Section 3: Species range shifts

Learning outcomes

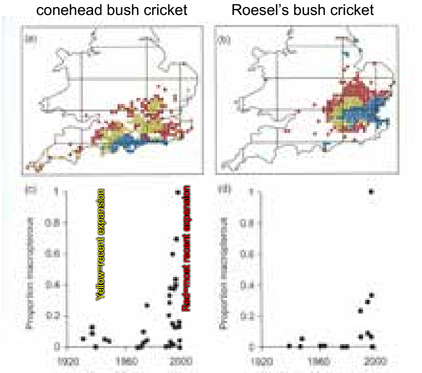
- understand concepts and mechanisms of range shifts
- give examples of the direct effect of climate change on range shifts as well as the indirect effects
- describe how range shifts have been used as evidence for climate change

Adaptation: Evolution

Blue=historical range
Yellow=recent expansion
Red=most recent expansion

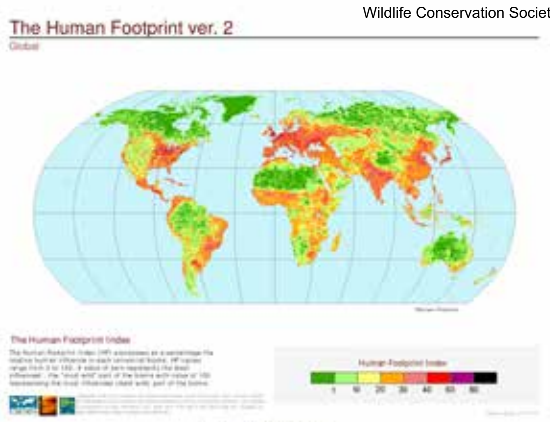
conehead bush cricket   Roesel's bush cricket

proportion longwinged

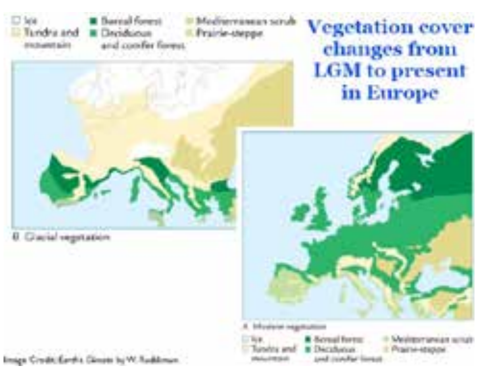


Hannah 2011

Wildlife Conservation Society



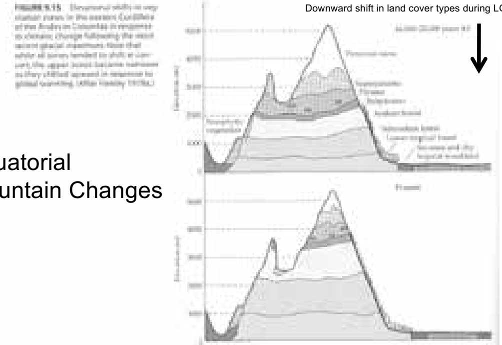
NatureServe



Slide courtesy C. Still

Equatorial Mountain Changes

Downward shift in land cover types during LGM



Lomolino et al., 2006

Differential species responses:
rates, direction

different climate sensitivities? habitat requirements? predators/parasites?

MacDonald 2009

Examples of recent range shifts

Edith's checkerspot butterfly: northward and upward in elevation shift

Hannah 2011

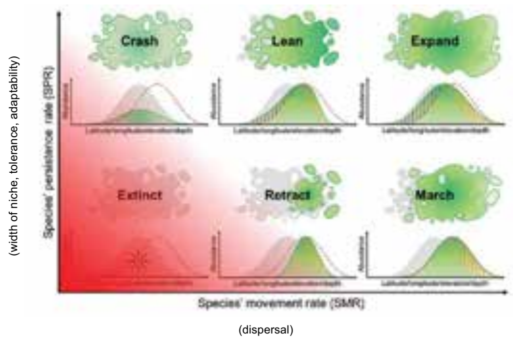
Examples of recent range shifts

pika: a cautionary tale

- sensitive to summer temperature
- recently, lower elevation populations have disappeared
- but pikas exist in hot places

Tricky to understand the role of climate change!

