Section 3:
Species range shifts

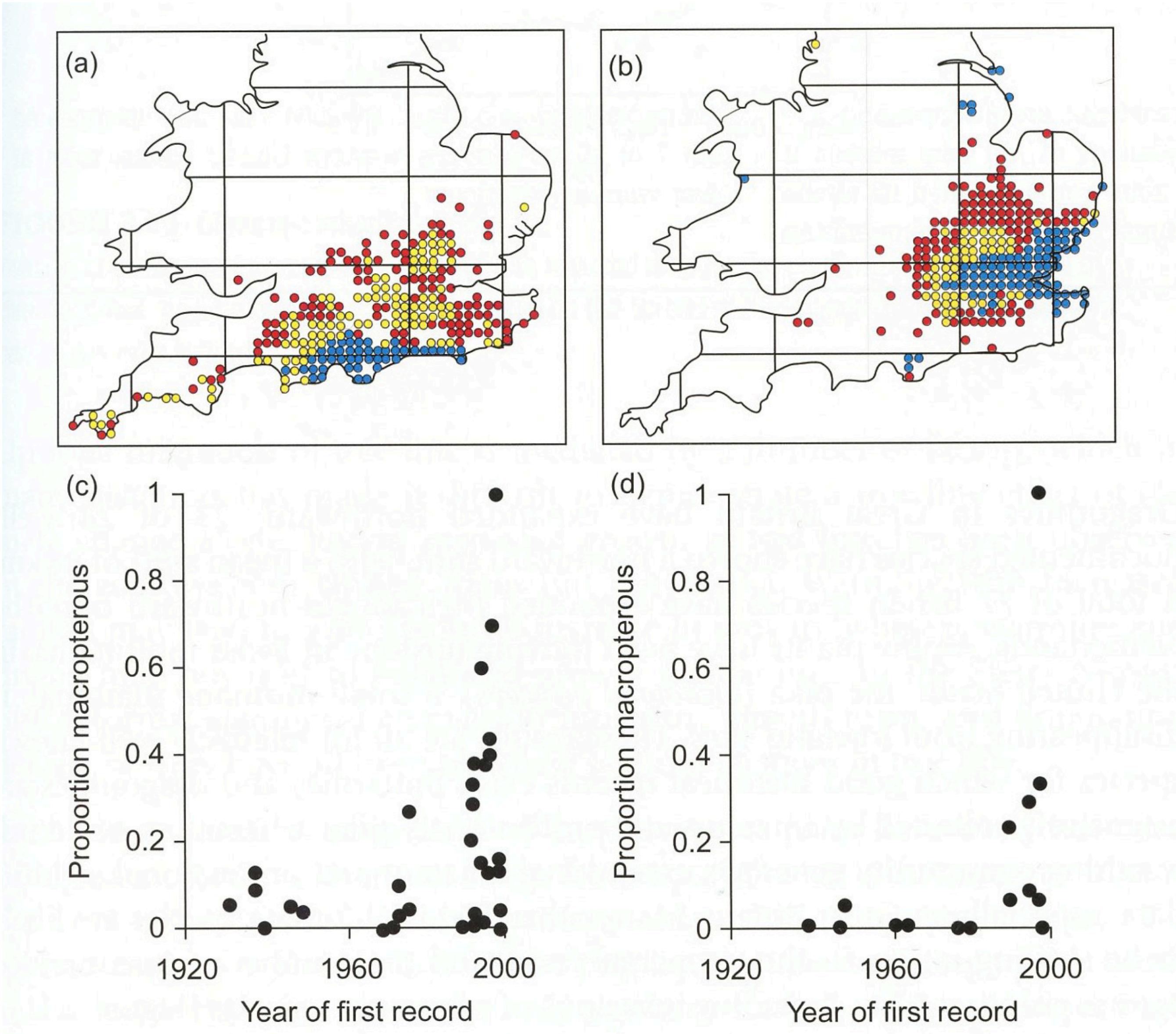
Learning outcomes

- 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

conehead bush cricket Roesel's bush cricket

amount longwinged

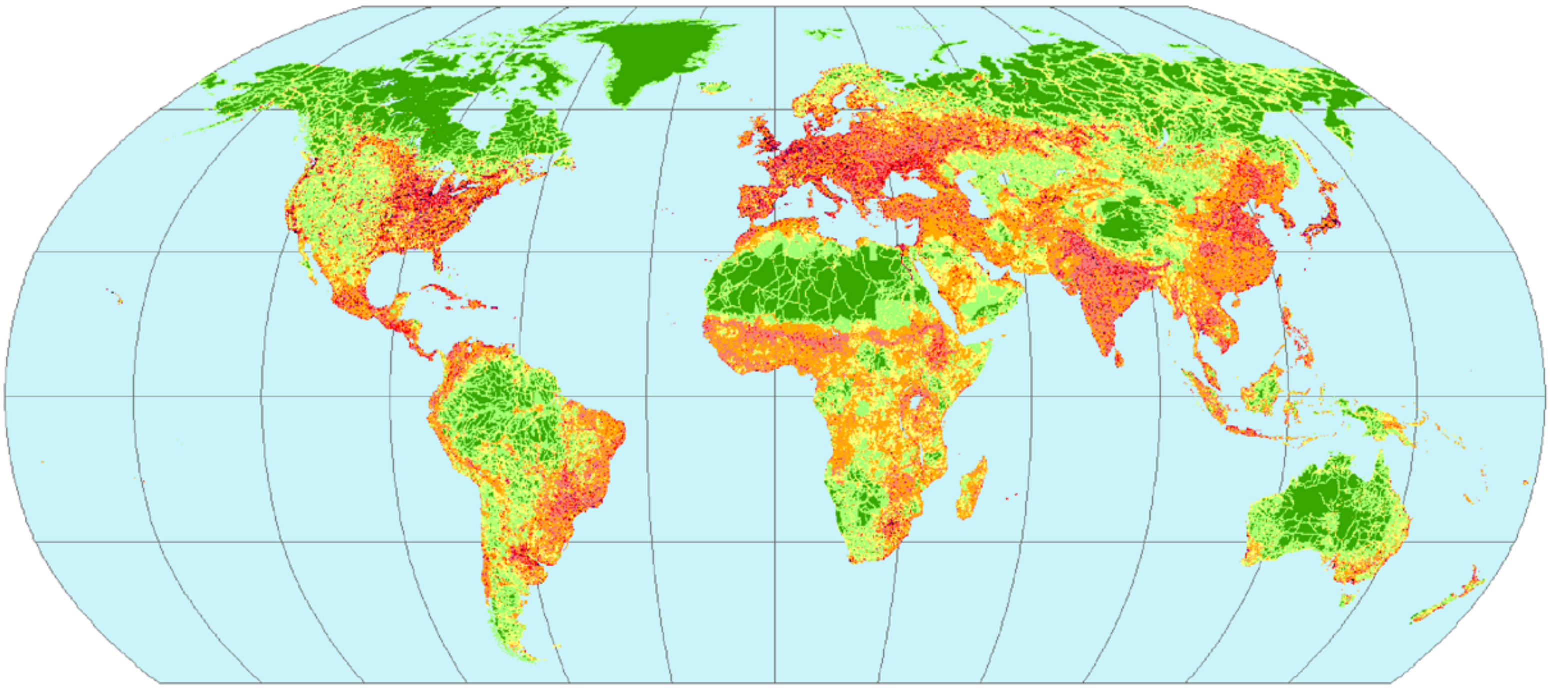


Hannah 2011

Wildlife Conservation Society

The Human Footprint ver. 2

Global

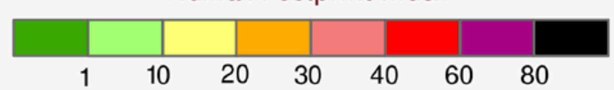


Robinson Projection

