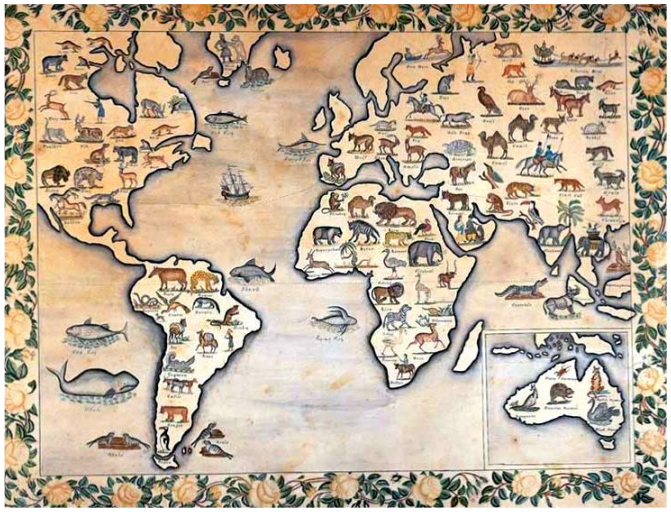


SDM Theory

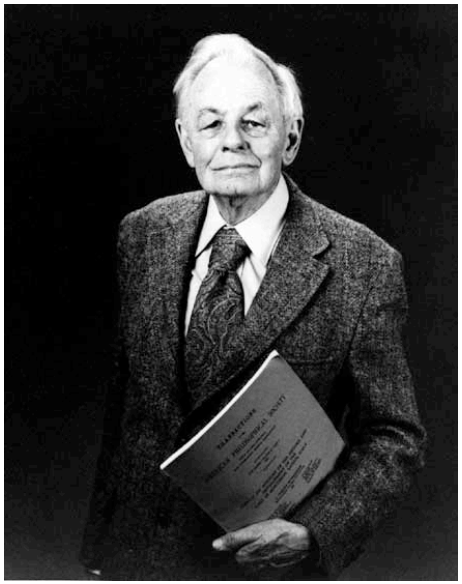
Distributions & Niches

Niche concept

and its changing definition over time:

- Grinnell (1917)
  - Habitat requirements and behaviors allowing persistence and produce offspring
- Elton (1927)
  - Functional role in the biotic community
- Hutchinson (1957)
  - Property of the species not the environment

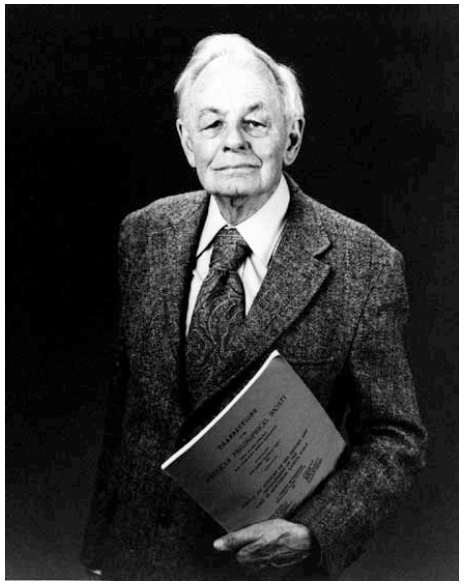
the most well-known and sticking

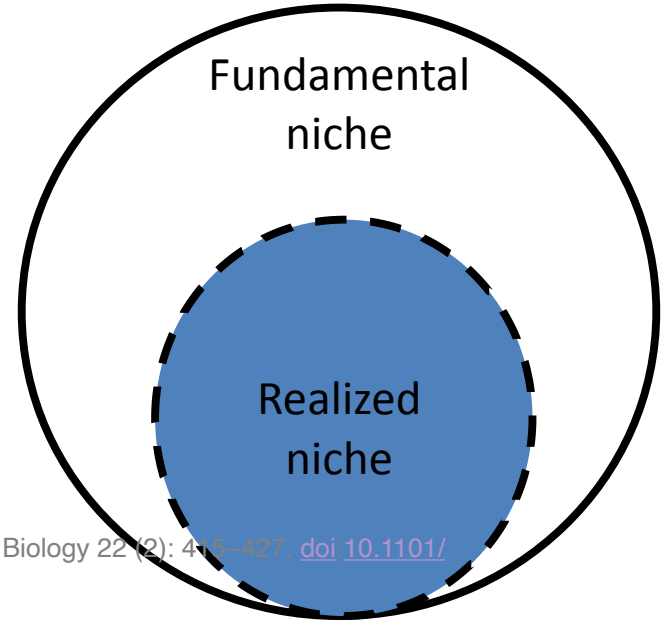


Hutchinson, G.E. (1957). Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology 22 (2): 415–427. doi:10.1101/sqb.1957.022.01.039.

