

Topic 5:
Mechanisms of influence: Species range shifts

Climate Change Ecology
Geography 404
Jeff Hicke

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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

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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

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Species range shifts

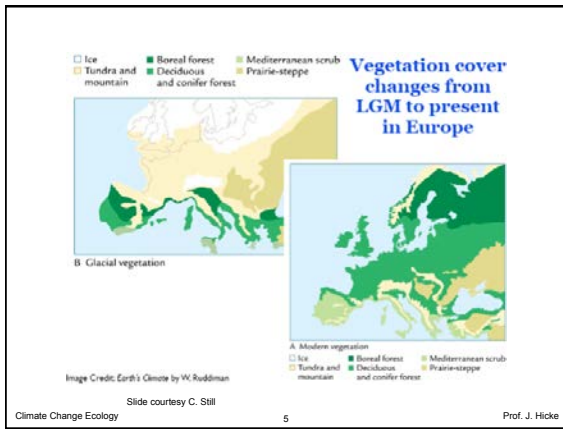
2. Definitions and concepts

- species ranges shift to track climate
- evidence from paleoclimatology

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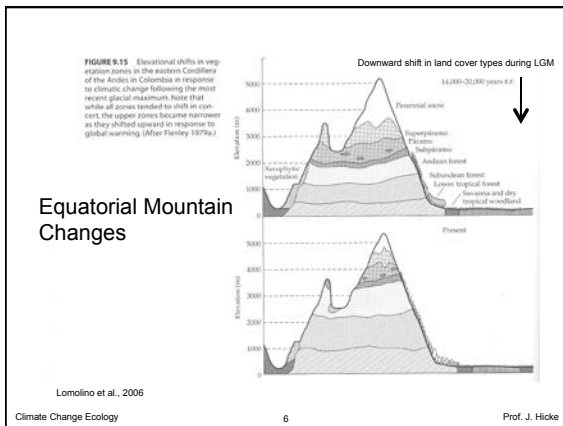
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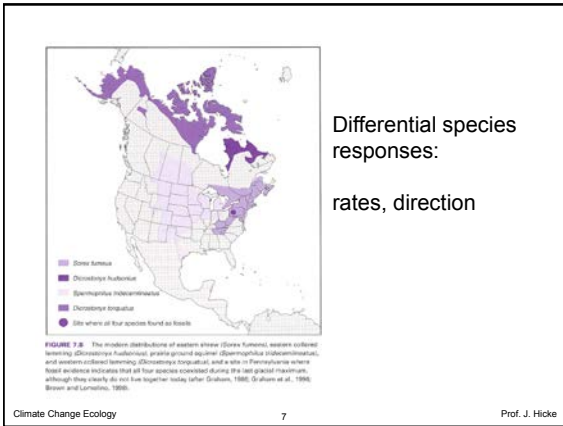
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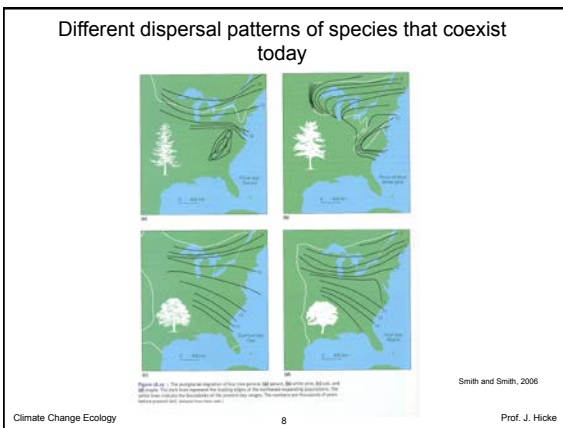


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Species range shifts

2. Definitions and concepts

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

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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

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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...

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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

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Species range shifts

2. Definitions and concepts

Indirect effects of climate change on range shifts

1. Effects of pathogens, disturbances

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Species range shifts

increase in burned area for 1° C increase in temperature

A - Cascade Mixed Forest	H - Submontane Semi-Desert - Desert
B - Northern Rocky Mt. Forest	I - High Alpk. Tundra/Alpine Forest
C - Middle Rocky Mts. Riparian Forest	J - South Rocky Mts. Riparian Forest
D - Intermountain Semi-Desert	K - American Semi-Desert and Desert
E - Crowned Sparrow/Parrot Tree Steppe	L - Colorado Plateau Semi-Desert
F - Sonoran Riparian-Mixed Forest	M - Ariz. Pine Mts. Sky. Semi-Desert
G - California Dry Steppe	N - Chihuahuan Semi-Desert

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.

