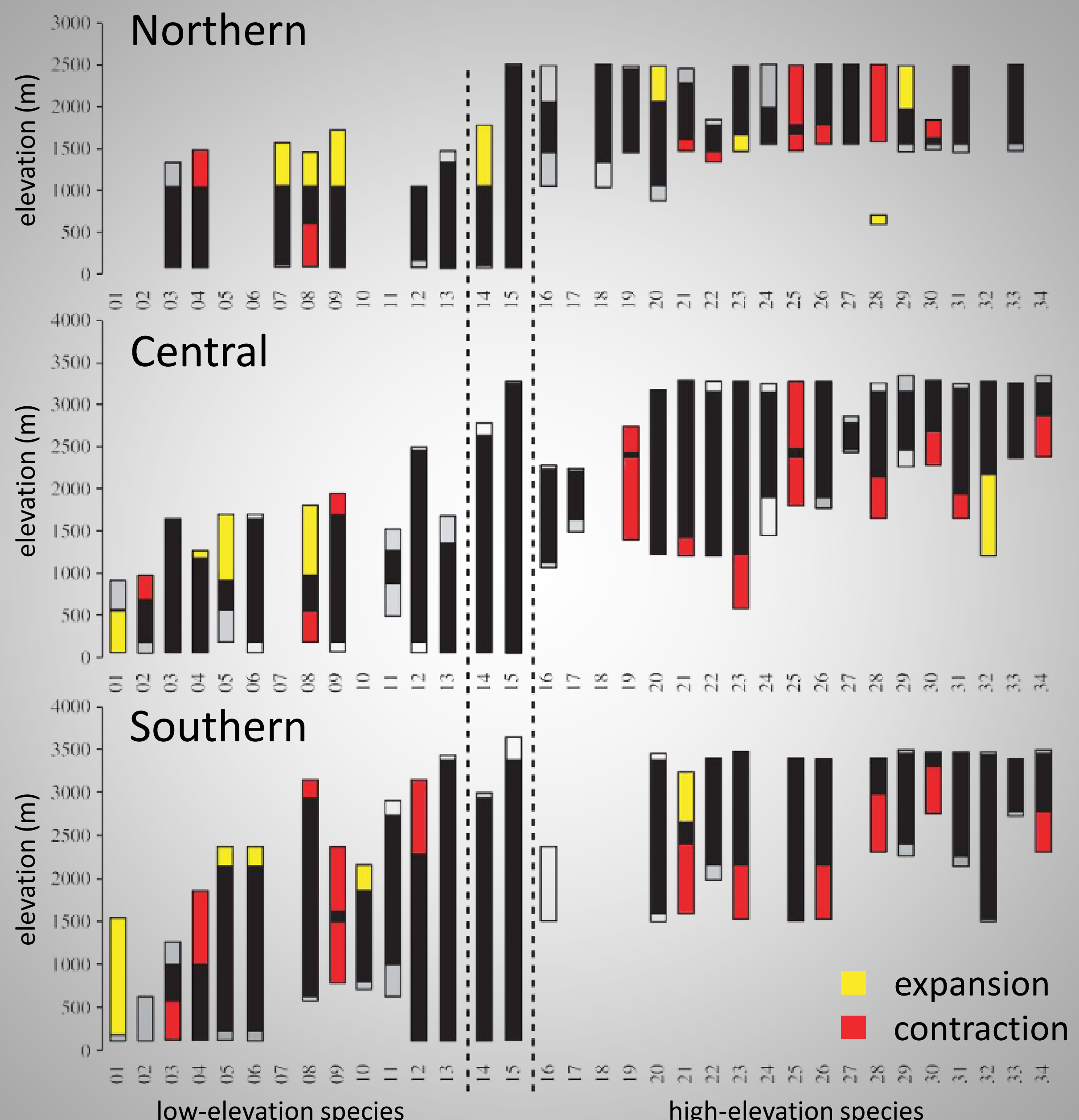
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate



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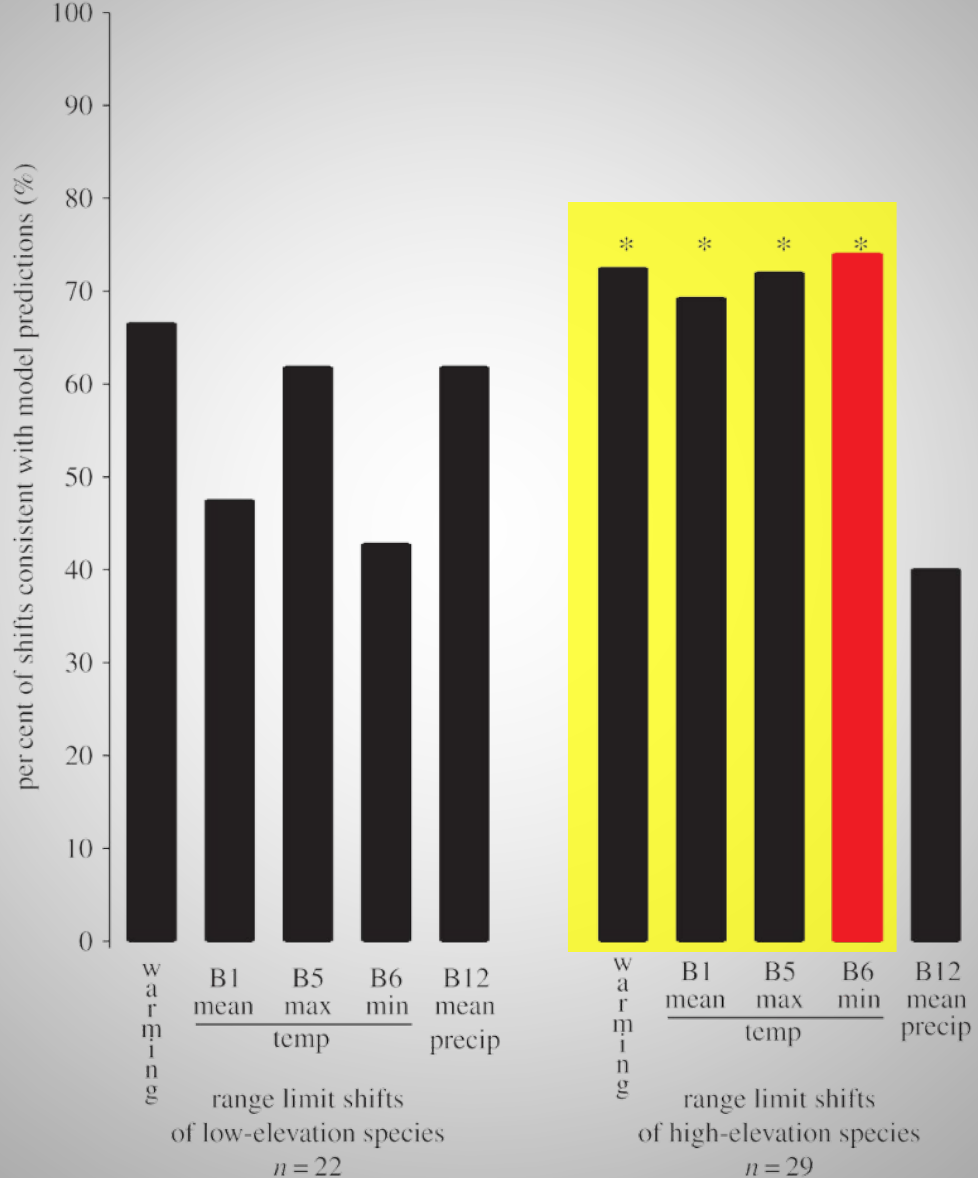
Climate Change Predictions: Small Mammal Range Shifts