Niche concept

- **Fundamental** niche: an "*n*-dimensional hypervolume", every point in which corresponds to a state of the environment which would permit a species to exist





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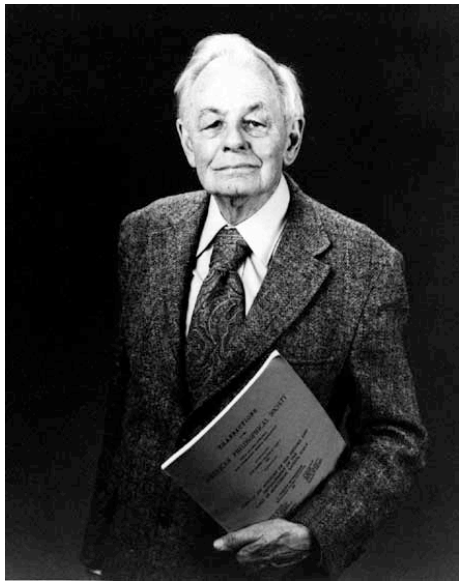
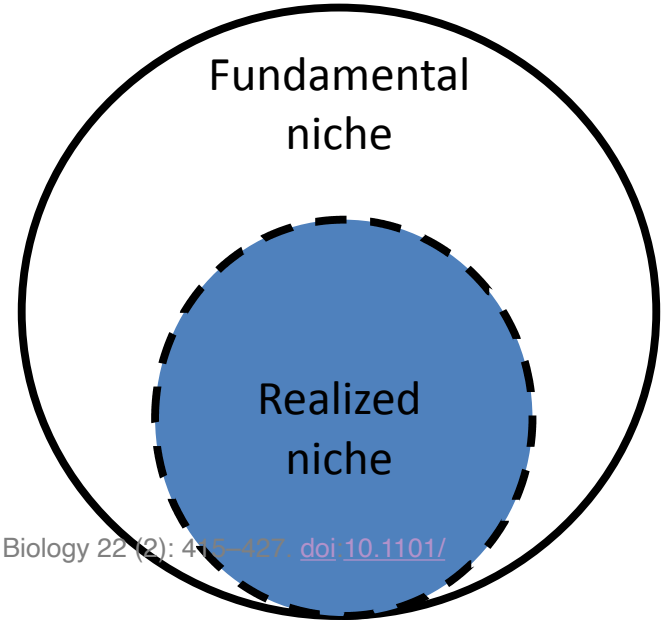
Niche concept



- **Fundamental** niche: an "*n*-dimensional hypervolume", every point in which corresponds to a state of the environment which would permit a species to exist

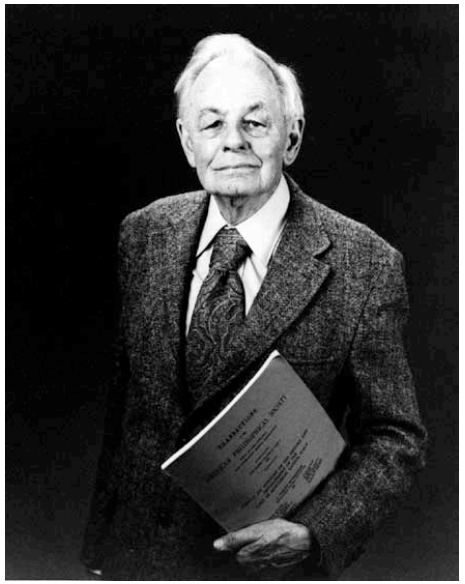
- **Realized** niche: portion (subset) of the fundamental niche where the species actually exists due to biotic interactions, dispersal limitations, etc. ie constraints in biotic factors