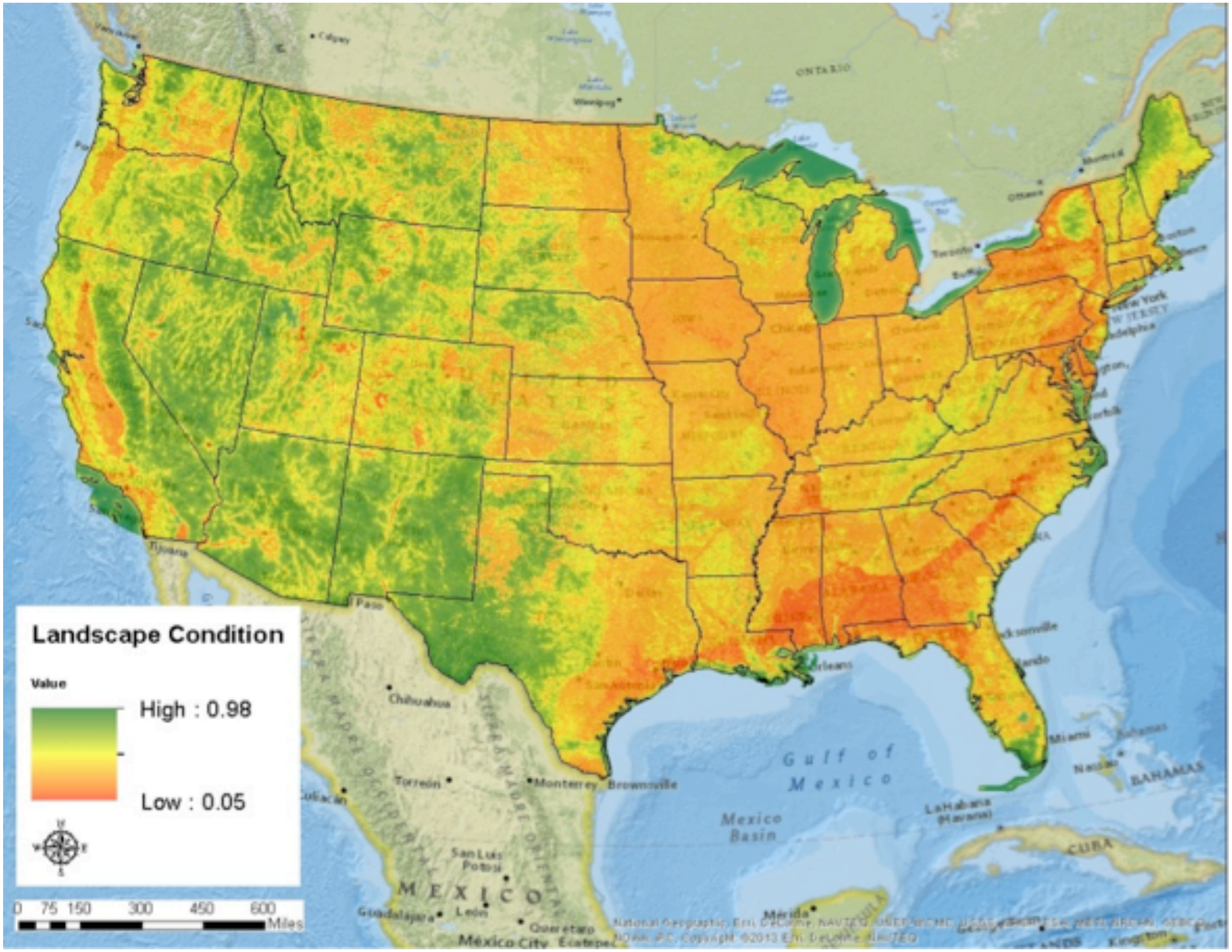
The Human Footprint Index

The Human Footprint Index (HF) expressses as a percentage the relative human influence in each terrestrial biome. HF values range from 0 to 100. A value of zero represents the least influenced - the "most wild" part of the biome with value of 100 representing the most influenced (least wild) part of the biome.