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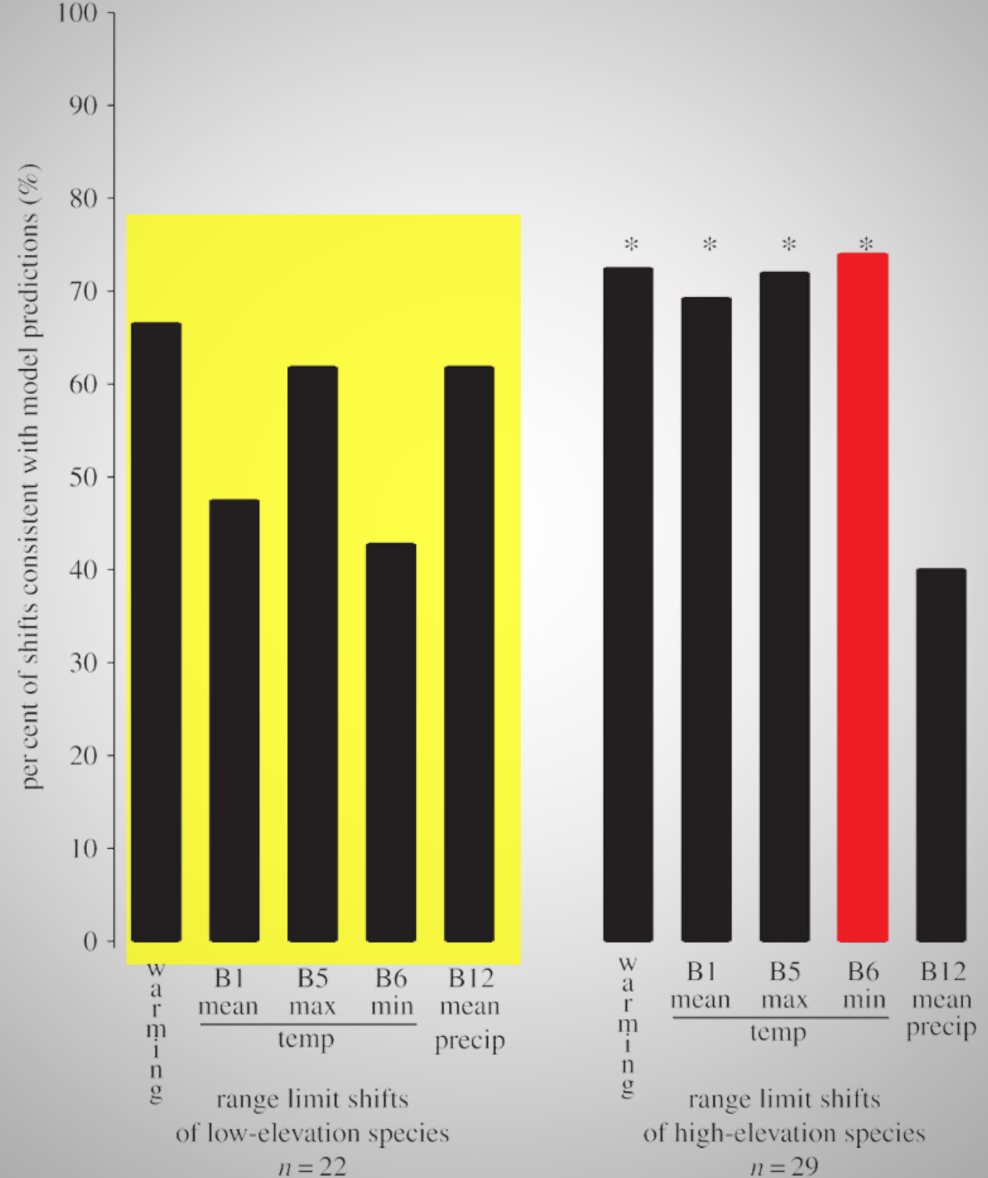