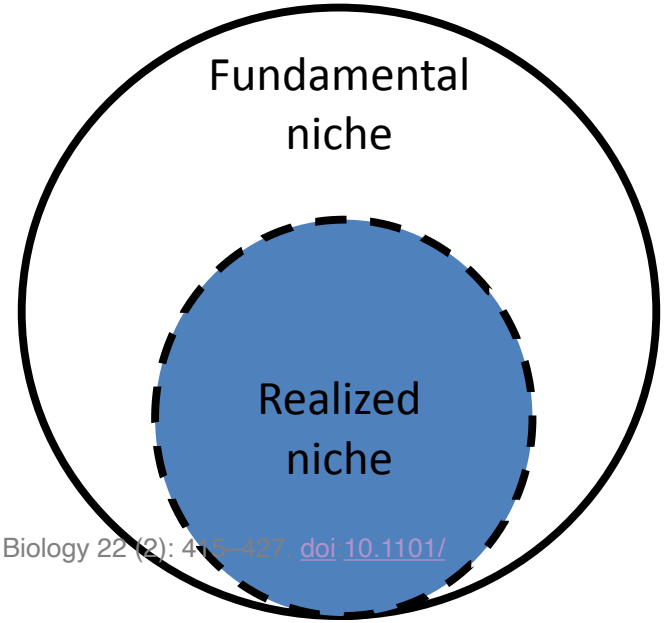


Hutchinson, G.E. (1957). Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology 22 (2): 415–427. doi:10.1101/sqb.1957.022.01.039.

Niche concept

- Hutchinson's (1957) differentiation of ***fundamental*** and ***realized*** niches is central to much ecological theory & is a critical concept in the application of species distribution models

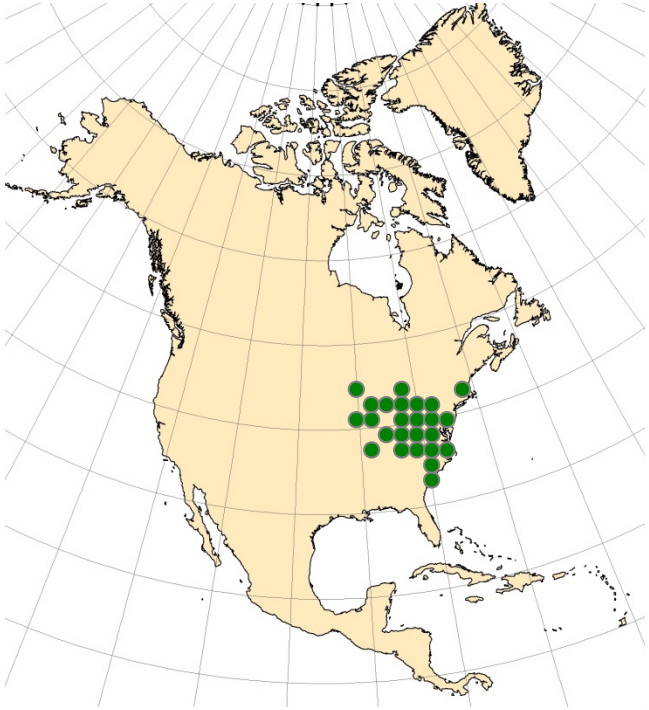




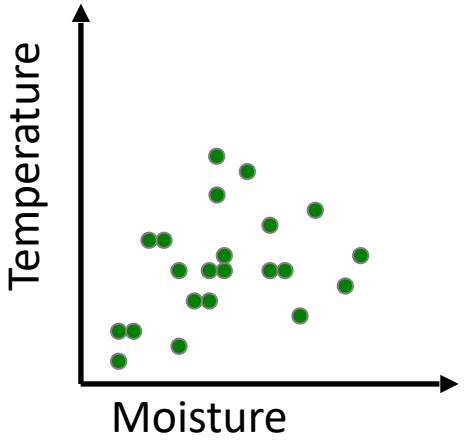
Hutchinson, G.E. (1957). Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology 22 (2): 415–427. doi:10.1101/sqb.1957.022.01.039.