Human Footprint Index

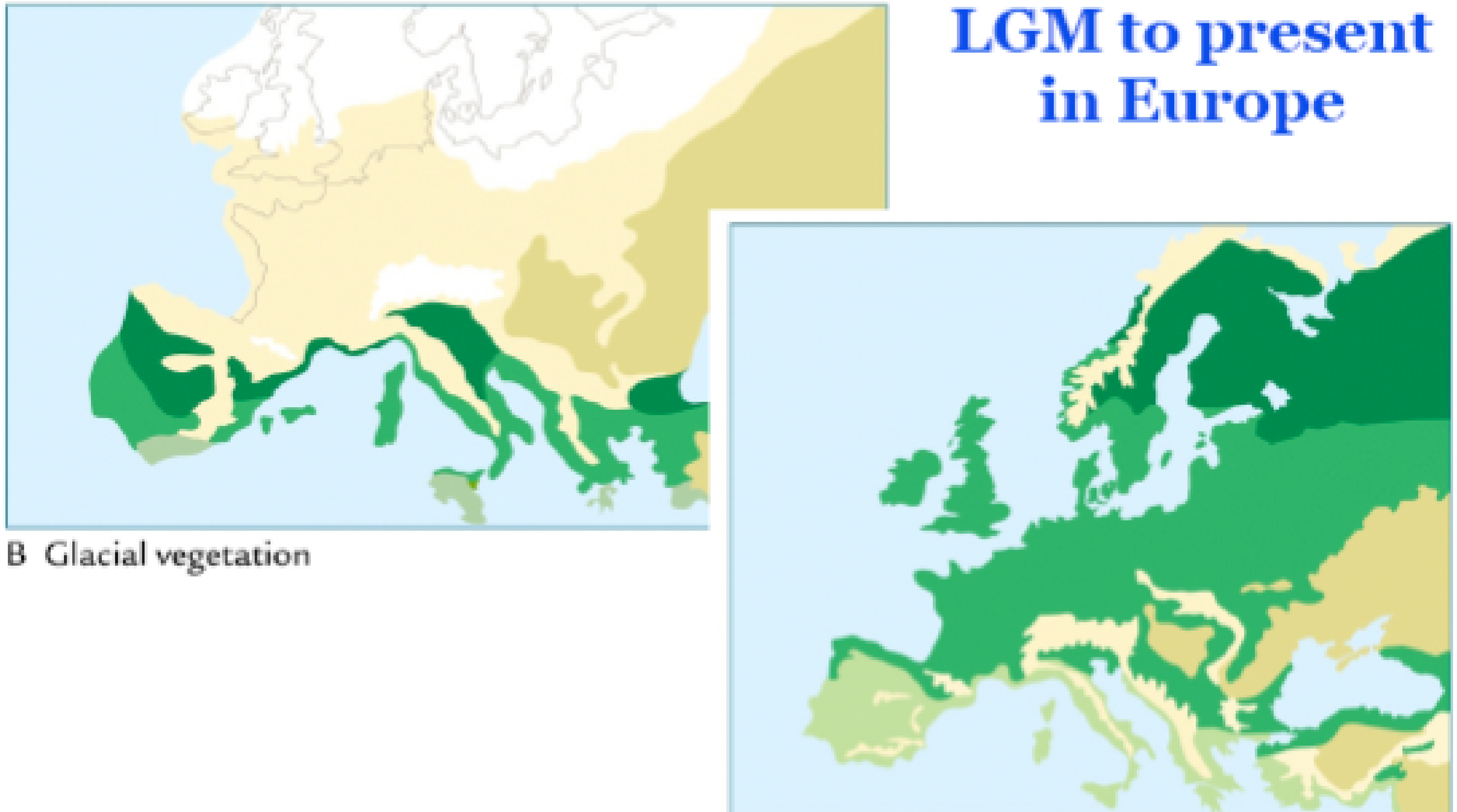


Publish Date: 03/07/08



NatureServe

Vegetation cover changes from LGM to present in Europe



B Glacial vegetation

A Modern vegetation

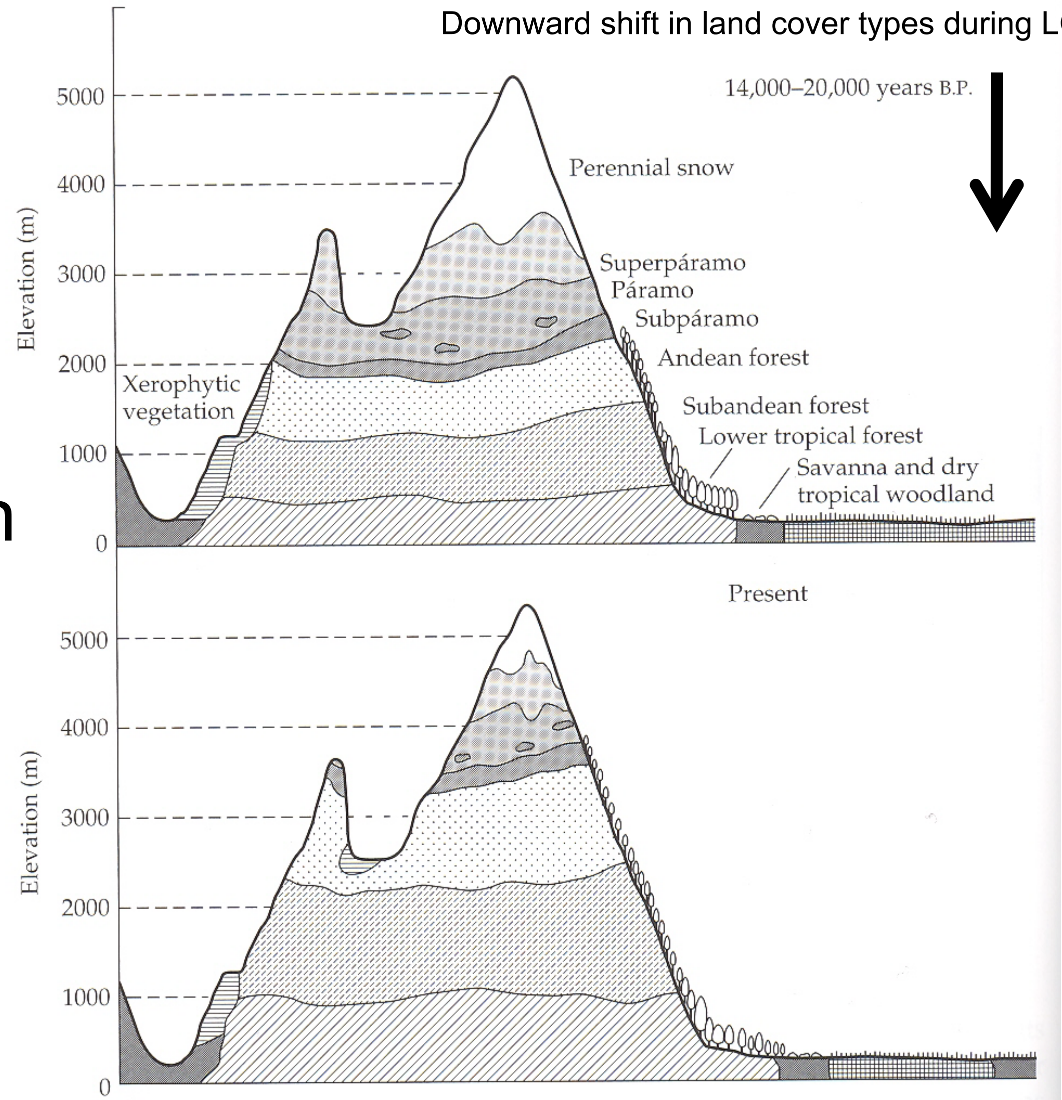
Image Credit: *Earth's Climate* by W. Ruddiman

Slide courtesy C. Still

Equatorial Mountain Changes

FIGURE 9.15 Elevational shifts in vegetation zones in the eastern Cordillera of the Andes in Colombia in response to climatic change following the most recent glacial maximum. Note that while all zones tended to shift in concert, the upper zones became narrower as they shifted upward in response to global warming. (After Flenley 1979a.)

Downward shift in land cover types during LGM



Lomolino et al., 2006

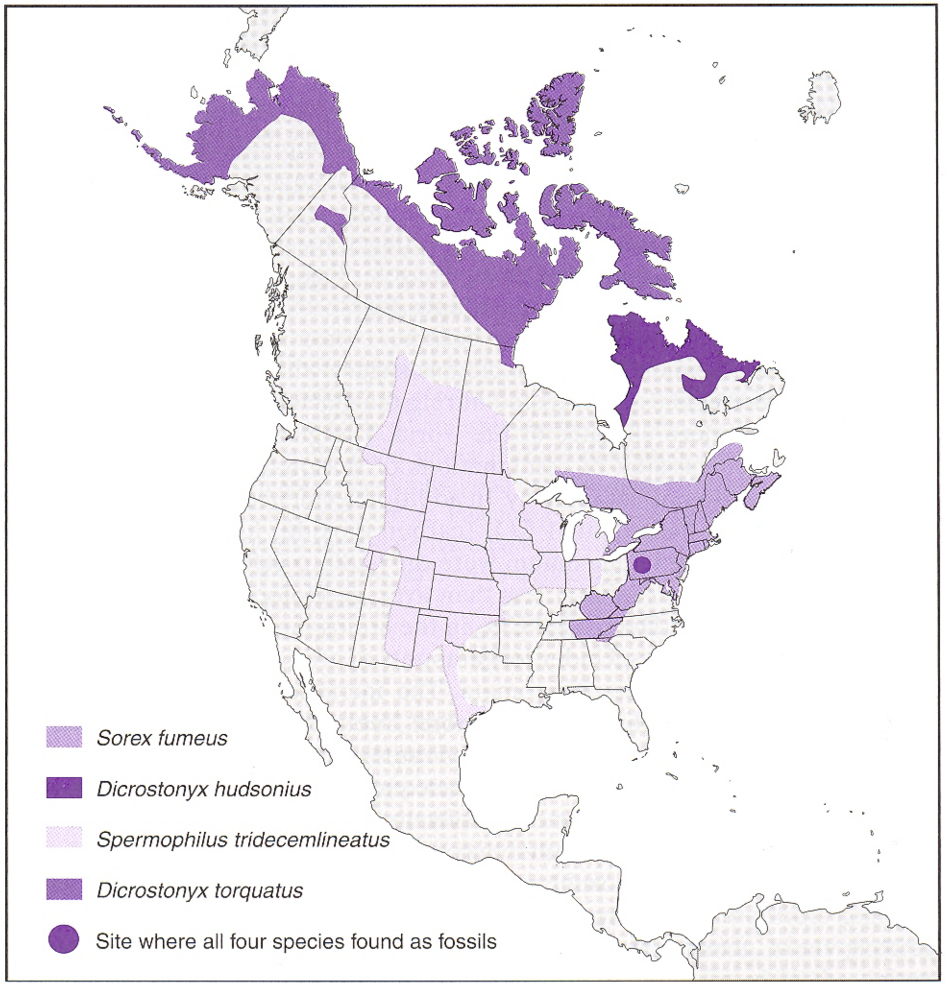


FIGURE 7.8 The modern distributions of eastern shrew *(Sorex fumens)*, eastern collared lemming *(Dicrostonyx hudsonius)*, prairie ground squirrel *(Spermophilus tridecemlineatus)*, and western collared lemming *(Dicrostonyx torquatus)*, and a site in Pennsylvania where fossil evidence indicates that all four species coexisted during the last glacial maximum, although they clearly do not live together today (after Graham, 1986; Graham et al., 1996; Brown and Lomolino, 1998).

