Effects of Recent Climate Change on Terrestrial Vertebrate Ranges in California:
The Grinnell Resurvey Project

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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 Legacy

Joseph Grinnell
MVZ Director 1908-39
Published transects

Pre-1940 MVZ: Specimen Locality Records
Pre-1940 MVZ:
Field Notes

[Page content]

MUSEUM OF Vertebrate ZOOLOGY

Date: July 2, 1928
Observer: J. M. Currell

Time in field: 7:30 a.m. - 4:00 p.m.
Approximate number of birds: 400

Species | Hours |
--------|-------|
Aggled Pipit | 2 |
White-Winged Sparrow | 4 |
Western Robin | 3 |
Northern Oriole | 3 |
Cassin's Pewee | 16 |
Canada Warbler | 3 |
Gray-crowned Sparrow | 17 |
Swainson's Thrush | 7 |
Pacific Wren | 5 |
Ruby-crowned Kinglet | 2 |
Pine Siskin | 2 |
Bohemian Waxwing | 3 |
Wilson's Thrush | 1 |
Barred Warbler | 1 |
Henry's Warbler | 1 |

| | | | | |
| | | | | |

TOTALES (hours and species):

[Table contents]
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
The Grinnell Resurvey Project

- Coastal 2009-10
- Lassen 2006-07
- Tahoe 2008
- Yosemite 2004-07
- White/Inyo 2008-13
- Western Deserts 2015-18
- Central Valley 2015-18
- Southern Sierra 2008-10
- San Jacinto (SDMNH) 2009-13

Grinnell's Life Zones:
- Boreal
- Upper Sonoran
- Transition
- Lower Sonoran
- Water
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:

\[
P_{fa} = \prod_{j=1}^{m} \prod_{i=1}^{n} (1 - p_{ij})
\]

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

Low- & Mid-Elevation Species

Historic: Expand Upper Limit
Modern: Expand Upper Limit

Mid- & High-Elevation Species

Historic: Contract Lower Limit
Modern: Contract Lower Limit
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

Mammal Trapping Data and Occupancy Profiles

Alpine chipmunk
*Tamias alpinus*

Mammal Trapping Data and Occupancy Profiles

Alpine chipmunk
*Tamias alpinus*

Mammal Trapping Data and Occupancy Profiles

Alpine chipmunk
*Tamias alpinus*

Elevational Range Change: 28 Yosemite Small Mammal Species

Elevational Range Change: Range Expansion

Elevational Range Change: Range Contraction

Elevational Range Change: No Change

Elevational Range Change

avg. ↑ 500 m

Range Change Predictors

• Strong:
  – Original elevational range:
    • Low: expand upper limit
    • High: contract lower limit
   \[\text{Consistent with naïve expectations}\]

• Weak:
  – Life history and ecological traits, specifically:
    • Longevity (life span in years): longer, ↓ probability of shift
    • Litters per year: more, ↑ probability of shift

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

Northern: Lassen

Central: Yosemite

Southern: S. Sierra
### Central

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<th>Elevation (m)</th>
<th>Low-elevation species</th>
<th>High-elevation species</th>
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### Northern

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

- **expansion**
- **contraction**
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
  – Are naïve predictions of upward shifts sufficient?
  – Dynamics at a broader spatial extent
  – The shortcomings of the naïve approach
Climate Change Since Grinnell: Substantial and Highly Variable

The Elevational Push and Pull of Climate Change: Nearest Climatic Neighbor (Temperature and Precipitation)

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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• Predictors of Range Change
Effects of Climate Change on Terrestrial Vertebrate Ranges

• Elevational Range Dynamics
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• Predictors of Range Change
  – Climate
Central

Northern

Southern

low-elevation species

high-elevation species

Rowe et al. 2015 Proc Royal Soc B 282: 20141857
Climate Change Predictions: Small Mammal Range Shifts

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

![Graph showing range limit shifts for low- and high-elevation species.](image)
Climate Change Predictions: Small Mammal Range Shifts

Rowe et al. 2015 Proc Royal Soc B 282: 20141857
Climate Change Predictions: Avian Range Shifts

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

Santos et al. 2015 Ecography 38, 556–568
Vegetation Change: Synchronicity in Mammalian Shifts

Santos et al. 2015 Ecography 38, 556–568
Vegetation Change: Synchronicity in Mammalian Shifts

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
Life History Traits: Birds

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- Elevational Range Dynamics
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- Predictors of Range Change
  - Climate
  - Vegetation
  - Life-history traits
  - Anthropogenic Climate Refugia
Anthropogenic Climate Refugia: Belding’s Ground Squirrel

Anthropogenic Climate Refugia: Belding’s Ground Squirrel

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)