Topic 5:
Mechanisms of influence: Species range shifts

Climate Change Ecology
Geography 404
Jeff Hicke

Species range shifts

1. Introduction

- focus on
  - historical (documented) range shifts
  - range shifts only

- reminders
  - niches (fundamental, realized)
  - roles of climate variables
  - when climate shifts, ranges can shift

Species range shifts

2. Definitions and concepts

- species range
  - area in which the species is found

- range shifts
  - caused by movement of individuals or appearance/ disappearance of individuals
    - contraction: loss of individuals at periphery of a species' range
    - expansion: dispersal to new habitat outside of current range

Species range shifts

2. Definitions and concepts

- species ranges shift to track climate
  - evidence from paleoclimatology

Vegetation cover changes from LGM to present in Europe

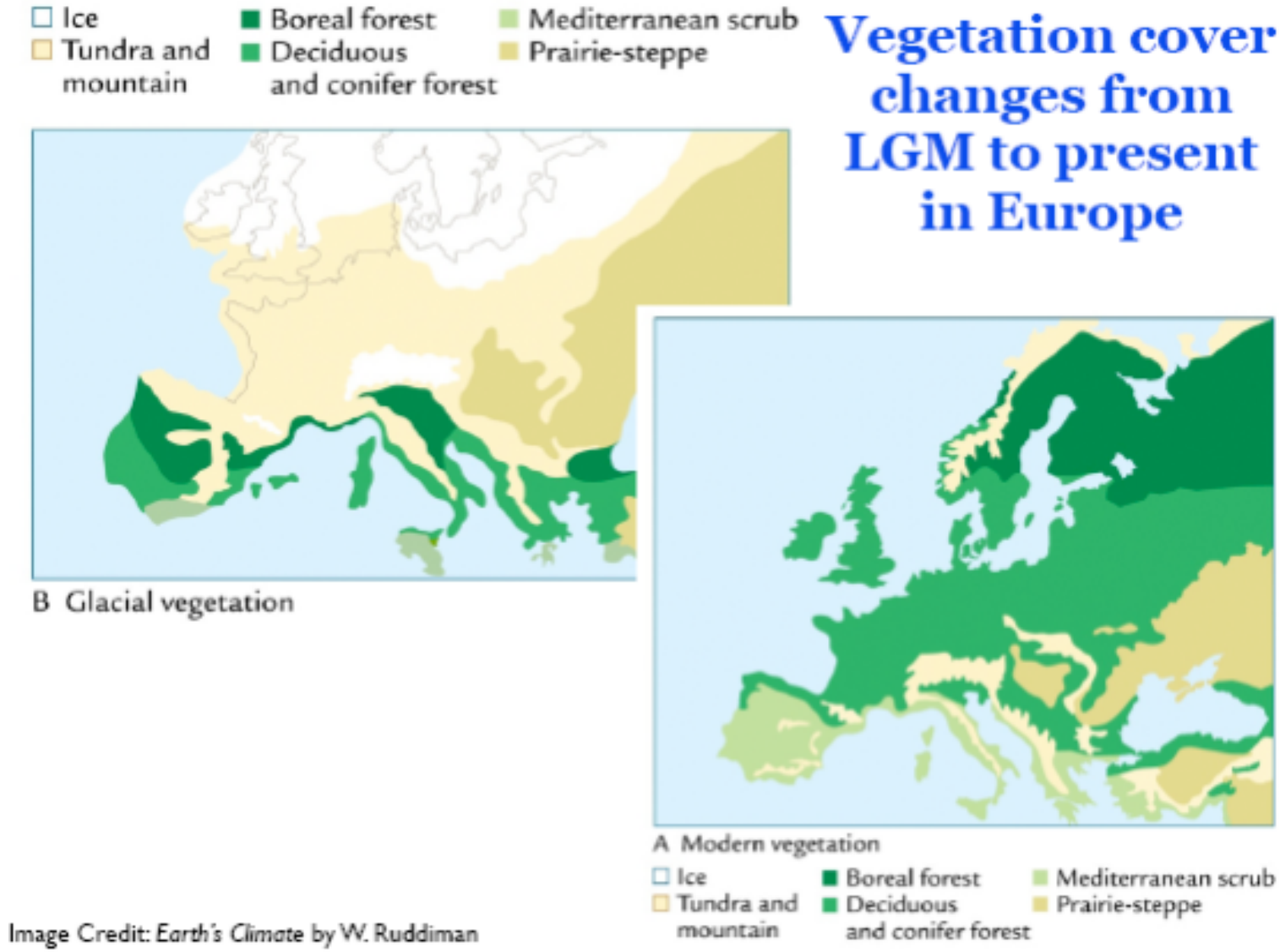


Image Credit: *Earth's Climate* by W. Ruddiman

Slide courtesy C. Still

Equatorial Mountain Changes

Downward shift in land cover types during LGM

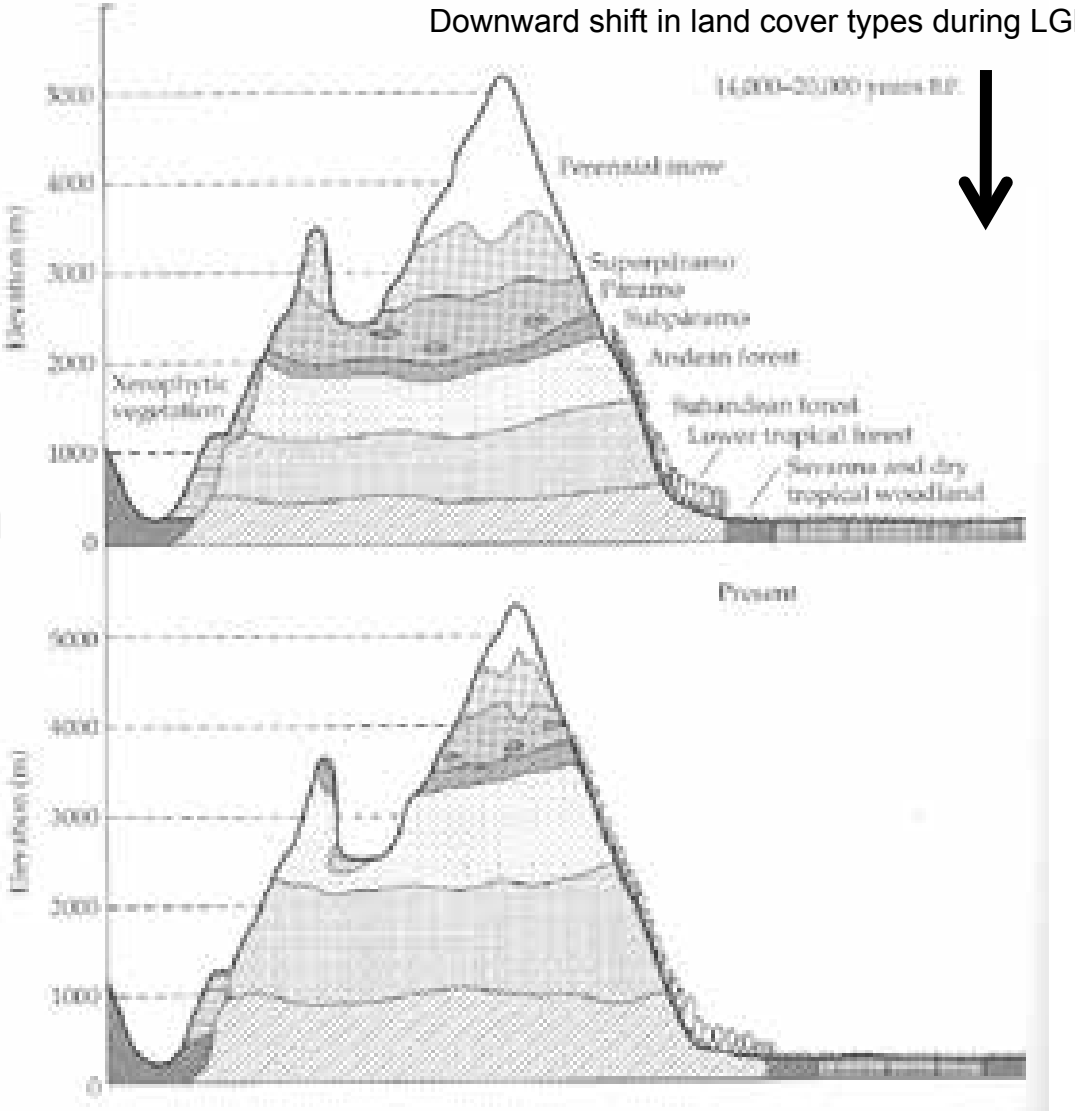


FIGURE 9.15 Elevational shifts in vegetation zones in the eastern Cordillera of the Andes in Colombia in response to climatic change following the most recent glacial maximum. Note that while all zones tended to shift in concert, the upper zones became narrower as they shifted upward in response to global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

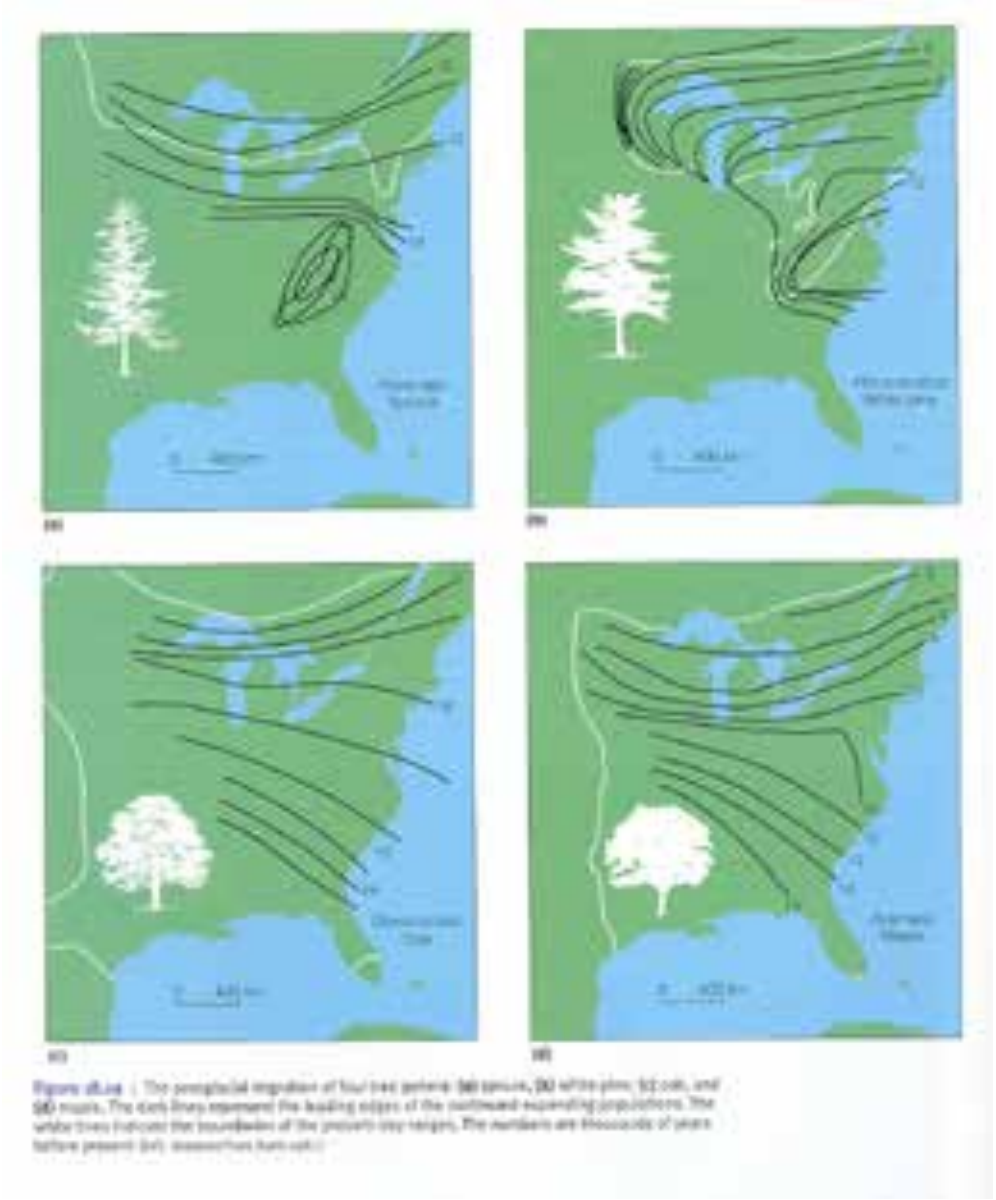
Lomolino et al., 2006

FIGURE 7.8 The modern distributions of eastern shrew (*Sorex fumeus*), 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 dispersal patterns of species that coexist today