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

FIGURE 3.5 Edith's Checkerspot Butterfly *(Euphydryas editha)*.
From http://www.nps.gov/pinn/naturescience/butterfly.htm.

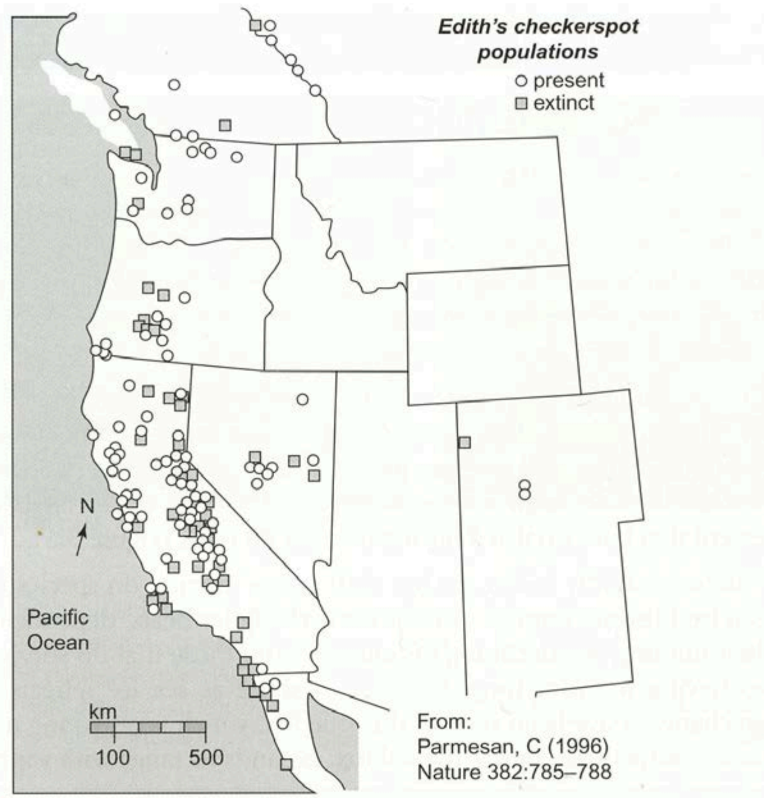


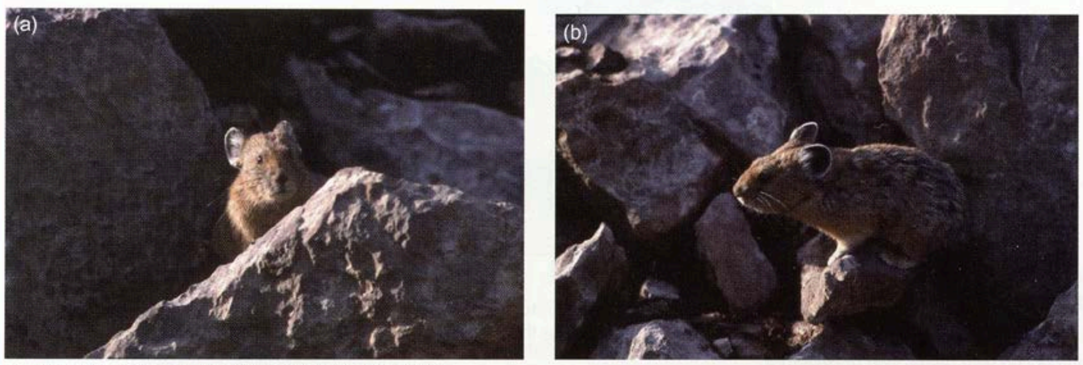
FIGURE 3.4 Edith's Checkerspot Butterfly Range Shift.
Southern populations of Edith's checkerspot butterfly are becoming extinct (shaded squares) more frequently than northern and montane populations, resulting in a northward and upslope range shift.
Reprinted by permission from Macmillan Publishers Ltd.

Hannah 2011

Examples of recent range shifts

pika: a cautionary tale

THE DISAPPEARING PIKA: CLIMATE AND PHYSIOLOGY



Pika (*Ochotona princeps*). From National Park Service, U.S.A.

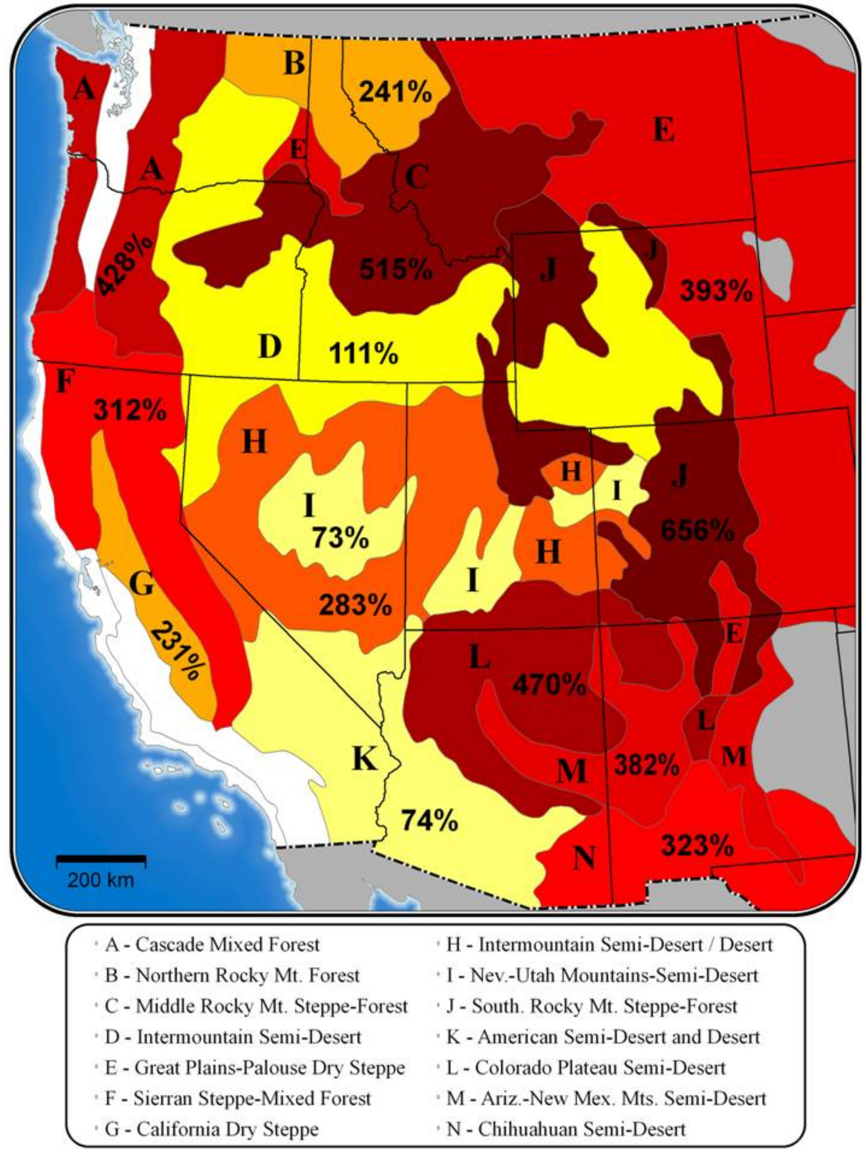
Pika, small high mountain residents, are disappearing due to climate change. The physiology of the Pika renders it susceptible to direct death from warming when its alpine habitats reach high temperatures, and elevated temperature inhibits foraging as a result. By 2004, Pika had disappeared from 7 of 25 sites in the western United States, most at lower, warmer elevations.