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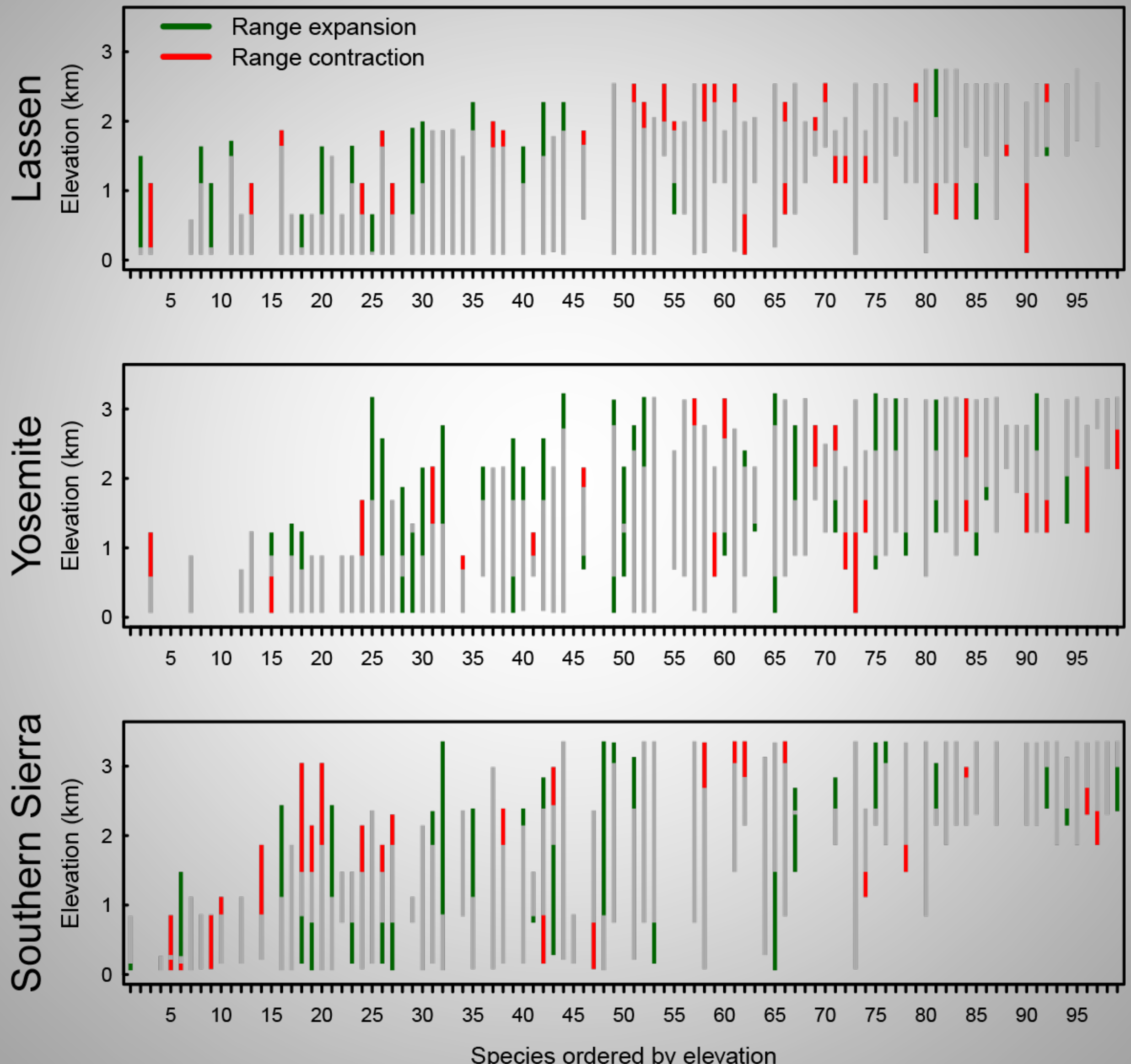
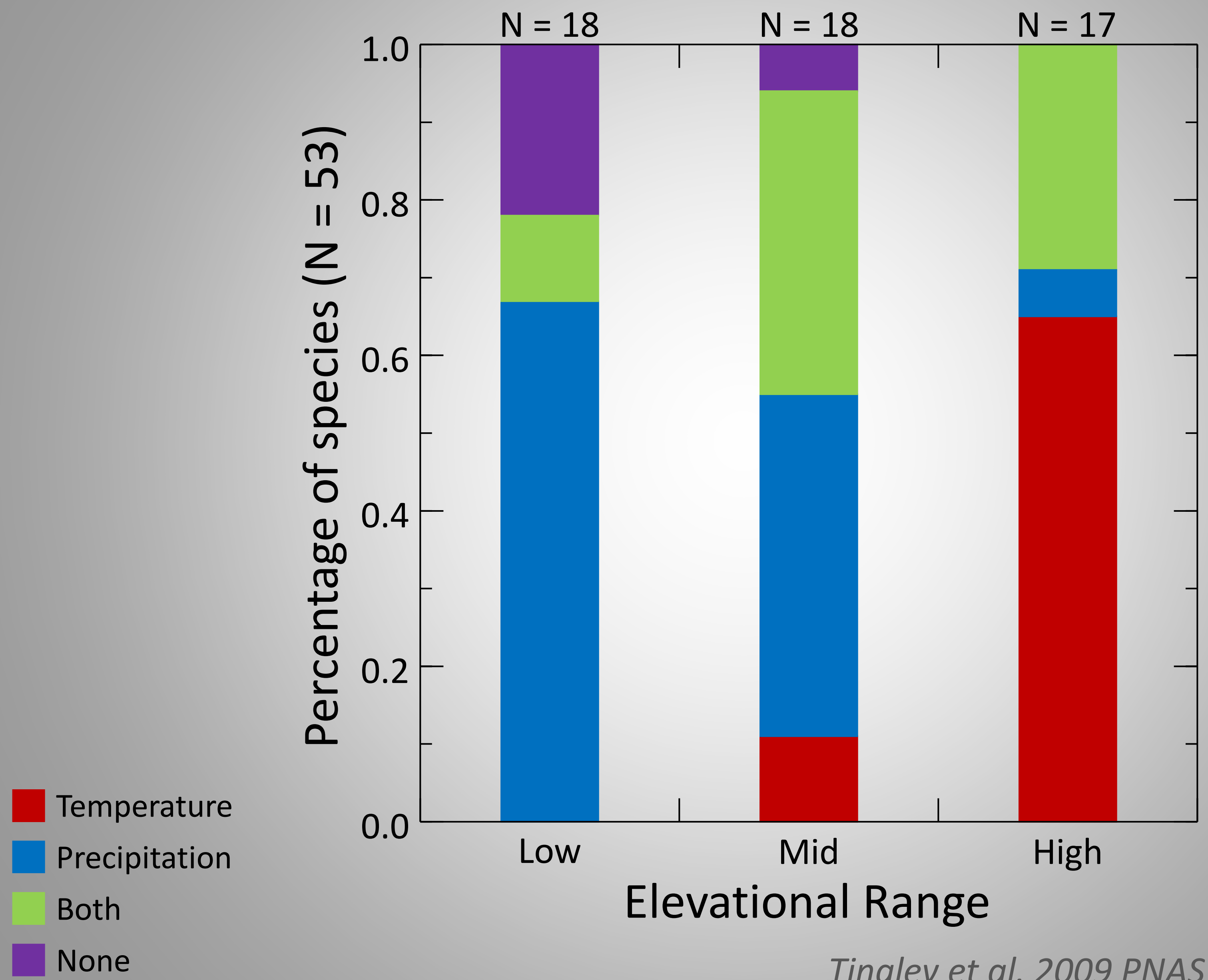
Climate Change Predictions: Avian Range Shifts