Theoretical framework for characterizing different range shift responses to climate change



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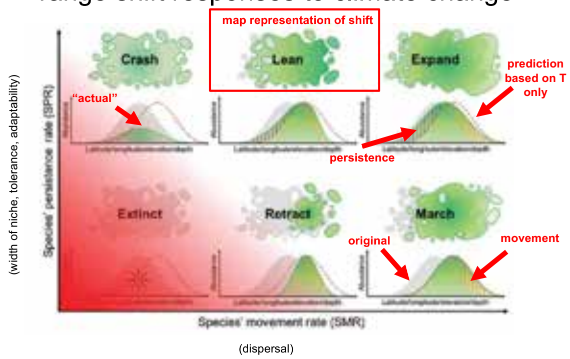
Theoretical framework for characterizing different range shift responses to climate change



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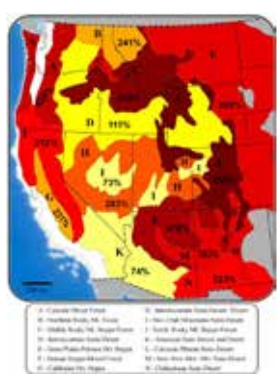
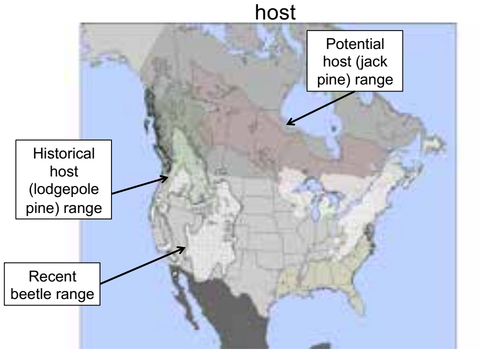
Indirect effects of climate change that lead to range shifts



increase in burned area for 1º C increase in temperature

Littell et al., *Ecological Applications*, 2009; National Academies, *Climate Stabilization Targets*, 2010

Expansion of mountain pine beetle into novel host



Logan and Powell 2001

Indirect effects of climate change that lead to range shifts

Competition with other species

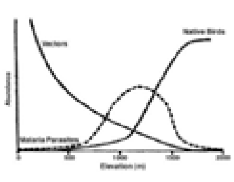
southern range limit retreating northward

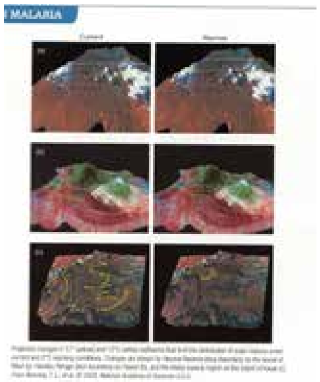
northward expansion

Hannah 2011

Interactions between climate change and biological invasions

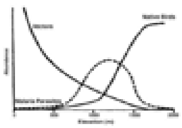
- 30 species of Hawaiian honeycreepers (*Drepanididae*)
  - endemic to Hawaiian islands





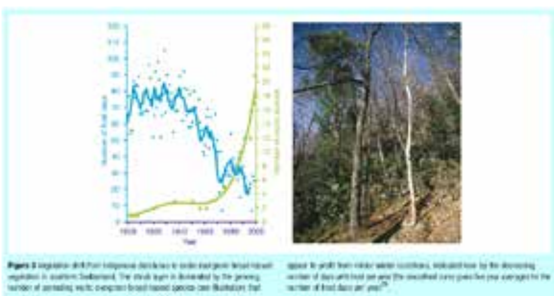
Warming => upward expansion of avian malaria parasite

Implications for native birds???



Hannah 2011

Climate change will facilitate invasions of exotic species



Walther et al., 2002

Climate change and extinctions

IPCC AR5 WG 2 (Intergovernmental Panel on Climate Change, Fifth Assessment Report (2013), Working Group 2 (Impacts, Adaptation, and Vulnerability")):

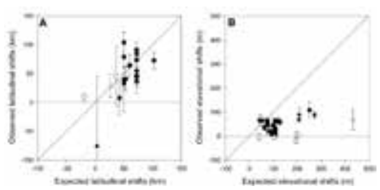
"Climate change may have already contributed to the extinction of a small number of species, such as frogs and toads in Central America, but the role of climate change in these recent extinctions is the subject of considerable debate."