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

Tricky to understand the role of climate change!

Hannah 2011

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

Indirect effects of climate change that lead to range shifts

Range shift allows utilization of new habitat

brown argus butterfly: northward expansion at twice global mean rate: why?

Host 1: rockrose occupies sites with warmer microclimate; not widespread

Host 2: geranium occupies sites with cooler microclimate; widespread

Patemann et al., Science, 2012

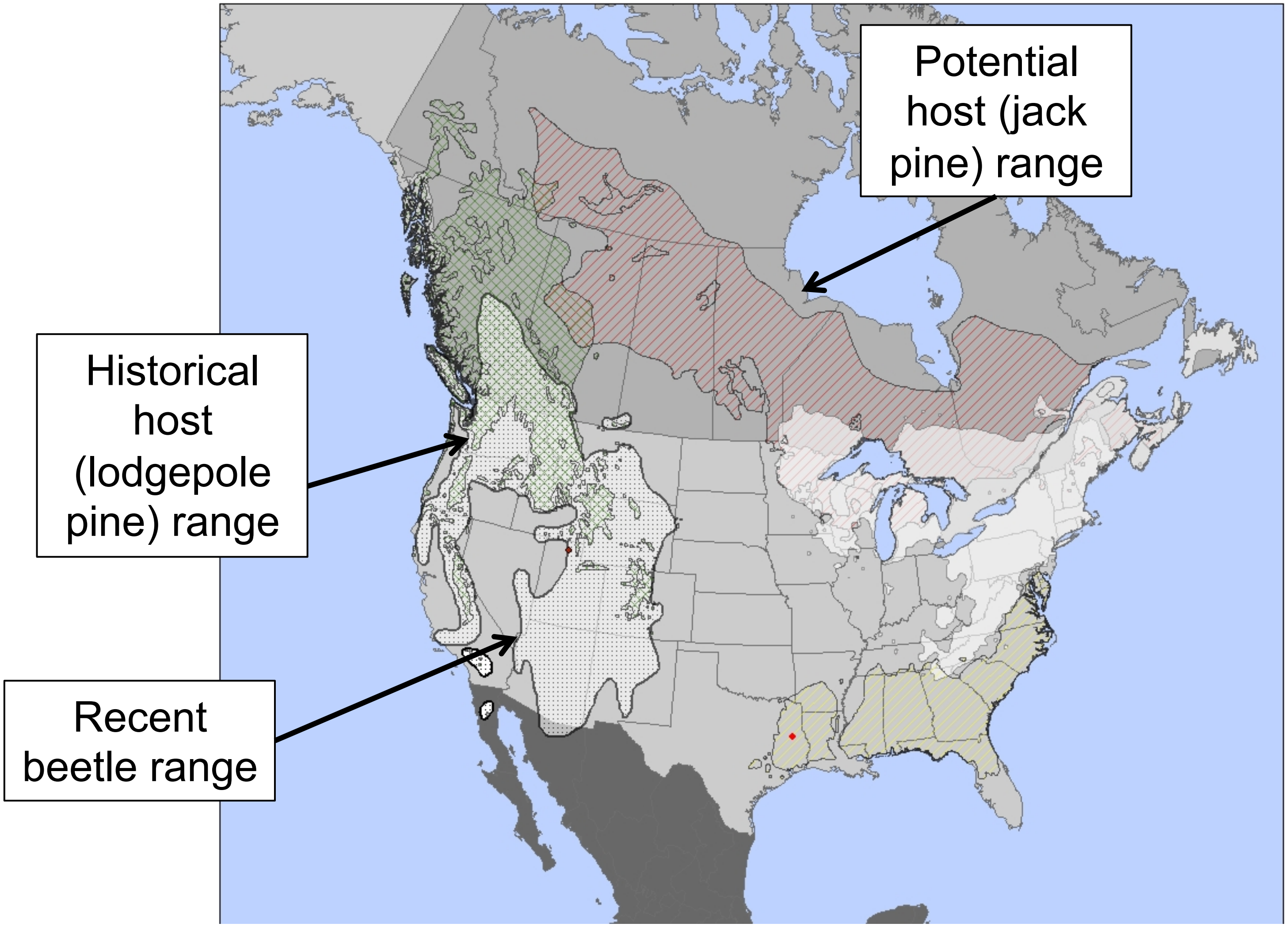
Indirect effects of climate change that lead to range shifts

Range shift allows utilization of new habitat

- with warming, brown argus uses geranium
- because geranium is more widespread, butterfly can disperse more easily
- warming facilitates expansion, allowing brown argus to adapt rapidly (benefit)
- species interactions are important for assessing climate change impacts

Patemann et al., Science, 2012

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

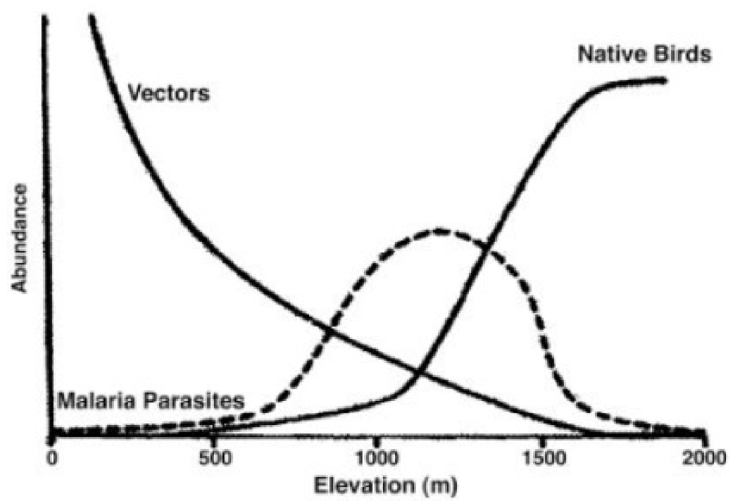
Arctic fox (a) and red fox (b). *From (a) Wikimedia Commons and (b) U.S. Fish and Wildlife Service.*