Smith and Smith, 2006

Species range shifts

2. Definitions and concepts

- climate change can cause range shifts through
  - changes in mean climate
  - short-term climate extremes
  - interactions with other species

Species range shifts

2. Definitions and concepts

- current climate change is different from climate change in the past for two reasons:
  1. humans have modified the landscape (habitat fragmentation)
  2. climate change is more rapid than in the past

Species range shifts

2. Definitions and concepts

Three responses of a species to climate change

1. move

2. adapt
   - evolve
   - change behavior

3. die (extinction or extirpation)

For insects, seems like most move…

Species range shifts

2. Definitions and concepts

Range shifts in tropics less well documented than in extratropics

- climate change has been less there
- less is known about tropical species
- but sensitivity may be greater there
  - lower T ranges
  - organisms (like insects) already at their optimum T

Species range shifts

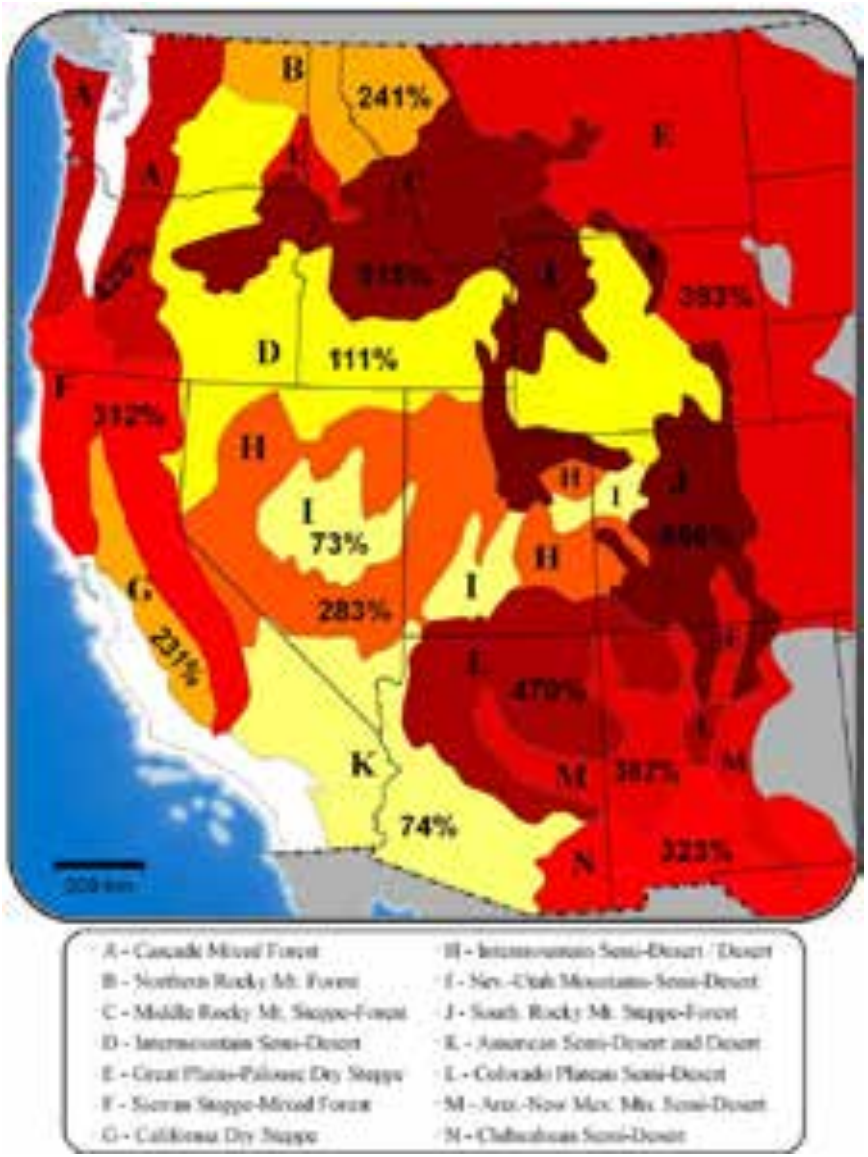
2. Definitions and concepts

Indirect effects of climate change on range shifts

1. Effects of pathogens, disturbances