Hannah 2011


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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


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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



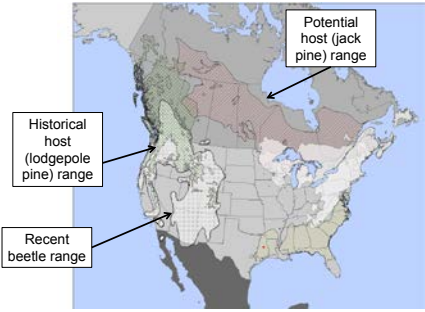
- with warming, brown argus uses geranium
- because geranium is more widespread, butterfly can disperse more easily
- warming facilitates expansion, allowing brown argus to adapt rapidly (benefit)
- species interactions are important for assessing climate change impacts



Patemann et al., Science, 2012

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Expansion of mountain pine beetle into novel host



Logan and Powell 2001

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Species range shifts

2. Definitions and concepts

Indirect effects of climate change on range shifts

3. competition with other species

ARCTIC FOX AND RED FOX RANGE CHANGES

Credits: the left and right by: Peter de Witte/Red Cross and © U.S. Fish and Wildlife Service

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

Koenig et al., Proc Biol Sci 268: 1055-1060 (2001)

- 30 species of Hawaiian honeycreepers (*Drepanidae*)
 - 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

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Species range shifts

MALARIA

Upward expansion of avian malaria parasite

Implications for native birds???

Proposed changes in 1.7° global and 1.7°C surface air temperature that shift the distribution of avian malaria parasite (red) and 2° warming conditions. Changes are shown for the case of no other climate change on the island of Maui. In Hawaii, Malaria has been reported on Maui, Oahu, and Molokai. The maps are based on the spatial data of Fromling et al., 2002, National Academy of Sciences (U.S.A.).

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Climate change will facilitate invasions of exotic species

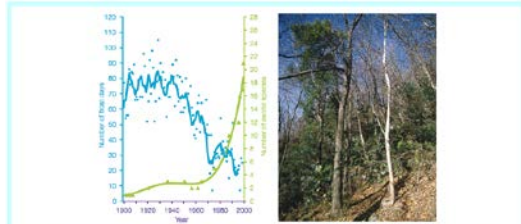


Figure 3 Vegetation shift from indigenous deciduous to exotic evergreen broad-leaved vegetation in southern Dutchessland. The shrub layer is dominated by the growing number of invading exotic evergreen broad-leaved species (see illustrations that appear to profit from milder winter conditions, indicated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

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

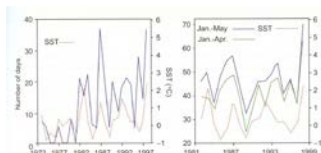


FIGURE 2.13 Drying Trends in Monteverde Cloud Forest, Costa Rica. Number of dry days per year in Monteverde and increases in monthly sea surface temperature from long-term average. Note the long-term increase in the number of dry days and the peak in 1987, which is the year of the disappearance of the 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

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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

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Species range shifts

3. Meta-analyses

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

Fig. 3. 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. Diagonally 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, bryophytes; solid diamond, fish; solid triangle, mollusks.

Chen et al., Science, 2011

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Species range shifts

3. Meta-analyses

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

Fig. 2. Observed latitudinal shifts of the northern range boundaries of species within four temperate biogeographic groups, studied over 75 years in Britain. (A) Twelve butterfly species, (B) general biotopes (10 species), (C) grasshoppers and allies (10 species), (D) grasshoppers and allies (10 species). Positive latitudinal shifts indicate movement based on mean species range shifts relative to their 1950 position. The solid line shows the shift, the dashed line indicates the median observed shift, and the horizontal line indicates the predicted range shift.

Chen et al., Science, 2011

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Species range shifts

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

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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.pca.gov/pnw/natureandscience/butterfly.htm>.

FIGURE 3.4 Edith's Checkerspot Butterfly Range Shift
Southern populations of Edith's checkerspot butterfly are becoming extinct (solid squares) more frequently than northern and midrange populations, resulting in a northward and upward range shift. Reprinted by permission from Maureen P. Fullerton 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!