Tingley et al. 2012 Glob Change Biol 18: 3279-3290

Elevational Differences in Avian Niche Tracking



Tingley et al. 2009 PNAS 106: 19637-19643

Effects of Climate Change on Terrestrial Vertebrate Ranges

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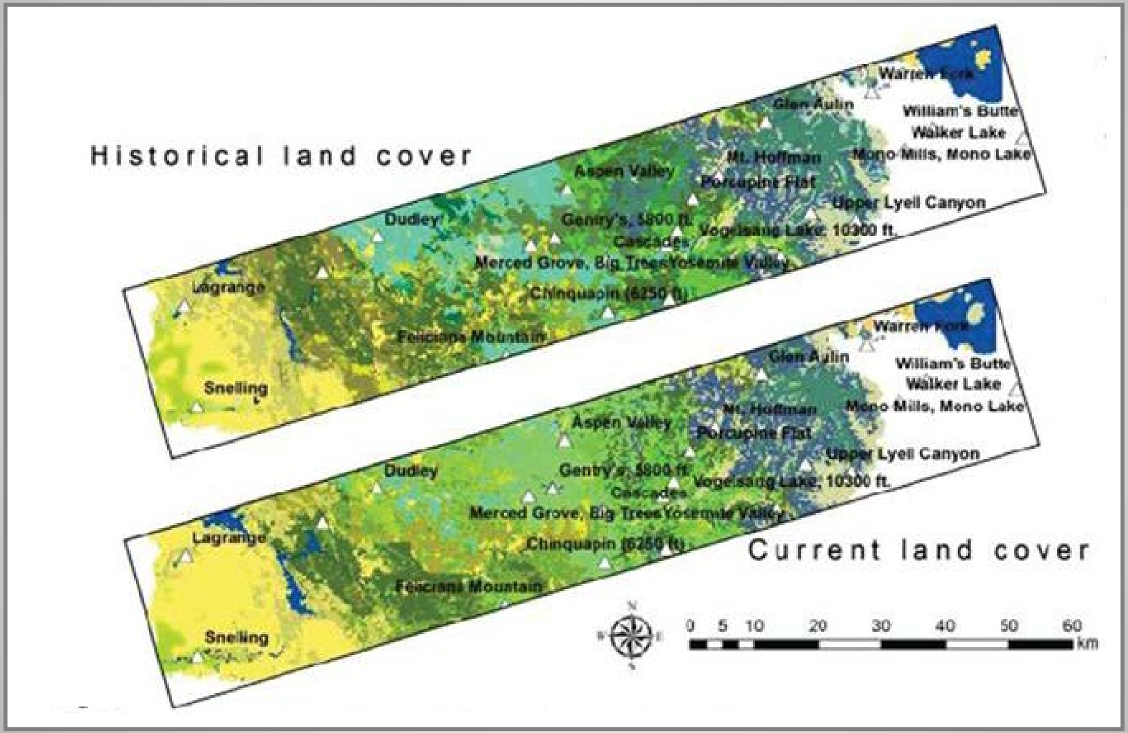
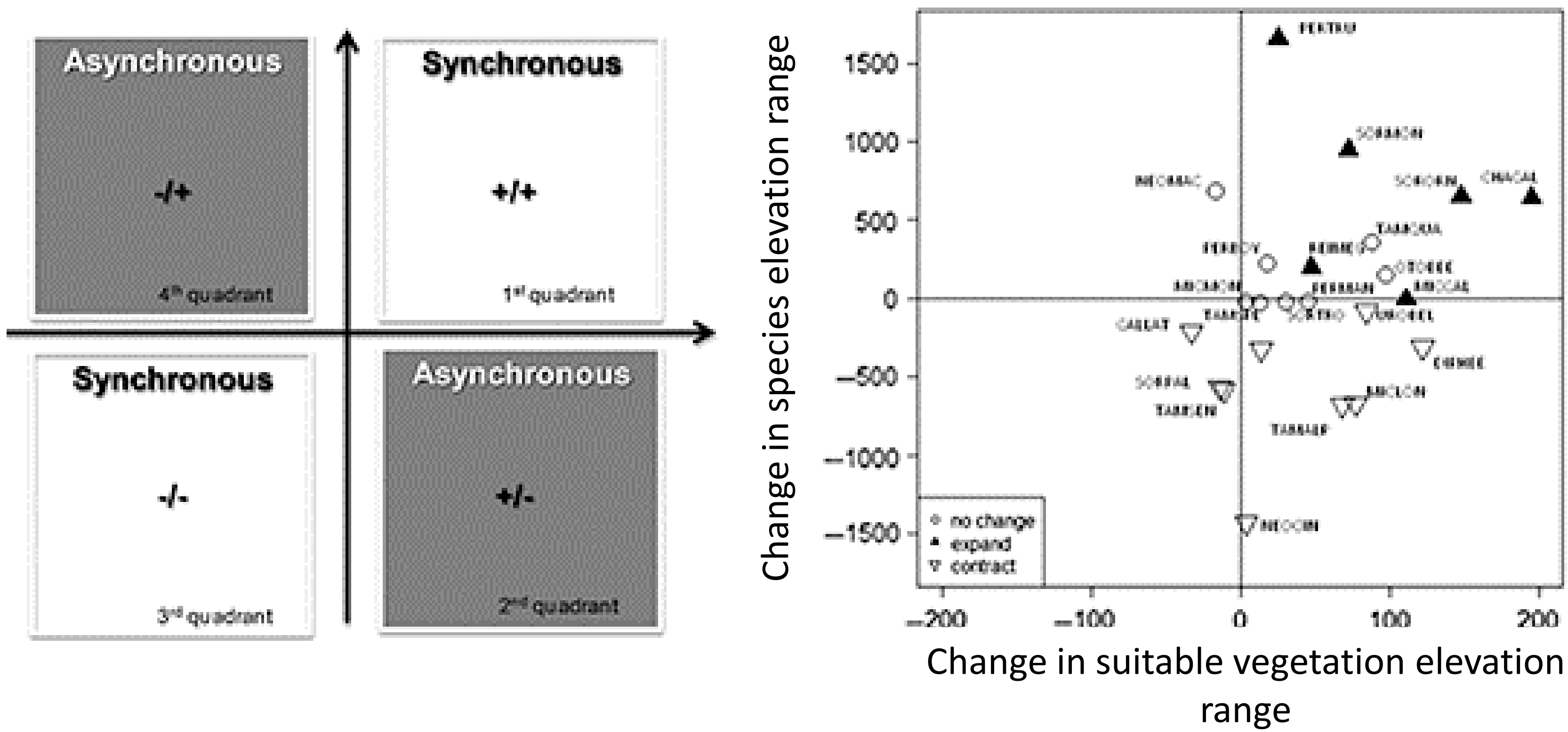
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate
  - Vegetation