Species range shifts

increase in burned area for 1º C increase in temperature



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

Species range shifts

Malaria and people

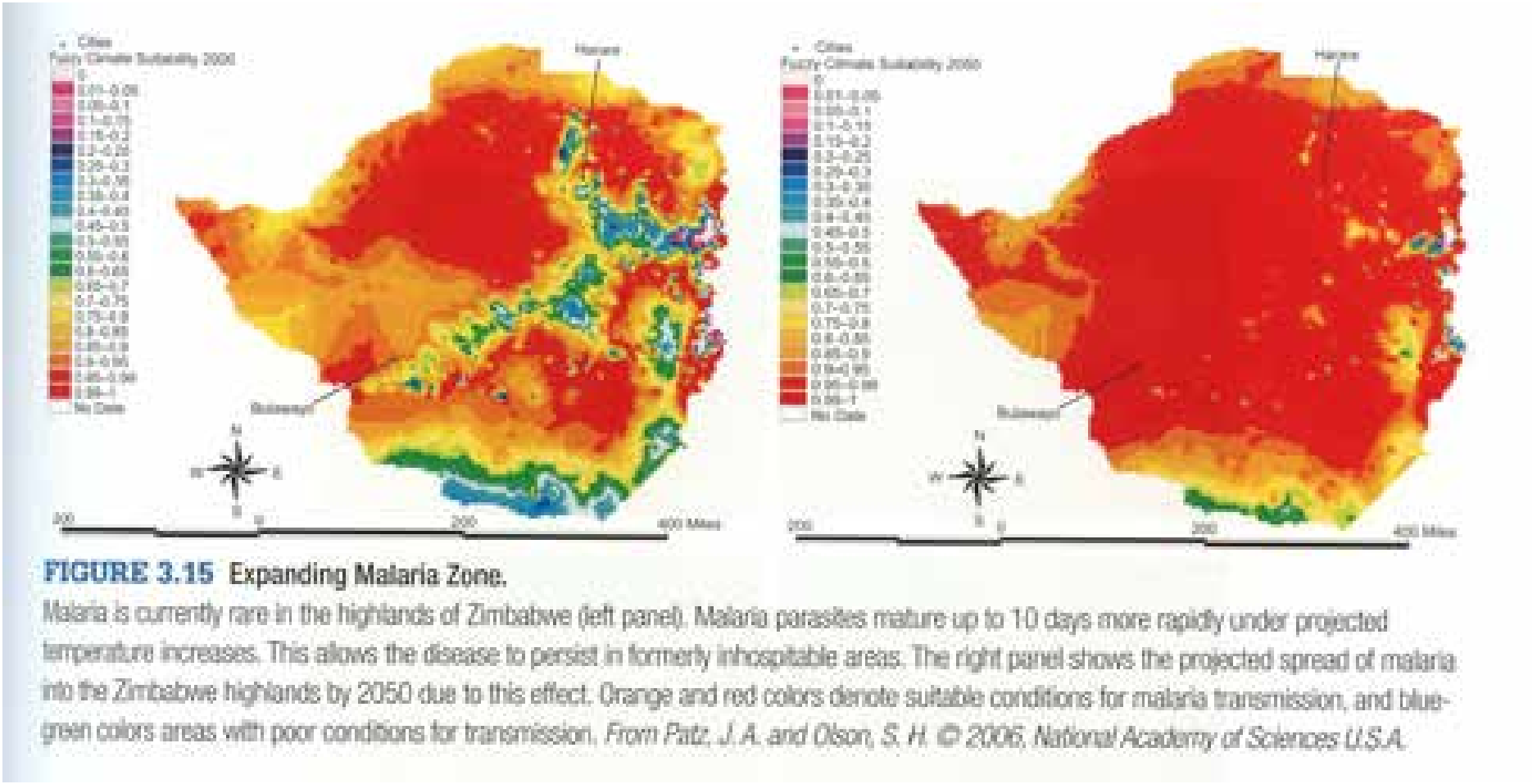


FIGURE 3.15 Expanding Malaria Zone.

Malaria is currently rare in the highlands of Zimbabwe (left panel). Malaria parasites mature up to 10 days more rapidly under projected temperature increases. This allows the disease to persist in formerly inhospitable areas. The right panel shows the projected spread of malaria into the Zimbabwe highlands by 2050 due to this effect. Orange and red colors denote suitable conditions for malaria transmission, and blue-green colors areas with poor conditions for transmission. *From Patz, J. A. and Olson, S. H. © 2006, National Academy of Sciences U.S.A.*

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Species range shifts

2. Definitions and concepts

Indirect effects of climate change on range shifts

2. 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

Species range shifts

2. Definitions and concepts

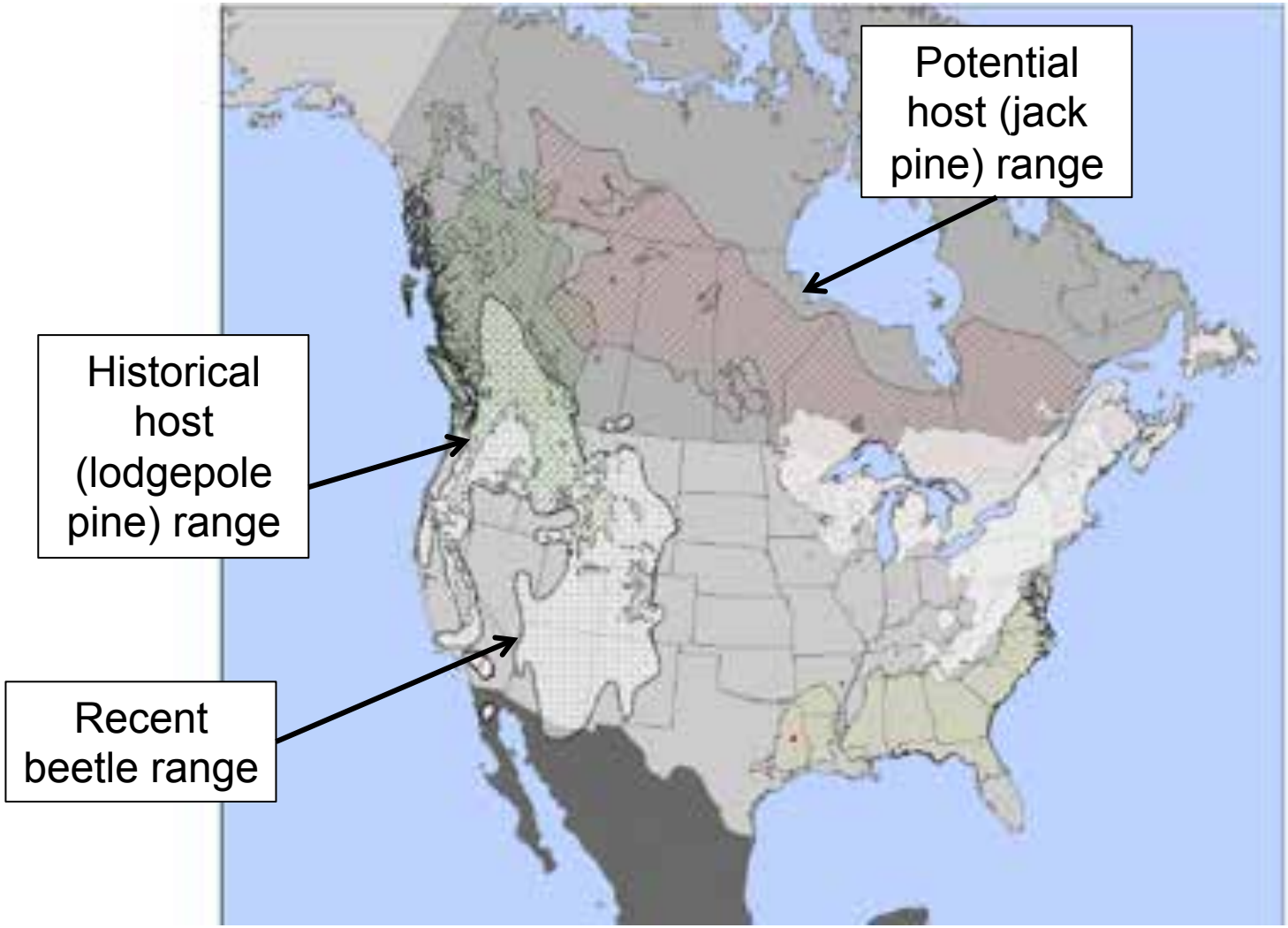
Indirect effects of climate change on range shifts