Moving from geographic to environmental (niche) space – where models operate

Geographic space



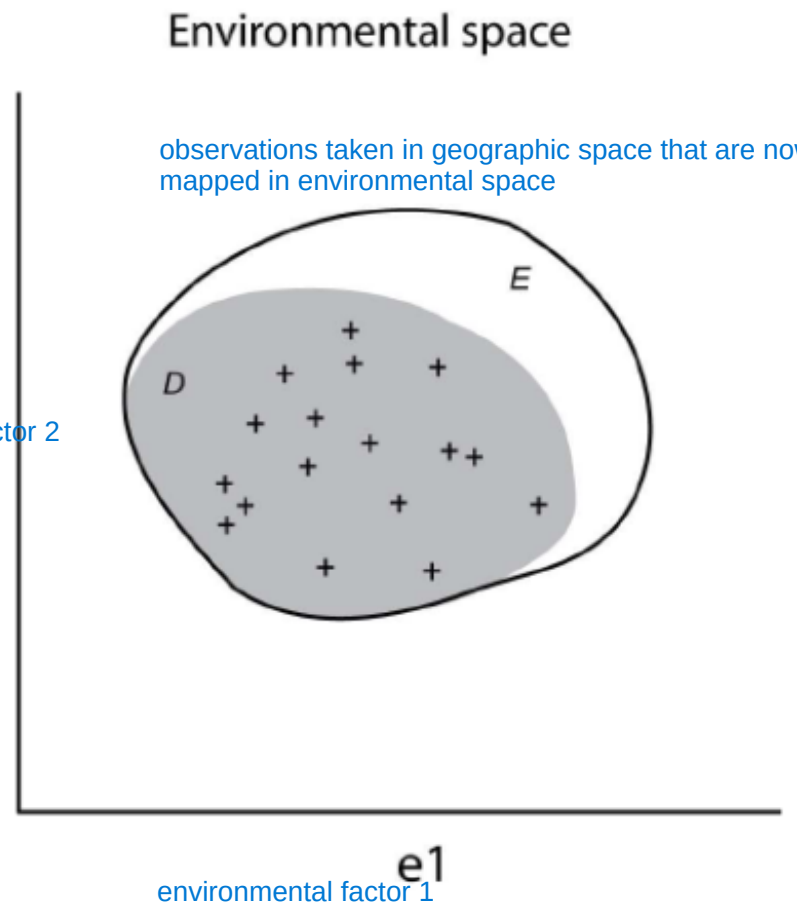
Environmental space



Geographical *versus* environmental space

- Fundamental niche
  - Potential niche/ distribution
  - Physiological niche
- Realized niche
  - Actual distribution
  - Occupied niche