Vegetation Change: Yosemite Transect Mammals



Santos et al. 2015 Ecography 38, 556–568

Vegetation Change: Synchronicity in Mammalian Shifts



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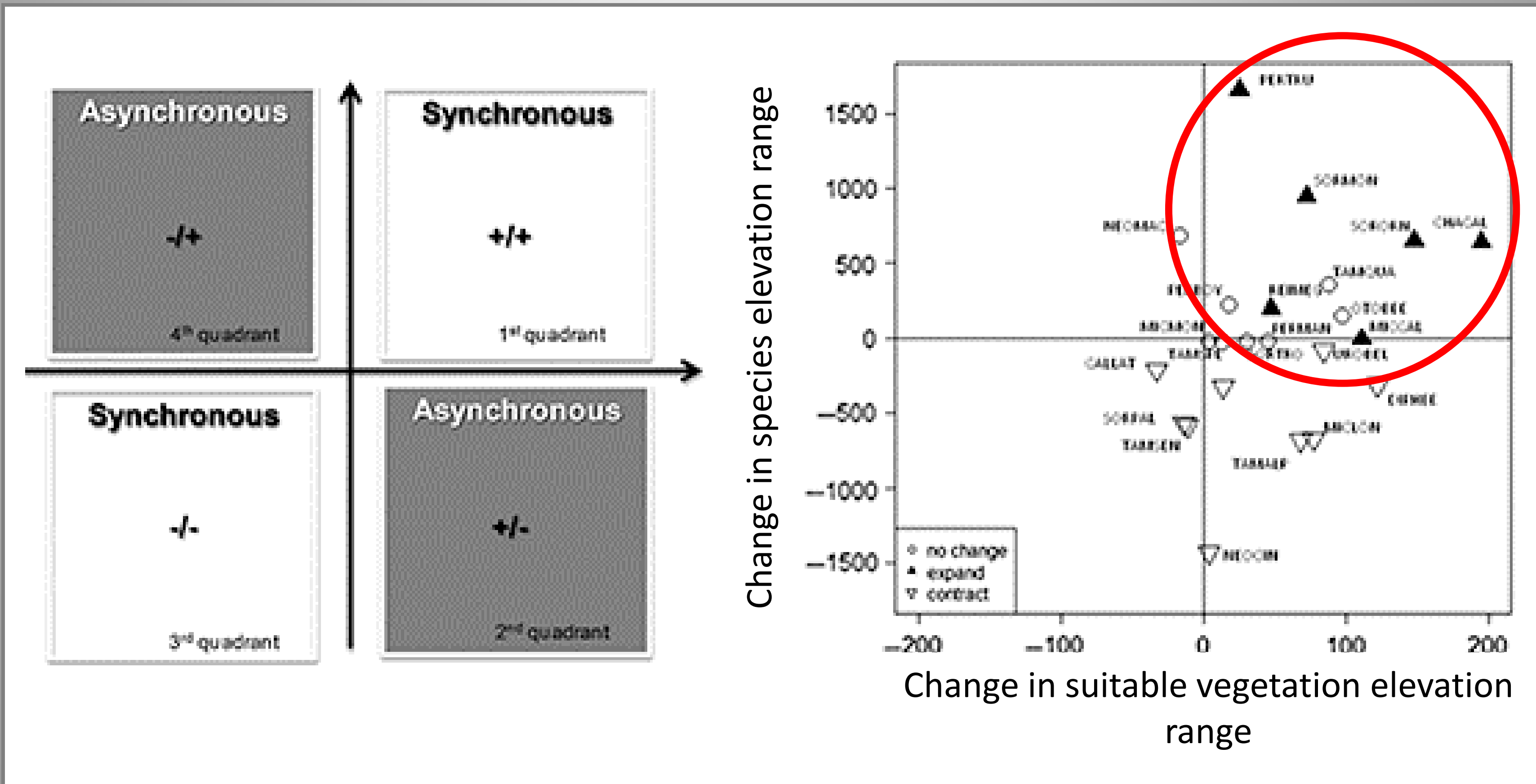