2. 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

Species range shifts

2. Definitions and concepts

Indirect effects of climate change on range shifts

3. competition with other species

southern range limit retreating northward

northward expansion

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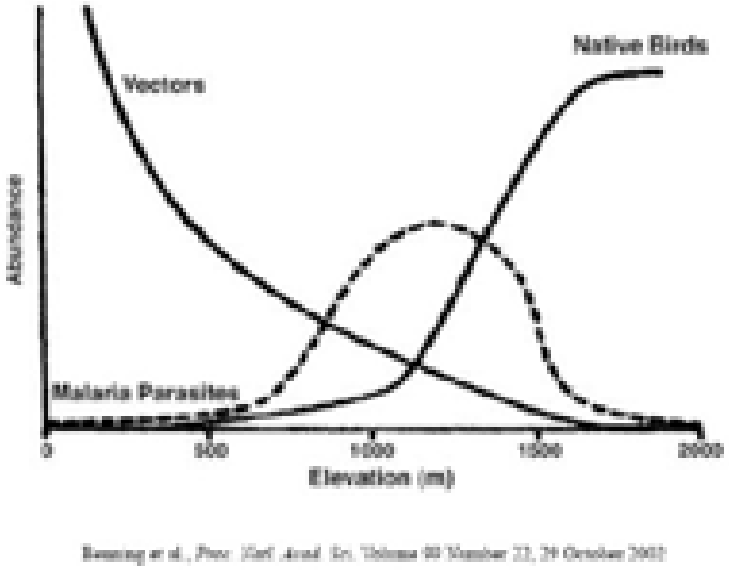
Species range shifts