southern range limit retreating northward

northward expansion

Hannah 2011

Interactions between climate change and biological invasions



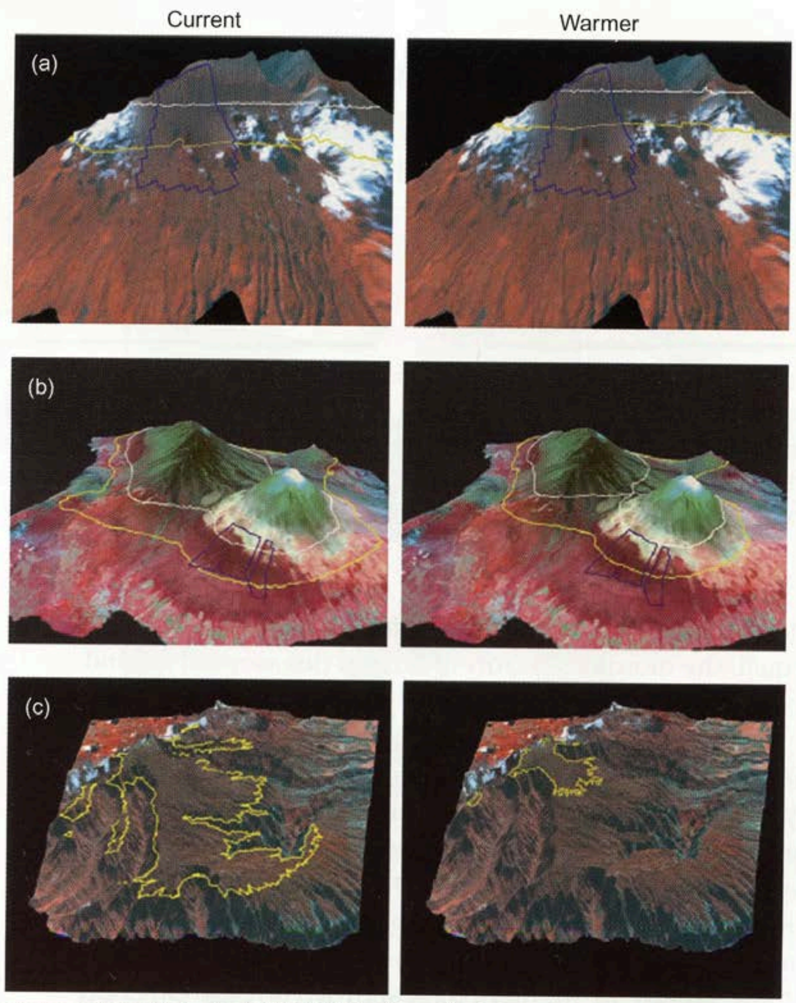
Benning et al., *Proc. Natl. Acad. Sci.* Volume 99 Number 22, 29 October 2002

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

- on Oahu, 6 species extinct by 1900
  - declines in lower elevation species but not higher elevation

- tied to introduction of *Culex* mosquitoes in 1820s by Europeans
  - carriers of avian malaria
  - lack of evolution in presence of mosquitoes => lack of defense in honeycreepers
  - limited in elevation extent by temperature

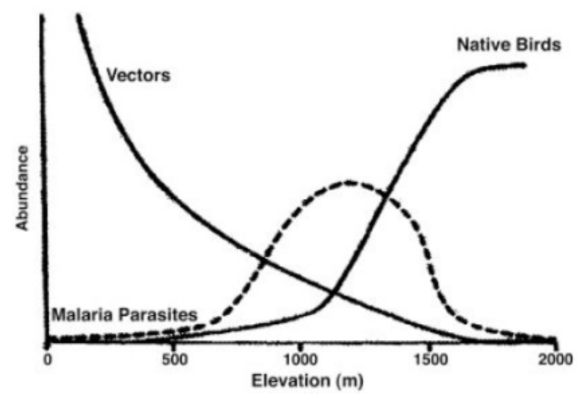
MALARIA



Projected changes in 17° (yellow) and 13°C (white) isotherms that limit the distribution of avian malaria under current and 2°C warming conditions. Changes are shown for Hanawi Reserve (blue boundary) on the island of Maui (a), Hakalau Refuge (blue boundary) on Hawaii (b), and the Alakai swamp region on the island of Kauai (c). *From Benning, T. L., et al. © 2002, National Academy of Sciences U.S.A..*

Warming => upward expansion of avian malaria parasite

Implications for native birds???



Hannah 2011

Climate change will facilitate invasions of exotic species

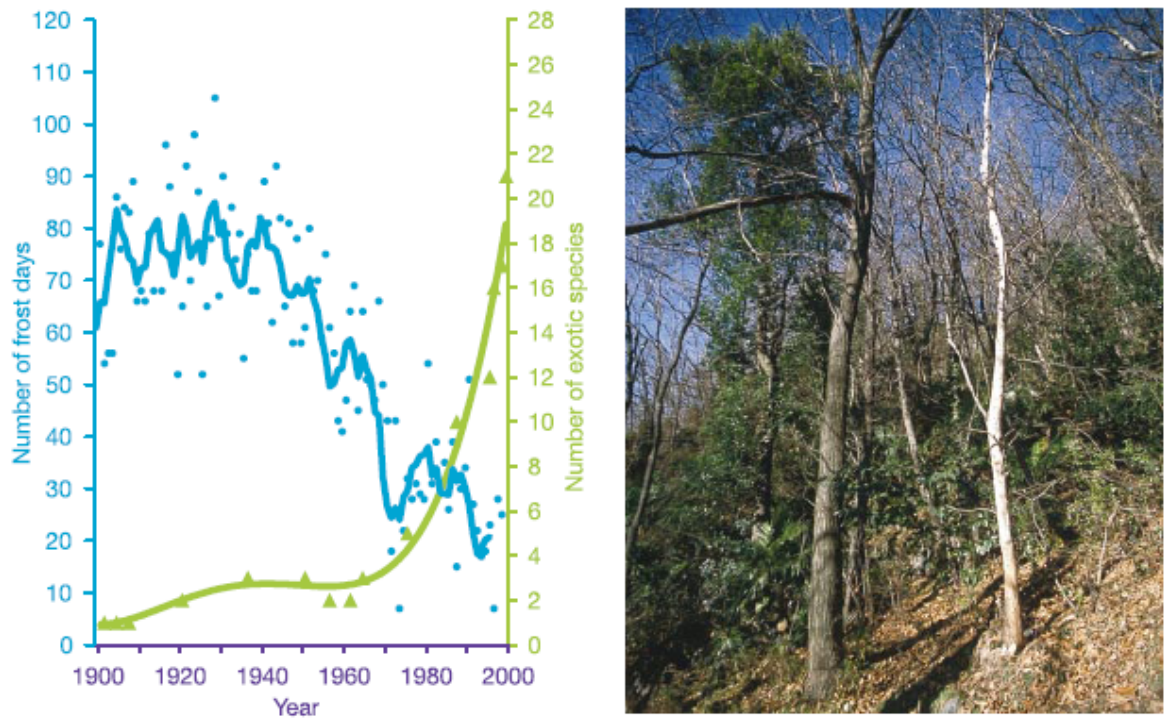
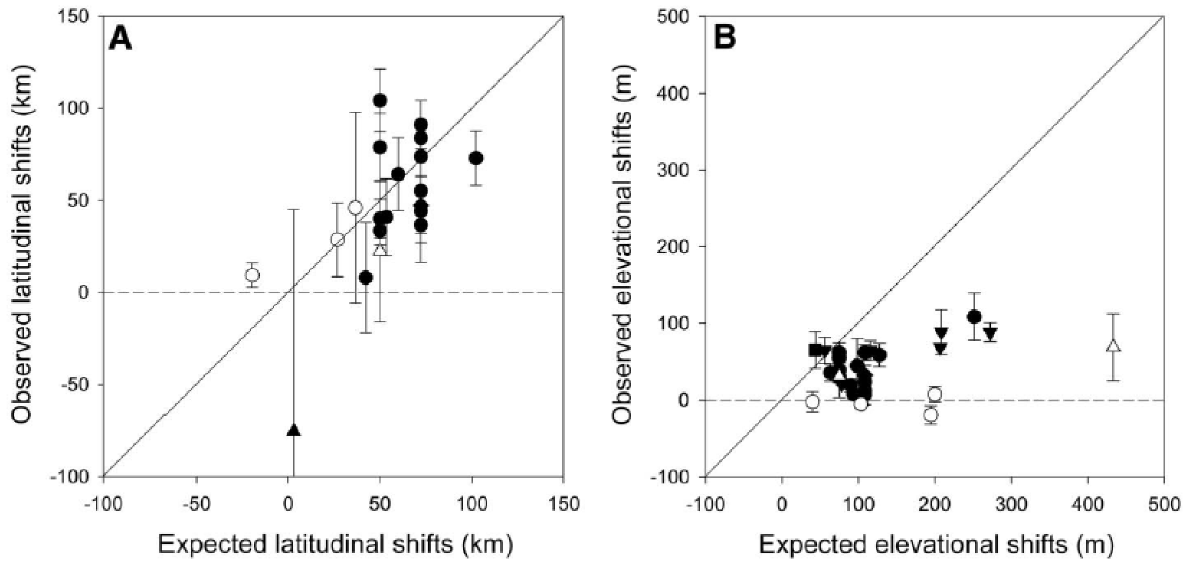


Figure 3 Vegetation shift from indigenous deciduous to exotic evergreen broad-leaved vegetation in southern Switzerland. The shrub layer is dominated by the growing number of spreading exotic evergreen broad-leaved species (see illustration) that appear to profit from milder winter conditions, indicated here by the decreasing number of days with frost per year (the smoothed curve gives five year averages for the number of frost days per year)[29].