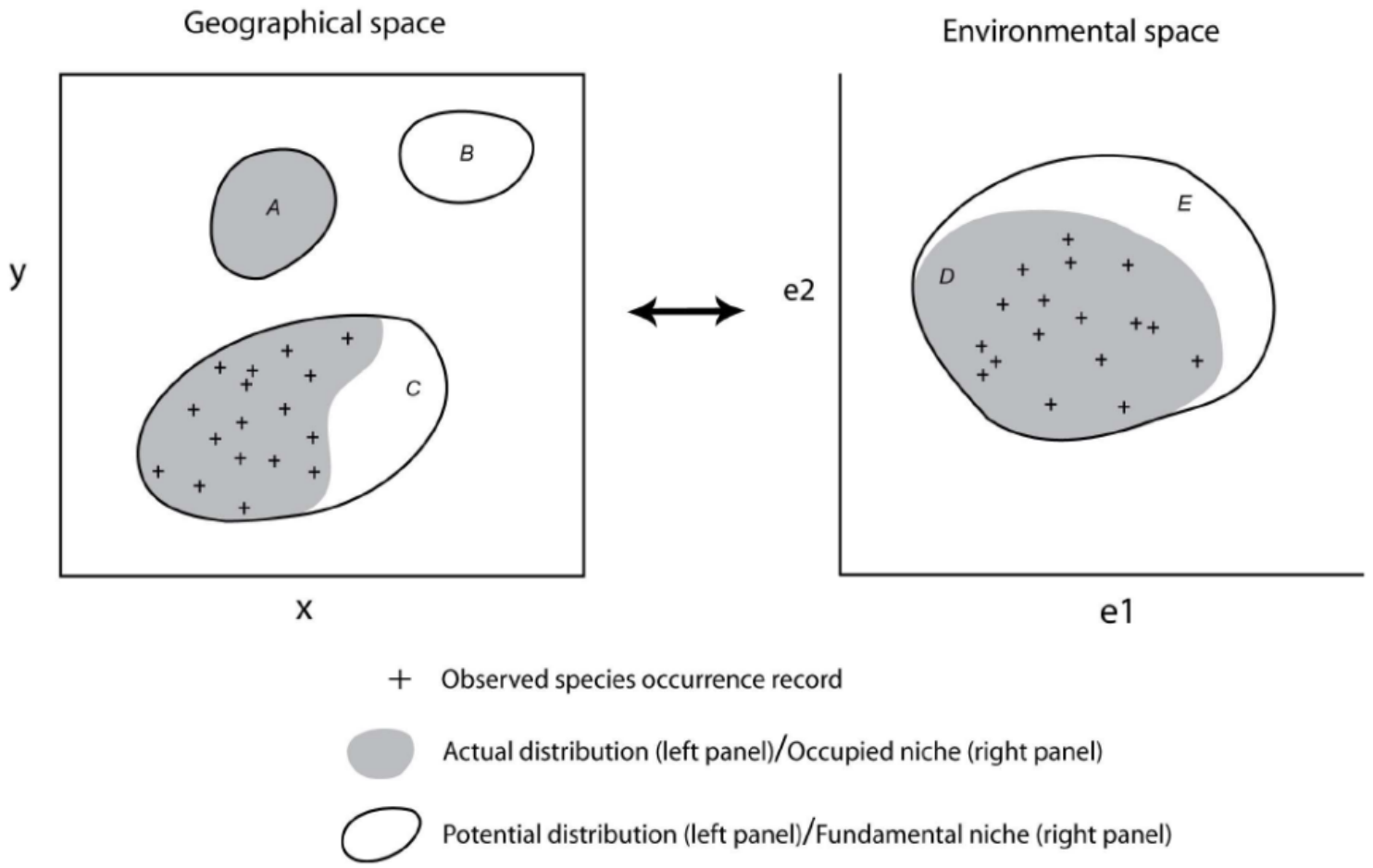
Pullium et al.