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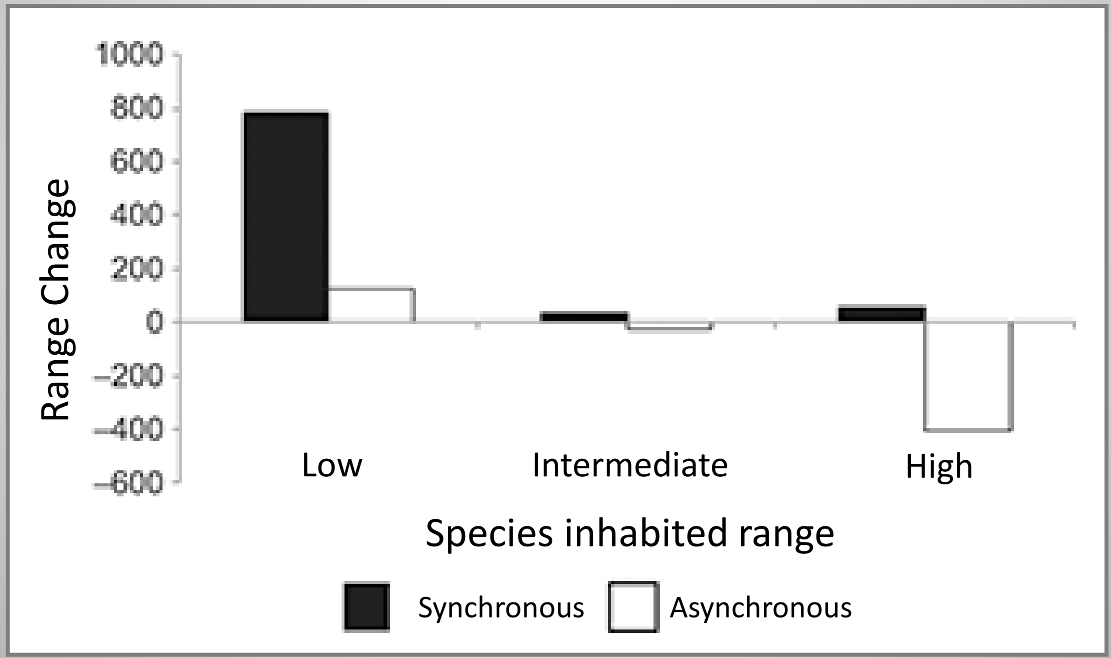
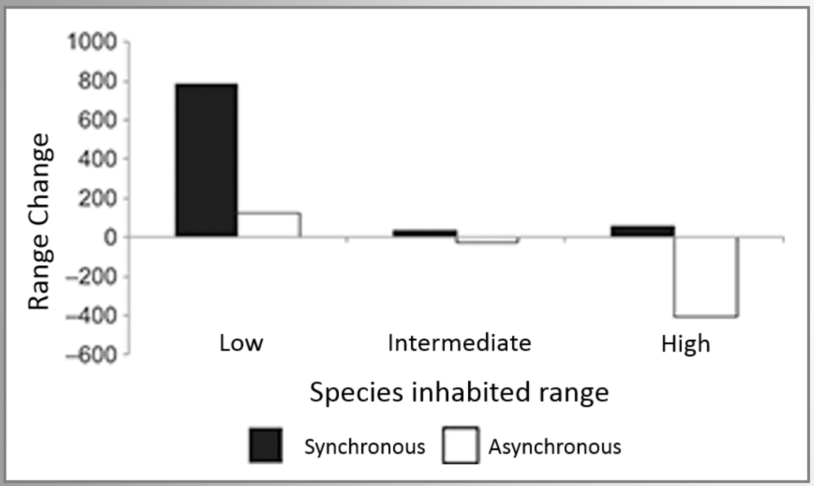
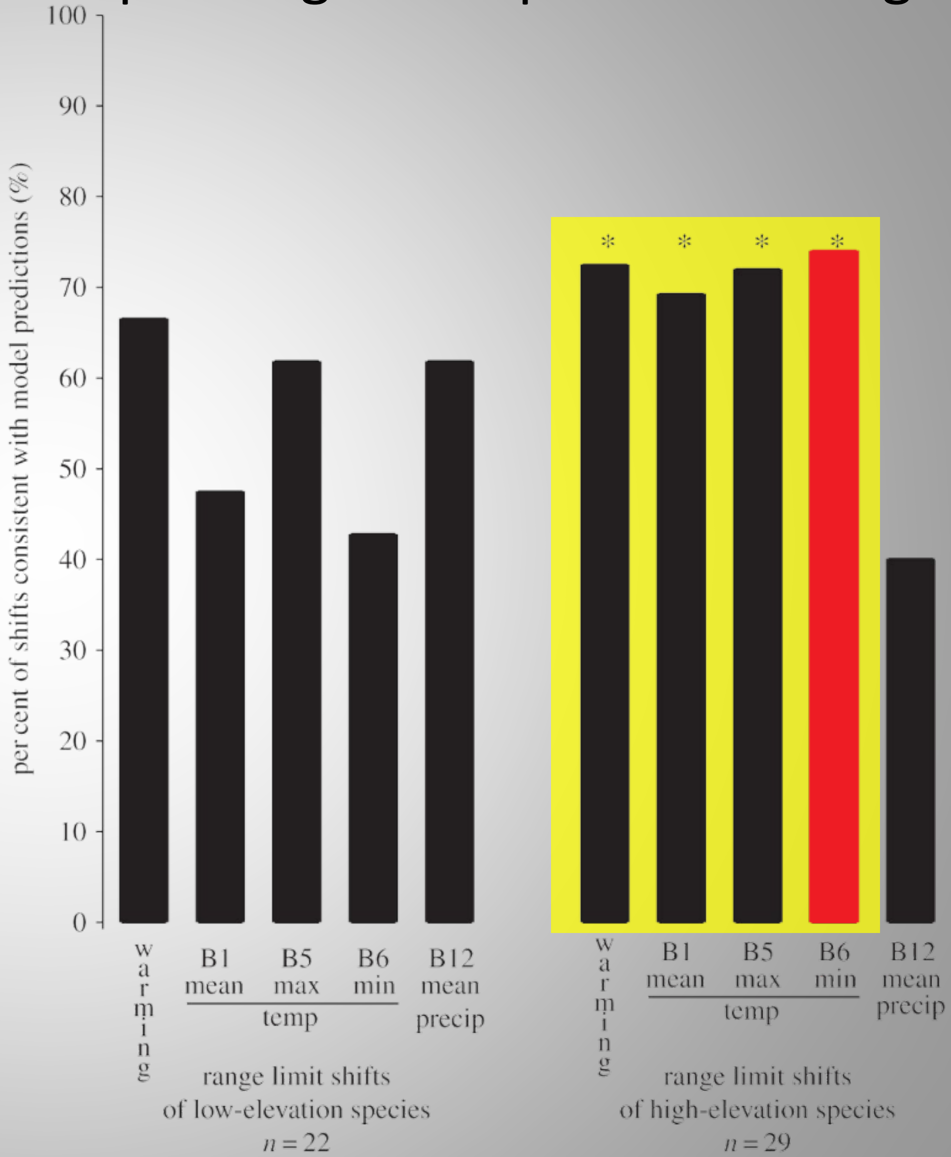


Santos et al. 2015 Ecography 38, 556–568

Low-elevation: responding to vegetation change

High-elevation: responding to temperature change





Rowe et al. 2015 Proc Royal Soc B; Santos et al. 2015 Ecography

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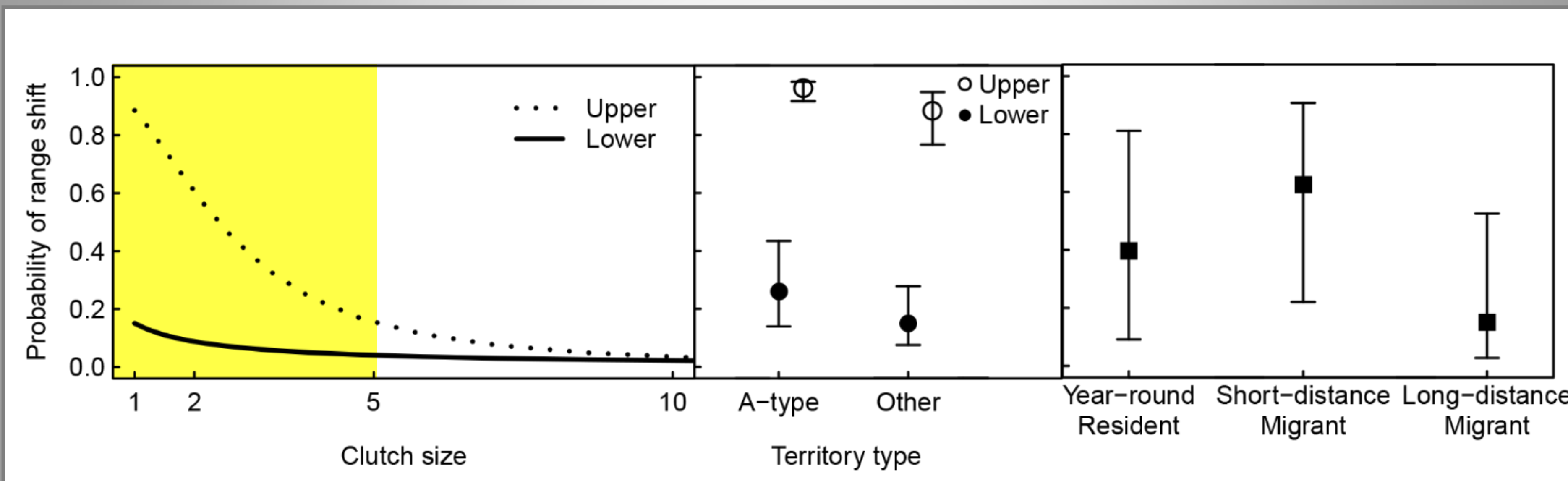
- Predictors of Range Change
  - Climate
  - Vegetation
  - Life-history traits