Walther et al., 2002

Meta-analyses of impacts

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



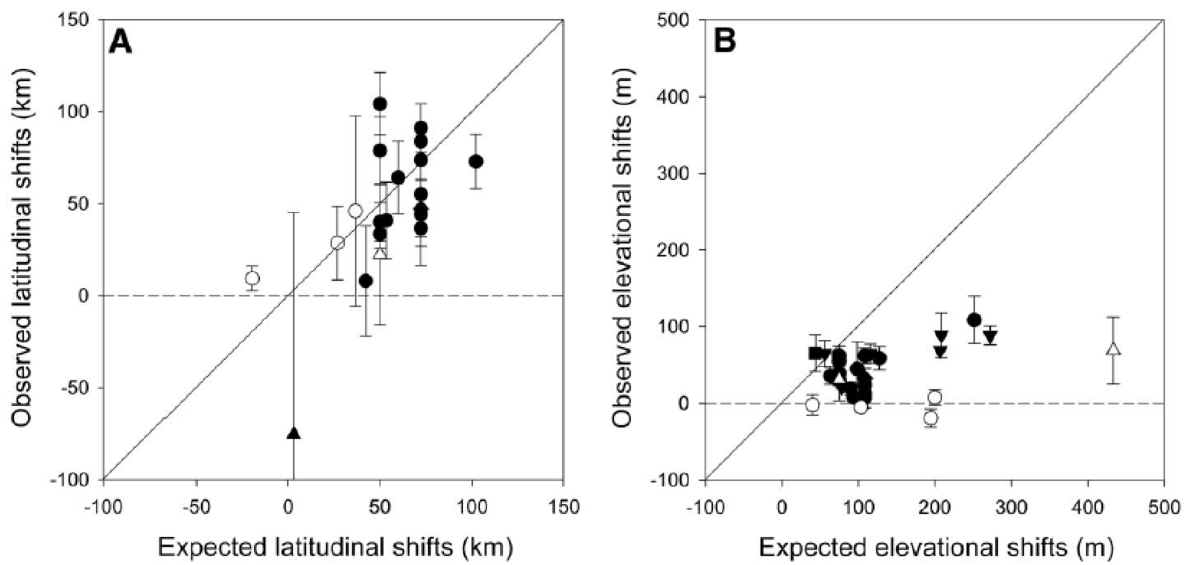
expected based on climate change

Fig. 1. Relationship between observed and expected range shifts in response to climate change, for (**A**) latitude and (**B**) elevation. Points represent the mean responses (±SE) of species in a particular taxonomic group, in a given region. Positive values indicate shifts toward the pole and to higher elevations. Diagonals represent 1:1 lines, where expected and observed responses are equal. Open circles, birds; open triangles, mammals; solid circles, arthropods; solid inverted triangles, plants; solid square, herptiles; solid diamond, fish; solid triangle, mollusks.

Chen et al., Science, 2011

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

Fig. 1. Relationship between observed and expected range shifts in response to climate change, for (**A**) latitude and (**B**) elevation. Points represent the mean responses (±SE) of species in a particular taxonomic group, in a given region. Positive values indicate shifts toward the pole and to higher elevations. Diagonals represent 1:1 lines, where expected and observed responses are equal. Open circles, birds; open triangles, mammals; solid circles, arthropods; solid inverted triangles, plants; solid square, herptiles; solid diamond, fish; solid triangle, mollusks.

Chen et al., Science, 2011

Meta-analyses of impacts

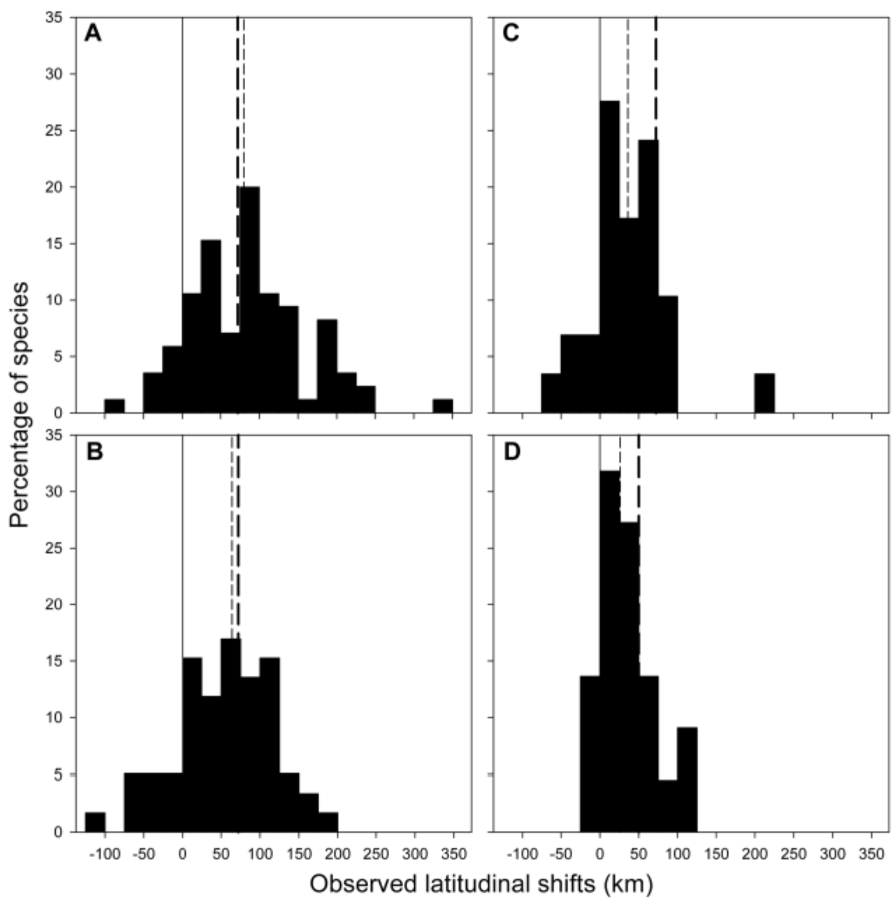
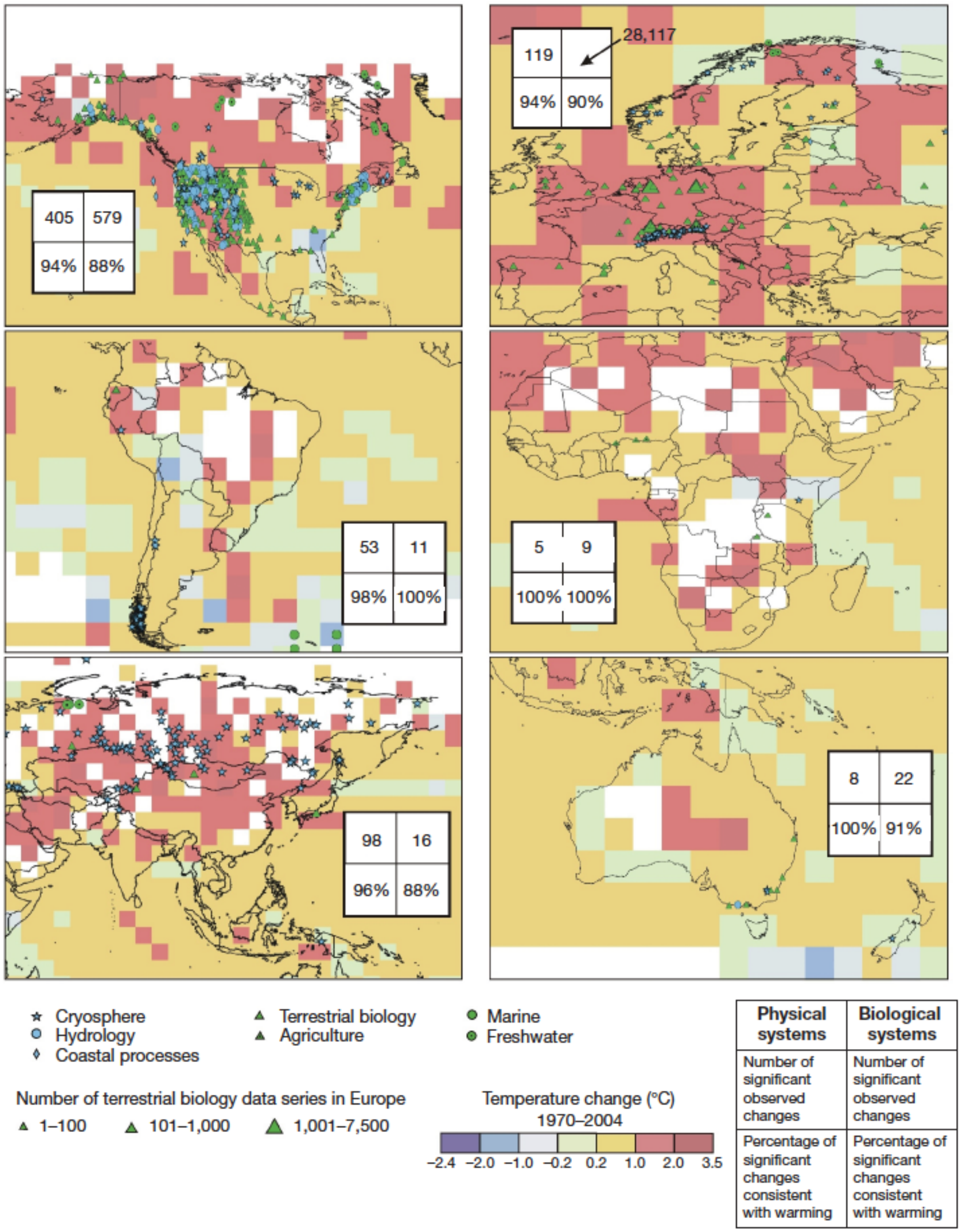