Rapid Range Shifts of Species Associated with High Levels of Climate Warming

- 23 taxonomic groups, 764 species
- found that most studies indicated expected shifts in response to warming

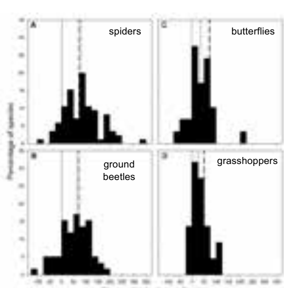
Meta-analyses of impacts

- latitude
  - 17 km/decade
  - range shifts of many species can keep up with warming
- elevation
  - 11 m/decade
  - range shifts of many species cannot



expected based on climate change

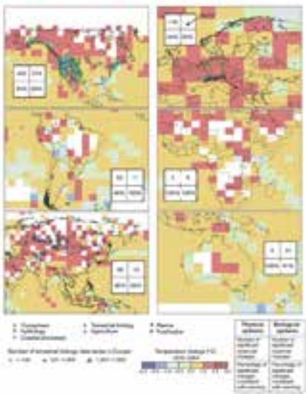
Meta-analyses of impacts



- substantial variability in species
- related to
  - time delays in responses
  - different physiological constraints
  - other drivers of change

Chen et al., Science, 2011

Meta-analyses of impacts

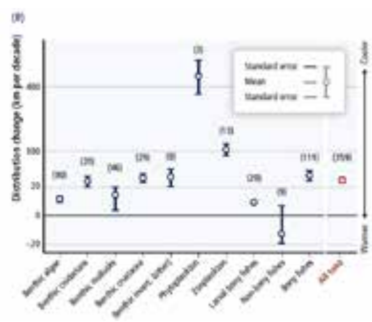


- physical and biological responses with observed changes
- 90% were consistent with warming
- consistent across continents
- very unlikely to be caused by natural climate variability

Rosenzweig et al., Nature, 2008

Meta-analyses of impacts

Rate of range shifts for marine taxa, 1900-2010



IPCC AR5 WG2, 2013

Section 3:
Species range shifts

Patterns within the Patterns

…

"In the species-by-species study, the overwhelming majority of species showed the poleward and upslope shifts expected with warming. In 1700 species studied, poleward range shifts averaged 6 km per decade. A total of 279 of the species showed responses that tracked climate change—poleward shift during warming periods and shift away from the poles in cooling periods—but a net poleward shift. This gives strong indication of climate causality."

(Hannah p 72-73)
Hannah, Lee. *Climate Change Biology, 2nd Edition*. Academic Press, 11/2014. VitalBook file.

articles

A globally coherent fingerprint of climate change impacts across natural systems

Camille Parmesan* & Gary Yohe†

[illegible]

Causal attribution of recent biological trends to climate change is complicated because non-climatic influences dominate local, short-term biological changes. Any underlying signal from climate change is likely to be revealed by analyses that seek systematic trends across diverse species and geographic regions; however, debates within the Intergovernmental Panel on Climate Change (IPCC) reveal several definitions of a 'systematic trend'. Here, we explore these differences, apply diverse analyses to more than 1,700 species, and show that recent biological trends match climate change predictions. Global meta-analyses documented significant range shifts averaging 6.1 km per decade towards the poles (or metres per decade upward), and significant mean advancement of spring events by 2.3 days per decade. We define a diagnostic fingerprint of temporal and spatial 'sign-switching' responses uniquely predicted by twentieth century climate trends. Among appropriate long-term/large-scale/multi-species data sets, this diagnostic fingerprint was found for 279 species. This suite of analyses generates 'very high confidence' (as laid down by the IPCC) that climate change is already affecting living systems.

Nature, 2003

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Table 1 Summary of data studying phenological and distributional changes of wild species

[illegible]

Climate Change Ecology *Parmesan and Yohe, Nature, 2003* Prof. J. Hicke

consistent with hypothesis

inconsistent with hypothesis

Table 2 Summary statistics and synthetic analyses derived from Table 1

Type of change	Changed as predicted	Changed opposite to prediction	P value
[illegible]	[illegible]	[illegible]	[illegible]

out of 1700 species, 920 had data about distribution or abundance changes

out of the 920, 460 species had a statistically or biologically significant change

out of the 460, 81% changed as predicted based on climate change

Climate Change Ecology *Parmesan and Yohe, Nature, 2003* Prof. J. Hicke

Table 3 **Biological fingerprint of climate change impacts**

Sign-switching pattern	Percentage of species showing diagnostic pattern
Community	
Abundance changes have gone in opposite directions for cold-adapted compared with warm-adapted species. Usually local, but many species in each category. Diverse taxa, n = 282*	80%
Temporal	
Advancement of timing of northward expansion in warm decades (1930s/40s and 1980s/90s), delay of timing or southward contraction in cool decades (1950s/60s). 30–132 years per species. Diverse taxa, n = 44*	100%
Spatial	
Species exhibit different responses at extremes of range boundary during a particular climate phase. Data are from substantial parts of both northern and southern range boundaries for each species. All species are northern hemisphere butterflies, n = 8*	100%