Life History Traits: Birds



Tingley et al. 2012 Glob Change Biol 18: 3279-3290

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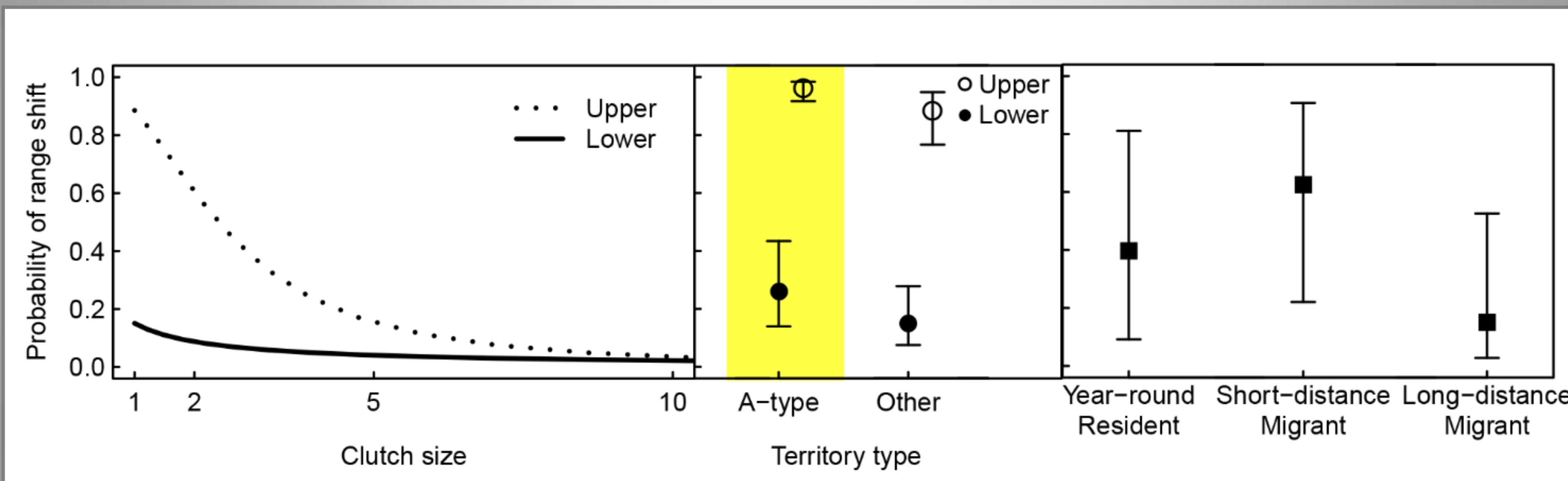

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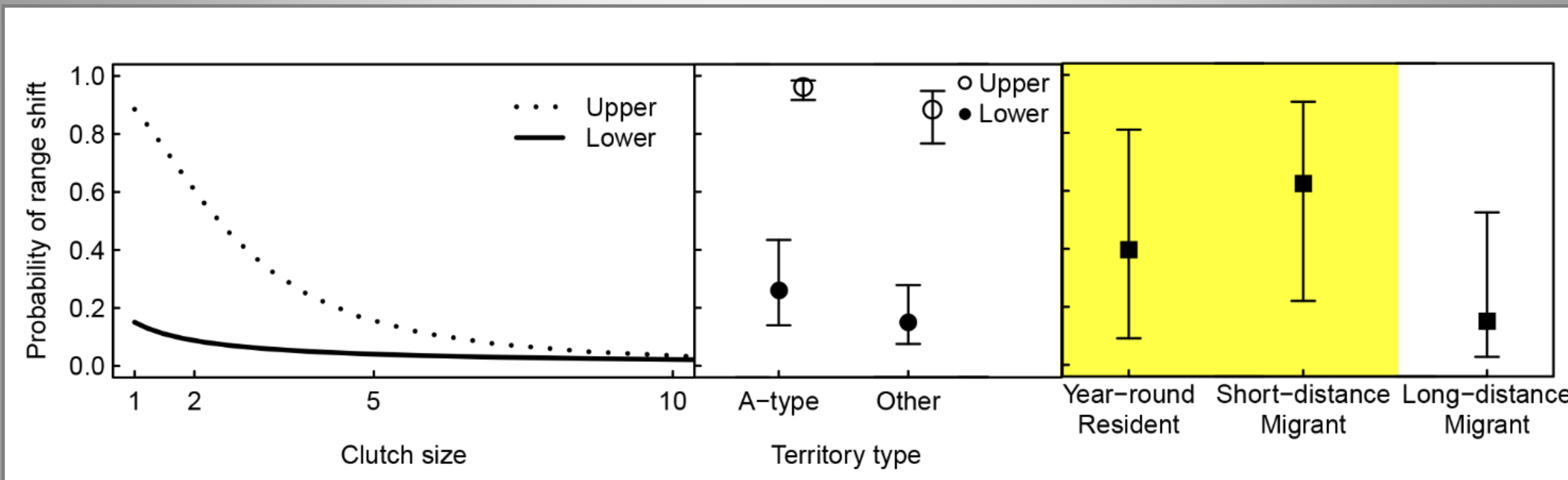