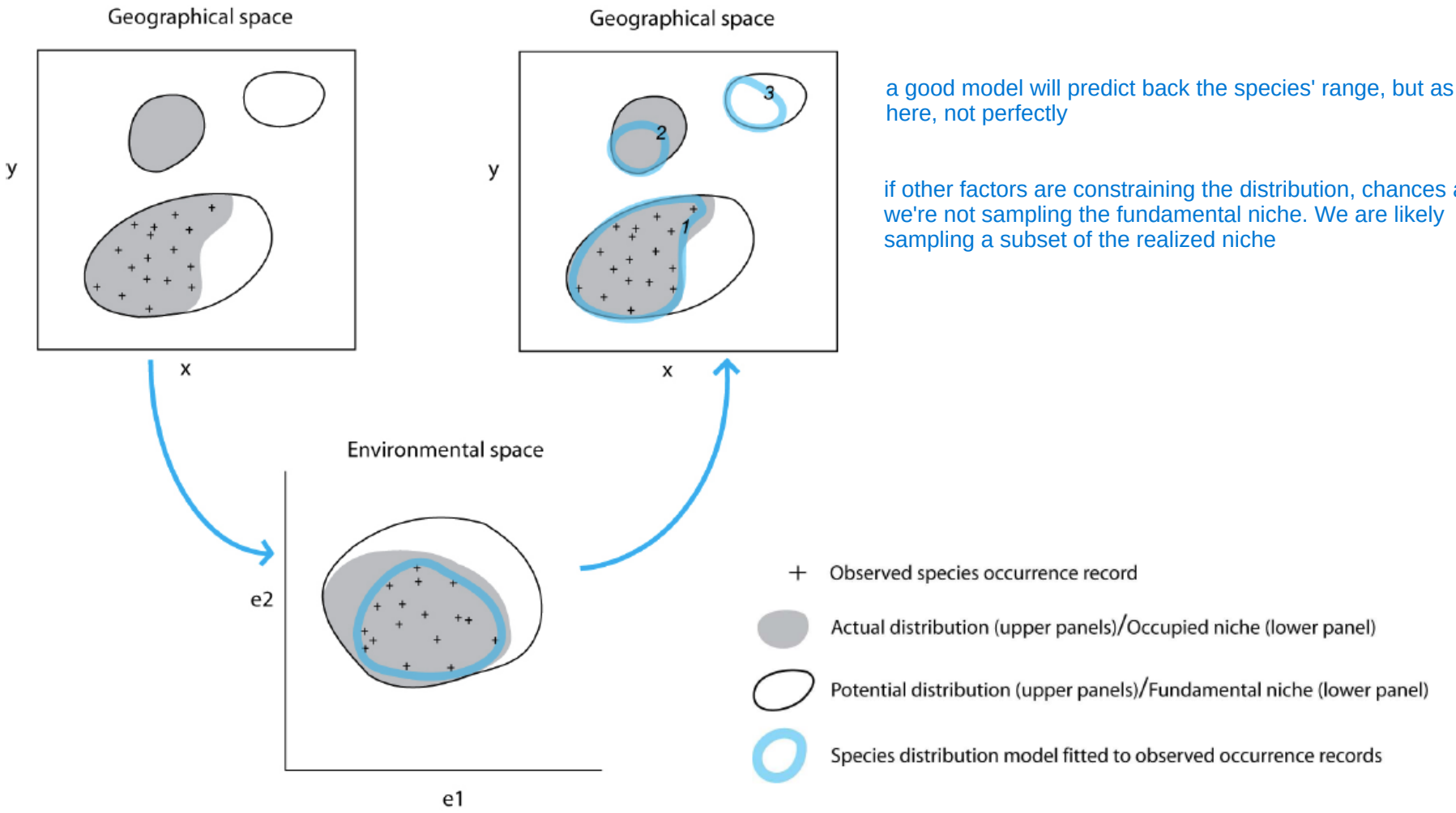
observations taken in geographic space that are now being mapped in environmental space

the environmental factors are able to be a dimensionally reduced set of axes such as in PCA

Geographical *versus* environmental space



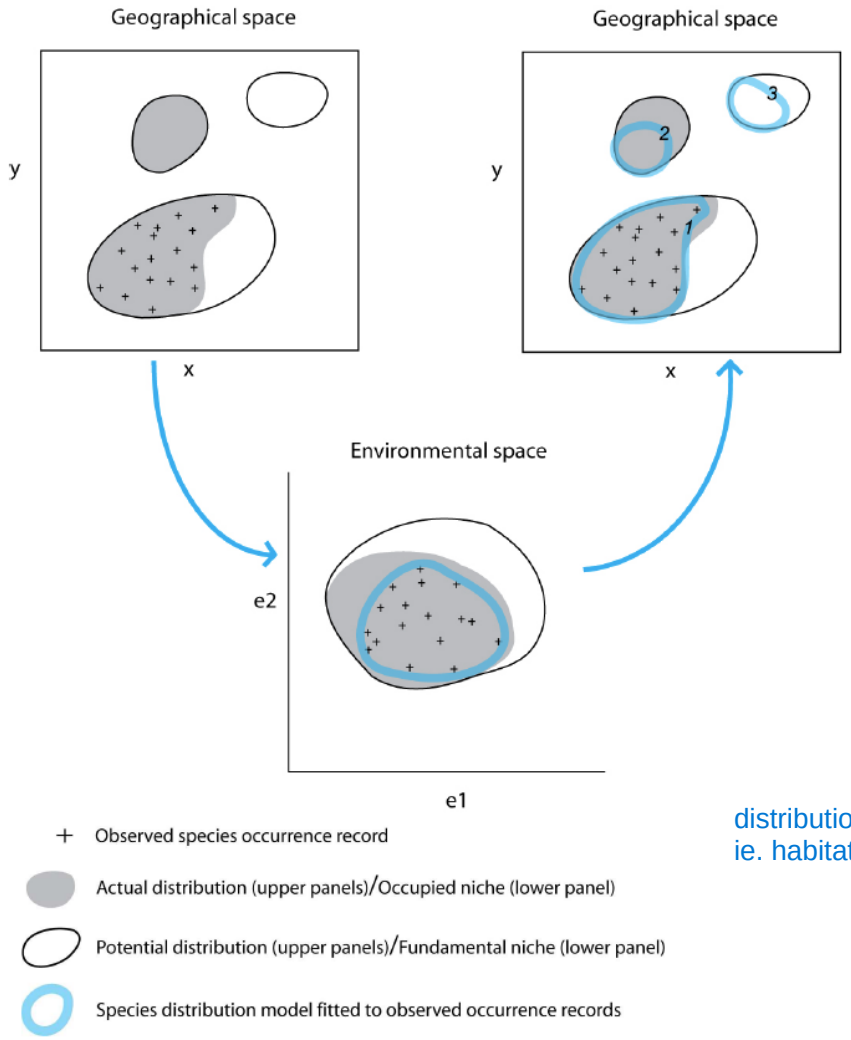
What do we actually model?