Differential sign-switching patterns diagnostic of climate change as the underlying driver.
*Numbers of species represent minimum estimates, as not all species were described in sufficient detail in each study to classify. A few species showed two types of sign switching, and so are included in more than one cell. Data are from references in text and from raw data provided by [illegible]

[in locations of overlapping ranges, polar (cold-adapted) species have responded negatively to warming whereas temperate (warm-adapted) species have responded positively]

out of 334 species, 279 showed one of these biological fingerprints

Parmesan and Yohe, Nature, 2003

Prof. J. Hicke

Sudden aspen decline

distribution of fundamental niche of aspen based on species distribution model

Worrall et al., Forest Ecology and Management, 2013

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Sudden aspen decline

Photo courtesy of W. Anderegg

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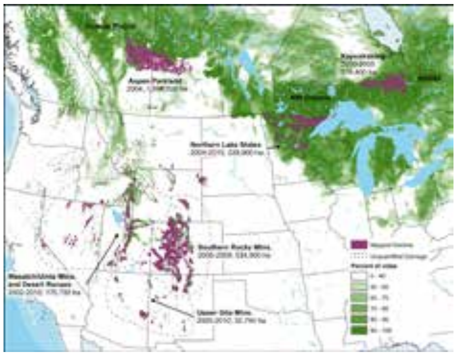
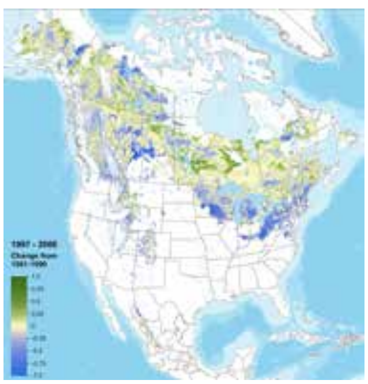
Sudden aspen decline

locations of SAD



Worrall et al., Forest Ecology and Management, 2013

Sudden aspen decline

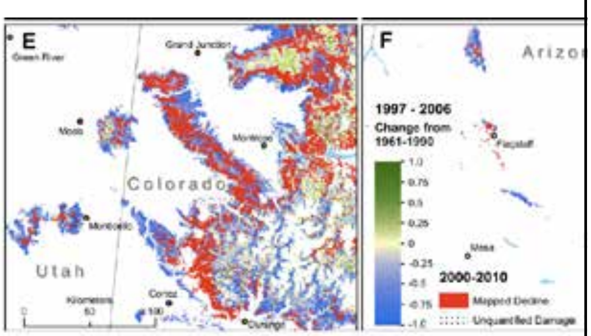


stress induced by recent changes in climate

Worrall et al., Forest Ecology and Management, 2013

Sudden aspen decline

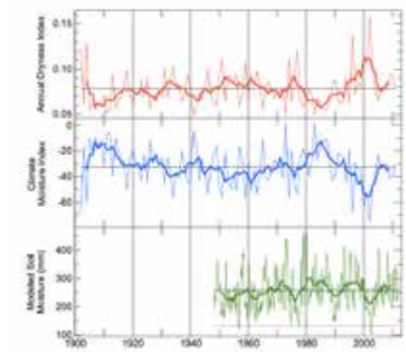
modeled stress (blue) and observed decline (red)



Worrall et al., Forest Ecology and Management, 2013

Sudden aspen decline

Climate in last 100 years in Colorado



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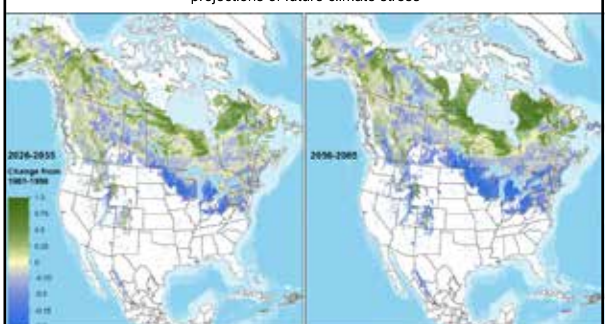
Sudden aspen decline

projections of future climate stress



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