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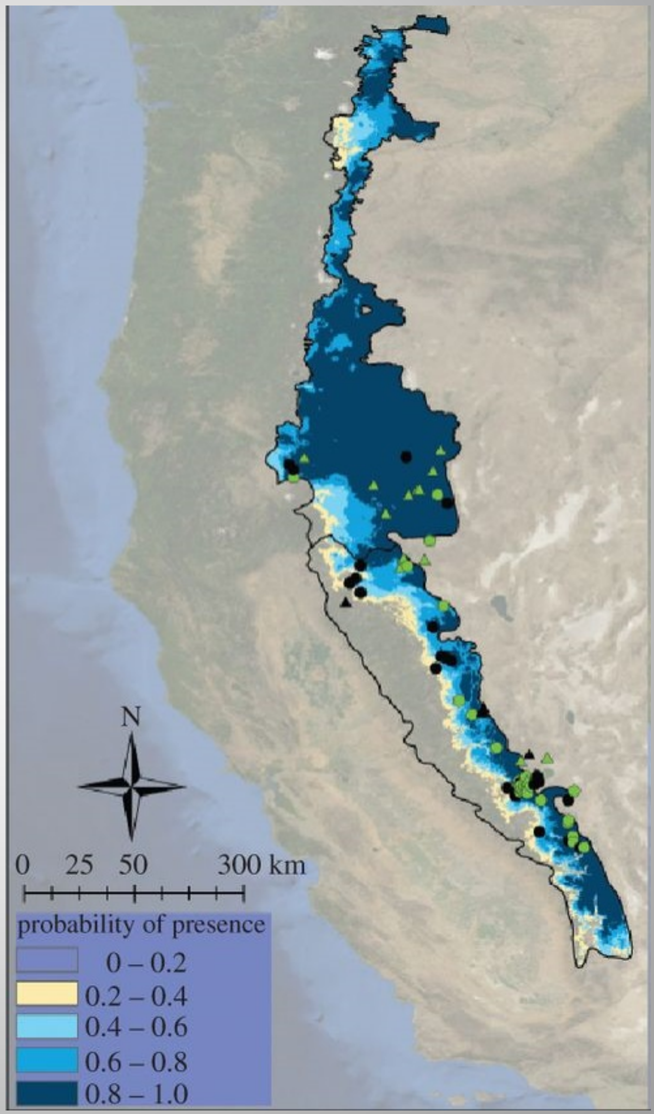
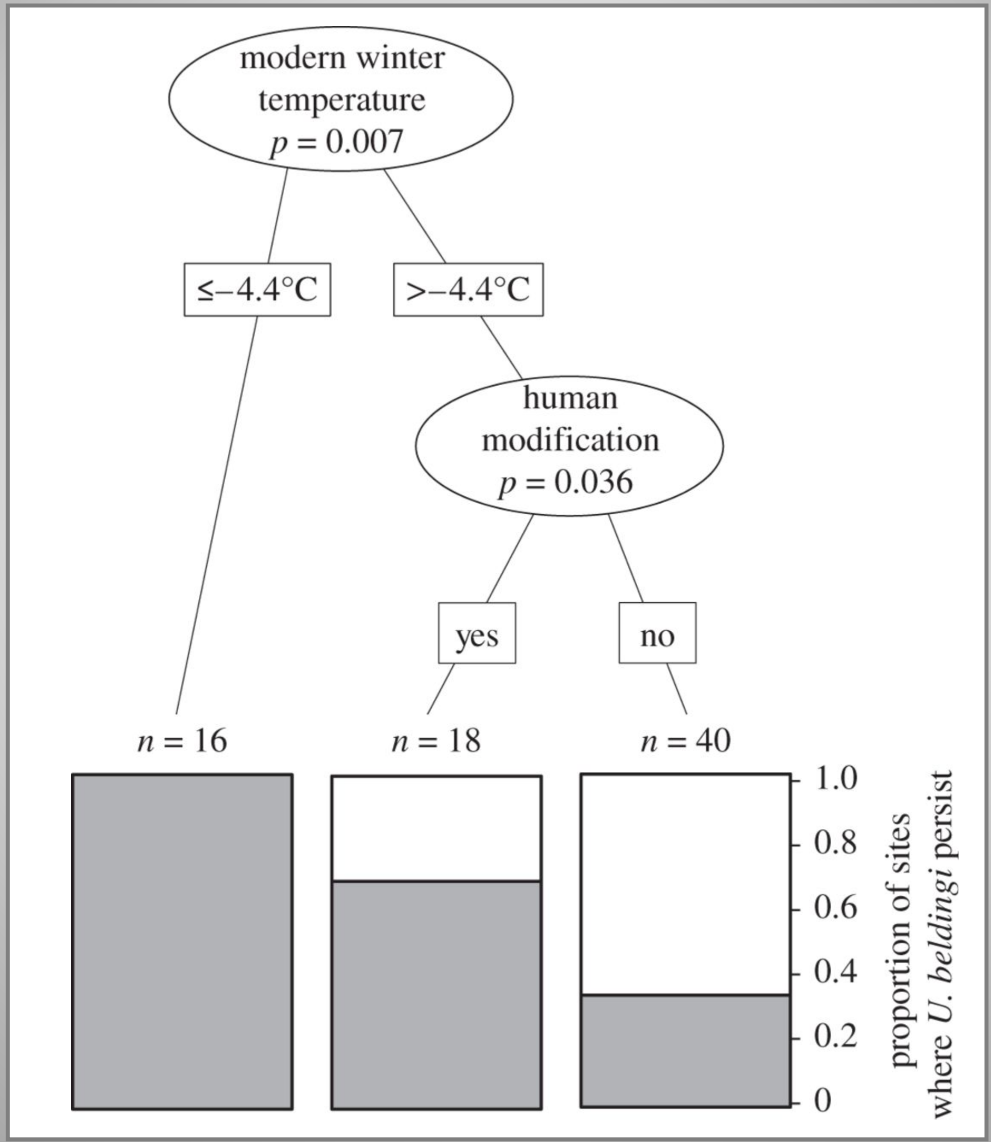
  - Life-history traits
  - Anthropogenic Climate Refugia

Anthropogenic Climate Refugia:
Belding's Ground Squirrel



Morelli et al. 2012 Proc R Soc B 279, 4279–4286

Anthropogenic Climate Refugia: Belding's Ground Squirrel



Morelli et al. 2012 Proc R Soc B 279, 4279–4286

Summary: Elevational Range Dynamics

- Naïve predictions of upward shifts
- The shortcomings of the naïve approach
  - Substantial heterogeneity in temperature/precipitation change
  - Large amounts of heterogeneity in regional species’ range responses

Summary: Predictors of Range Change

- Climate
  - Mammals:
    - High-elevation species: consistent with temperature
    - Low-elevation species: unpredictable by temperature or precipitation
  - Birds:
    - High-elevation species: tracked temperature
    - Low-elevation species: tracked precipitation
    - Intermediate-elevation: tracked both
- Vegetation
  - Mammals:
    - Low-elevation species expansions: synchronous with vegetation expansions

Summary: Predictors of Range Change

- Life-history traits
  - Mammals:
    - Weak support
  - Birds, more likely to shift if:
    - small clutch sizes
    - all-purpose territories
    - year-round residents
- Anthropogenic Climate Refugia
  - Mammals:
    - support low-elevation persistence (n=1)