Fig. 2. Observed latitudinal shifts of the northern range boundaries of species within four exemplar taxonomic groups, studied over 25 years in Britain. **(A)** Spiders (85 species), **(B)** ground beetles (59 species), **(C)** butterflies (29 species), and **(D)** grasshoppers and allies (22 species). Positive latitudinal shifts indicate movement toward the north (pole); negative values indicate shifts toward the south (Equator). The solid line shows zero shift, the short-dashed line indicates the median observed shift, and the long-dashed line indicates the predicted range shift.

- 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



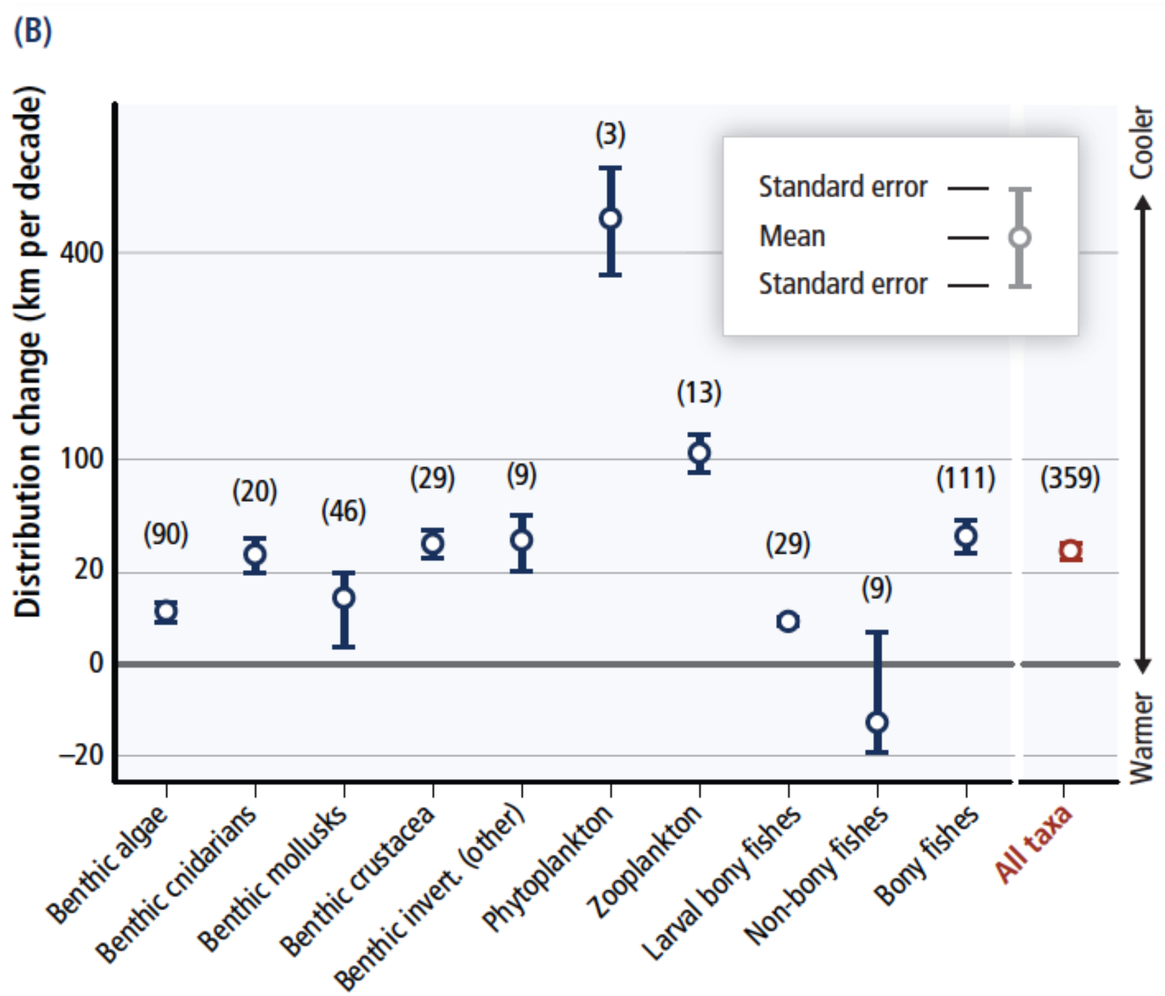
- physical and biological responses with observed changes
- 90% were consistent with warming
- consistent across continents
- very unlikely to be caused by natural climate variability

Rosenzweig et al., Nature, 2008

Prof. J. Hicke

Meta-analyses of impacts

Rate of range shifts for marine taxa, 1900-2010



IPCC AR5 WG2, 2013