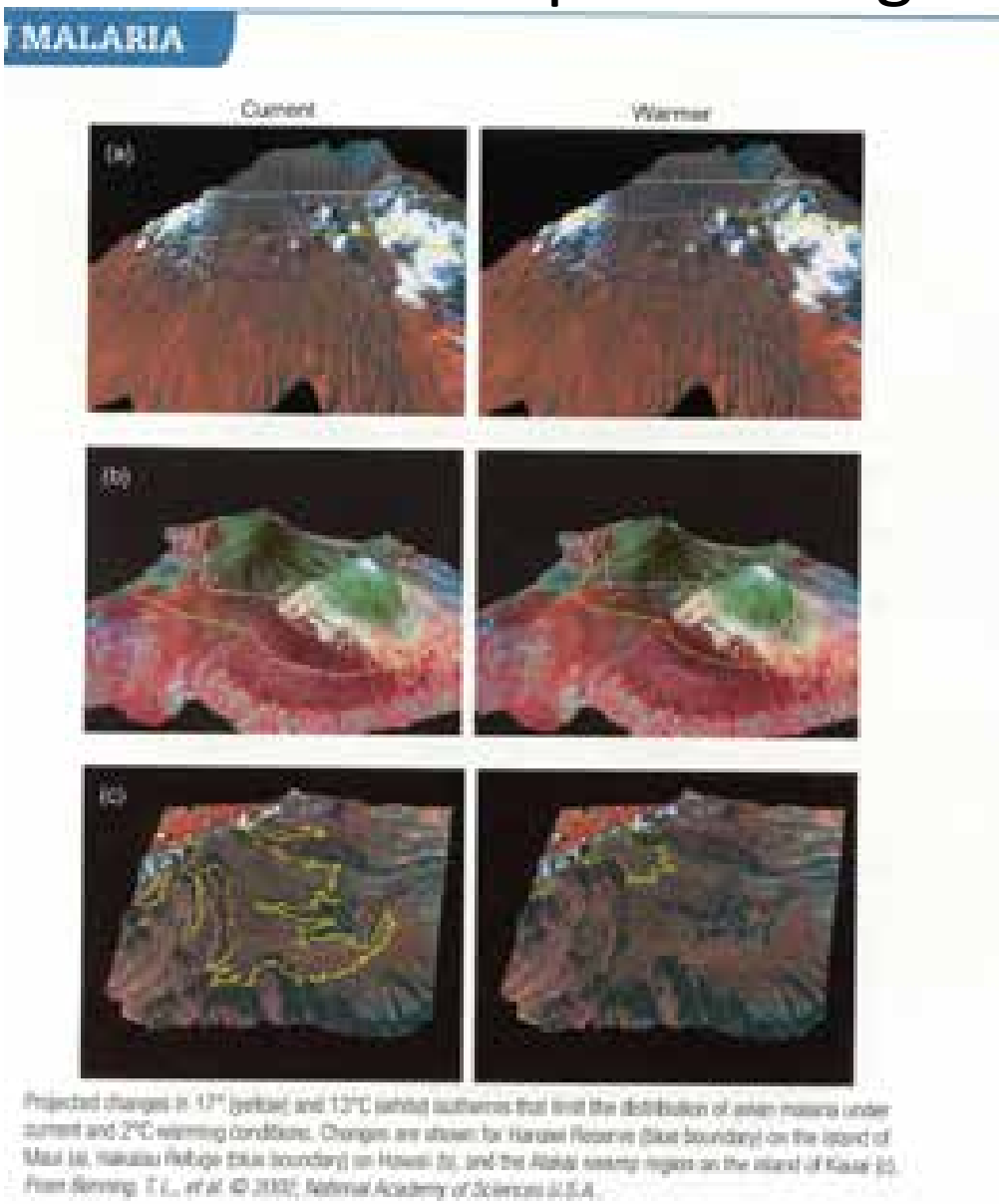
2. Definitions and concepts

Interactions between climate change and biological invasions



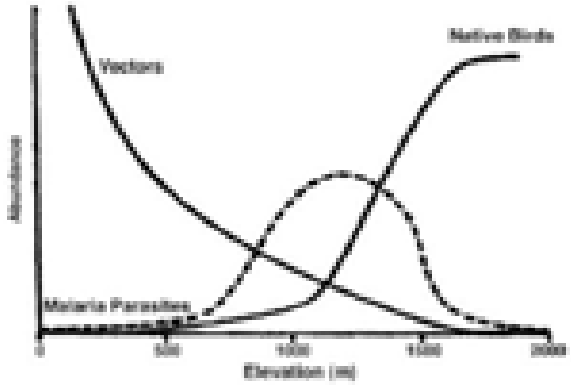
- 30 species of Hawaiian honeycreepers (*Drepanididae*)
  - endemic to Hawaiian islands
- on Oahu, 6 species extinct by 1900
  - declines in lower elevation species but not higher elevation
- tied to introduction of *Culex* mosquitoes in 1820s by Europeans
  - carriers of avian malaria
  - lack of evolution in presence of mosquitoes => lack of defense in honeycreepers
  - limited in elevation extent by temperature

Species range shifts



Upward expansion of avian malaria parasite

Implications for native birds???



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Climate change will facilitate invasions of exotic species

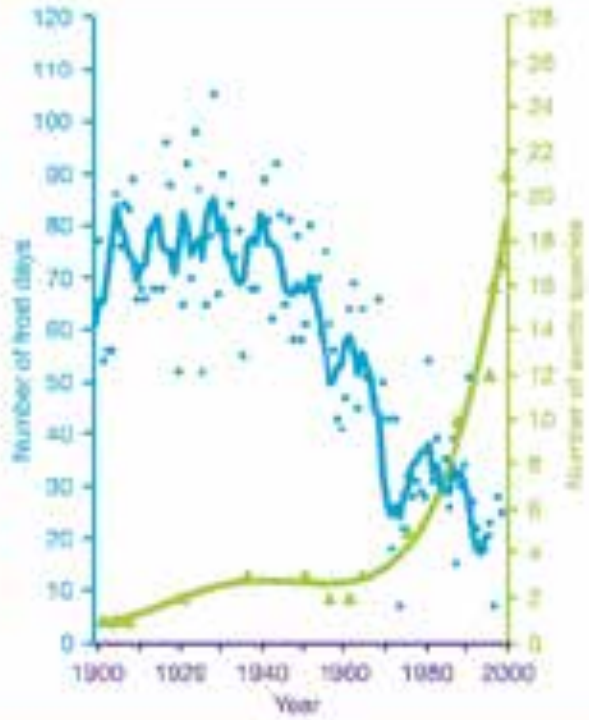

Figure 3 Vegetation shift from indigenous deciduous to exotic evergreen broad-leaved vegetation in southern Switzerland. The shrub layer is dominated by the growing number of spreading exotic evergreen broad-leaved species (see illustration) that appear to profit from milder winter conditions, indicated 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)[79].

Walther et al., 2002

Species range shifts

2. Definitions and concepts

Extinctions

higher probability if

- smaller populations
- highly sensitive to climate change
- limited habitat (including future habitat)

Species range shifts

2. Definitions and concepts

Extinctions

Example: golden toad in Costa Rica

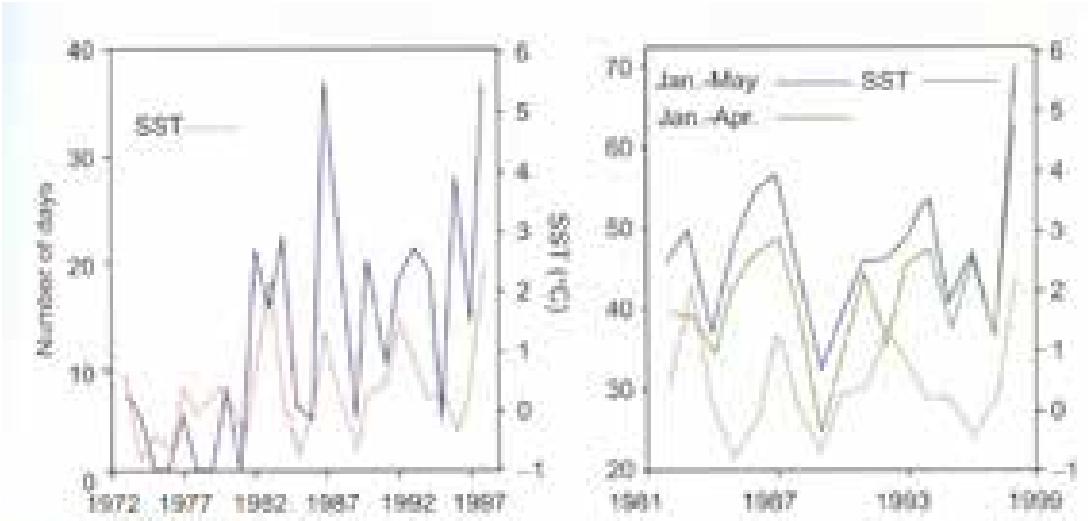

FIGURE 3.13 Drying Trends in Monteverde Cloud Forest, Costa Rica.
Number of dry days per year in Monteverde and departure of nearby sea surface temperature from long-term average. Note the long-term increase in the number of dry days and the peak in 1987, which is the year of the disappearance of the golden toad. *Reproduced with permission from Nature.*

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Species range shifts

3. Meta-analyses

Meta-analyses assess changes using 10s to 1000s of studies

Look for a consistent signal in responses of species to warming

- poleward shift
- upward (elevational) shift

Estimate average rates of shifts

Powerful evidence for existence of climate change

Species range shifts

3. Meta-analyses

Chen et al., Science, 2011

23 taxonomic groups, 764 species

median rate of range shift:

- elevation: 11 m/decade upward
- latitude: 17 km/decade poleward

Species range shifts

3. Meta-analyses

- more warming, greater shifts
- latitude: range shifts can keep up with warming

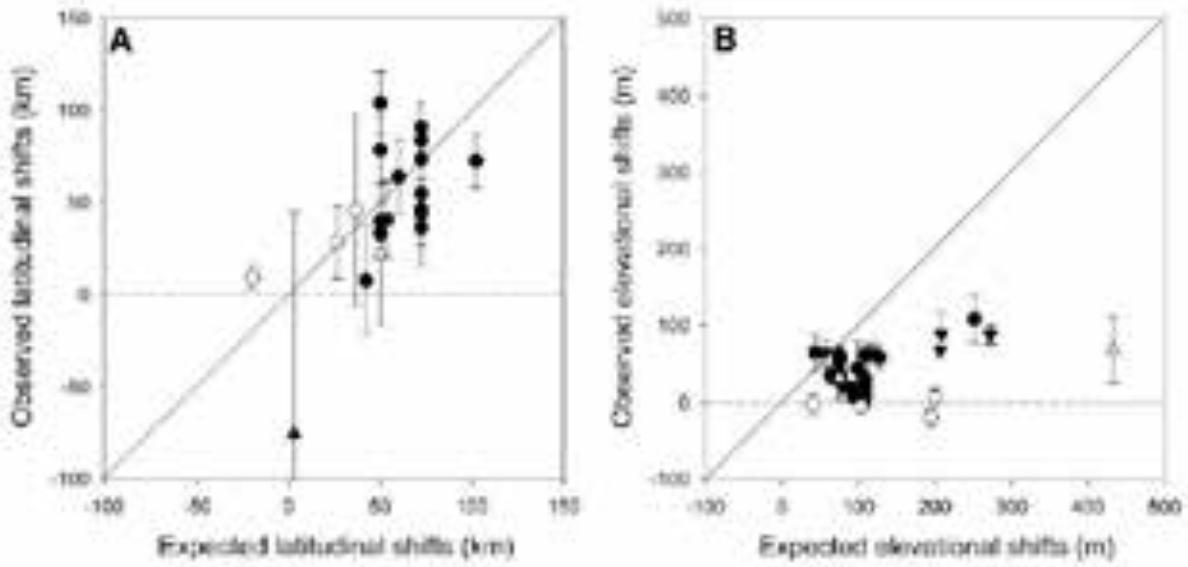


Fig. 1. Relationship between observed and expected range shifts in response to climate change, for (**A**) latitude and (**B**) elevation. Points represent the mean responses (±SE) of species in a particular taxonomic group, in a given region. Positive values indicate shifts toward the pole and to higher 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, molluscs.

Chen et al., Science, 2011

Species range shifts

3. Meta-analyses

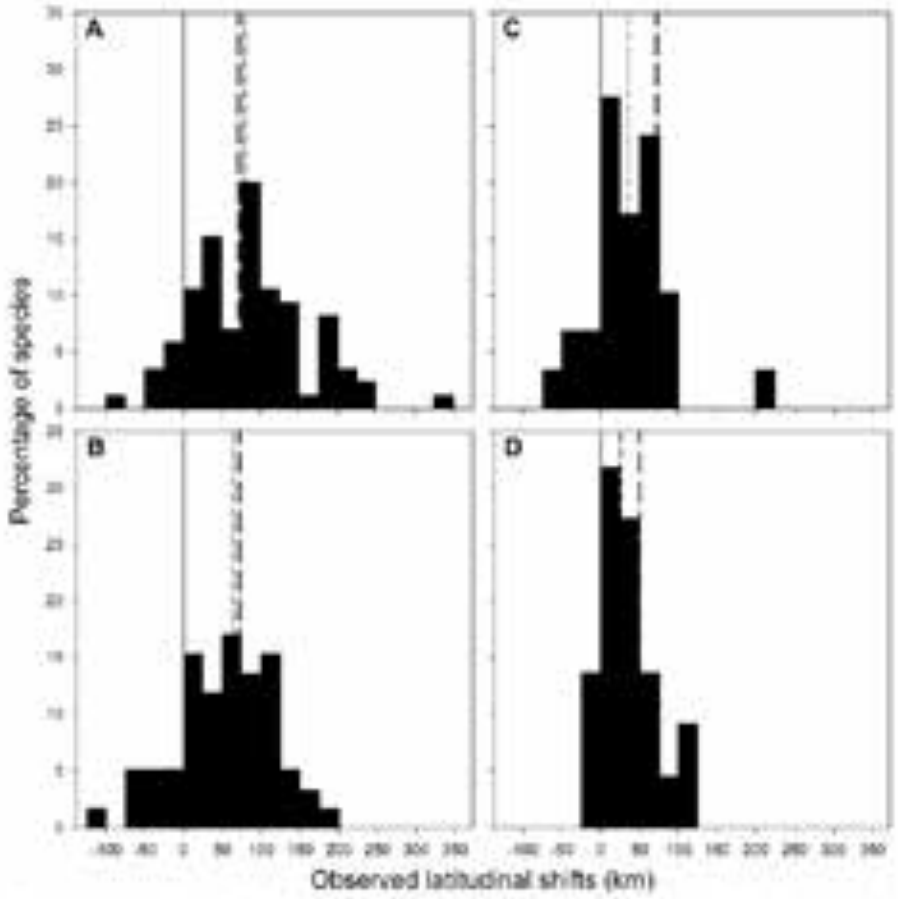
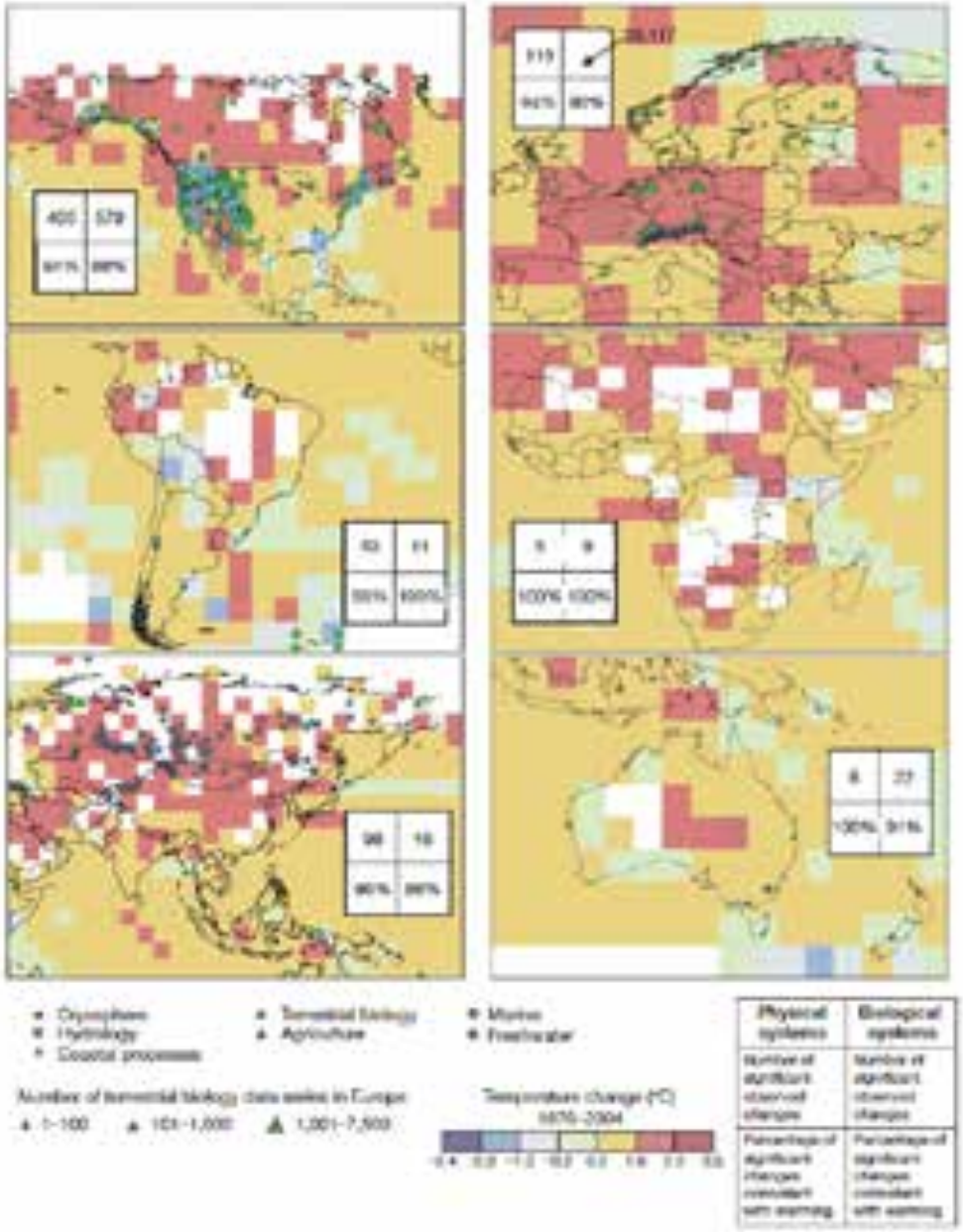