a good model will predict back the species' range, but as seen here, not perfectly

if other factors are constraining the distribution, chances are we're not sampling the fundamental niche. We are likely sampling a subset of the realized niche

What do we actually model?



- Probably not the fundamental niche
- Portion of the realized niche that has been sampled
- Ecological niche models vs. species distribution models vs. habitat suitability models

distributions may be a function of something else that happened historically as well ie. habitat destruction

there could be combinations of conditions that the species is fine in but that we can't even sample because they don't exist on earth

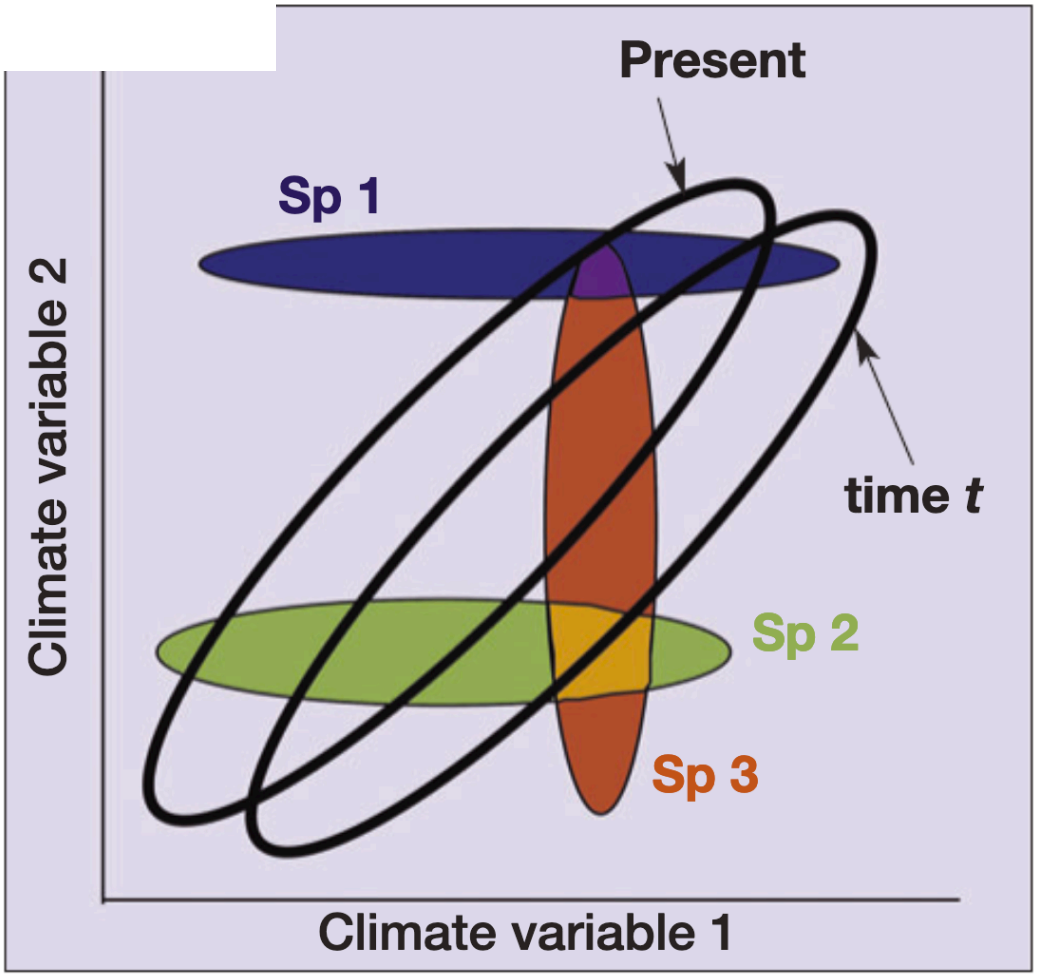
Niche vs. distribution

see joint species distribution models for an analysis of both abiotic covariates and biotic (ie. includes multiple species)

Novel climates, no-analog communities, and ecological surprises