Fig. 2. Observed latitudinal shifts of the northern range boundaries of species within four exemplar taxonomic groups, studied over 25 years in Britain. (A) Spiders (35 species), (B) ground beetles (29 species), (C) butterflies (29 species), and (D) grasshoppers and allies (22 species). Positive latitudinal shifts indicate movement toward the north (poleward); 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

3. Meta-analyses



- 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

Species range shifts

4. Additional examples of range shifts

Edith's checkerspot butterfly

FIGURE 3.5 Edith's Checkerspot Butterfly (*Euphydryas editha*)
From http://www.npwrc.gov/pins/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

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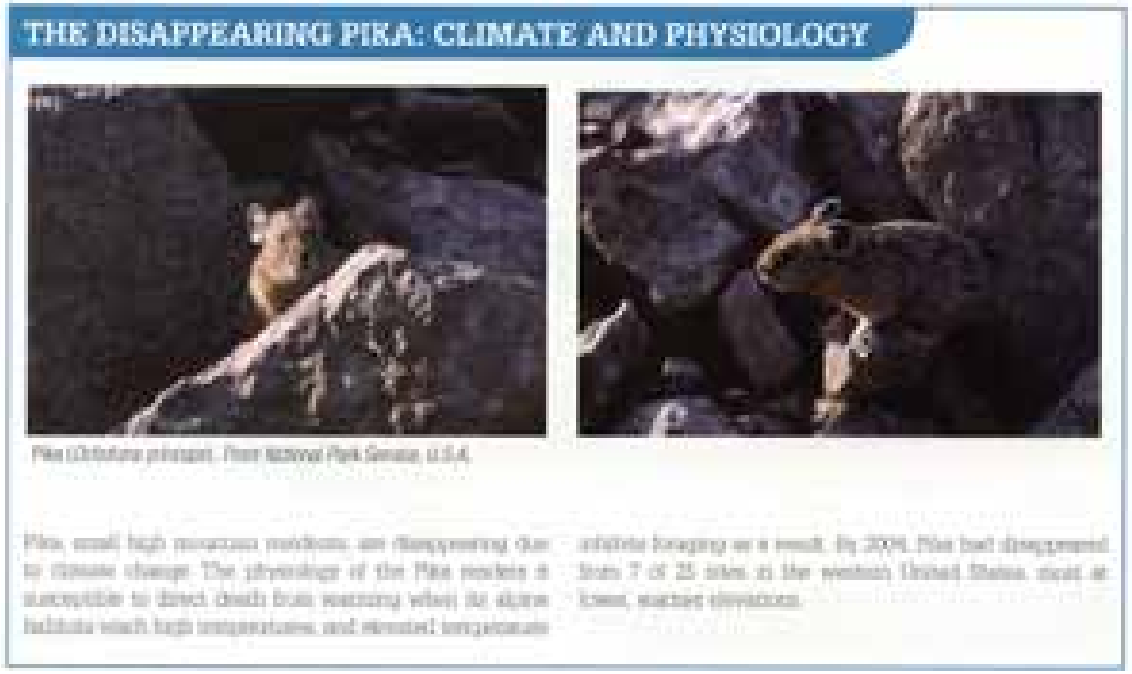
Species range shifts

4. Additional examples of range shifts

pika



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

Tricky to understand the role of climate change!