John W Williams[1*] and Stephen T Jackson[2]

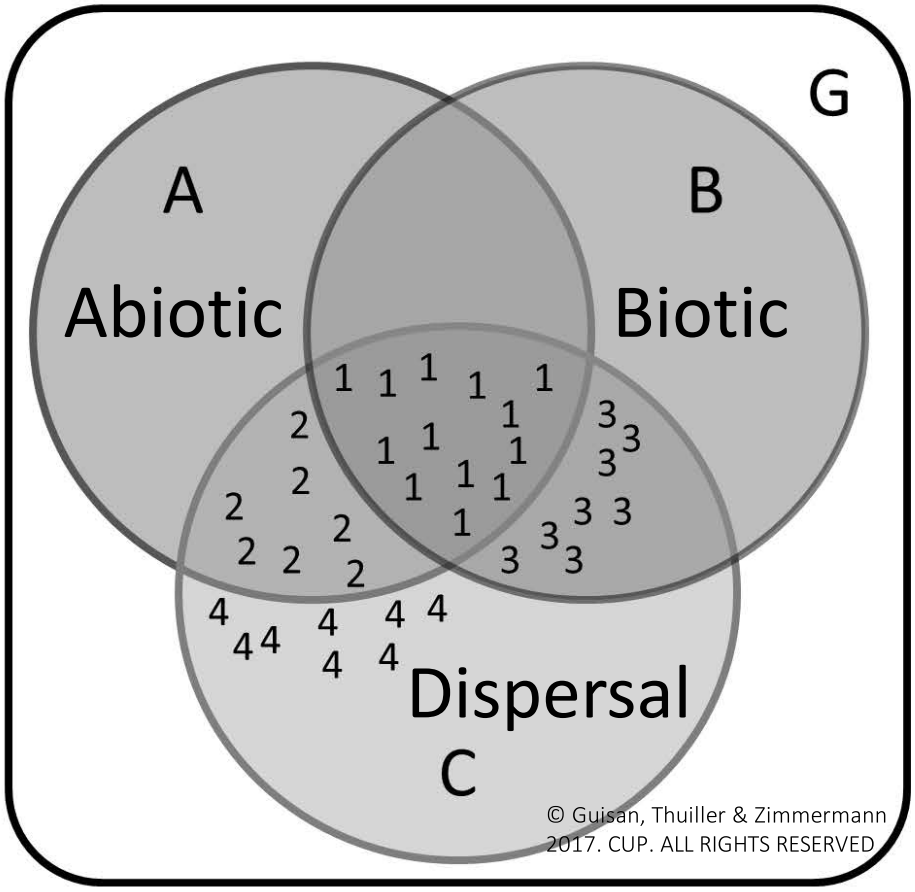
Associations between species can occur only when their fundamental niches overlap with one another and with the set of climates in existence at a particular time period. A present-day ecologist would therefore sometimes observe communities containing both Species 1 and 2, but would never observe cooccurrences of Species 2 and 3 (nor Species 1 and 3). If the right climates arise, however, Species 2 and 3 could co-occur, forming a "no-analog" community from the perspective of the present-day ecologist. Adapted from Figure 5 in Jackson and Overpeck (2000).



Ecology of species ranges

- All species are distributed in space – but within limits
- Understanding the factors that shape species ranges is a central question in ecology and evolution
- We probably do not have a comprehensive understanding of range limits for any species

3 primary factors that determine distribution



G: Geographic area

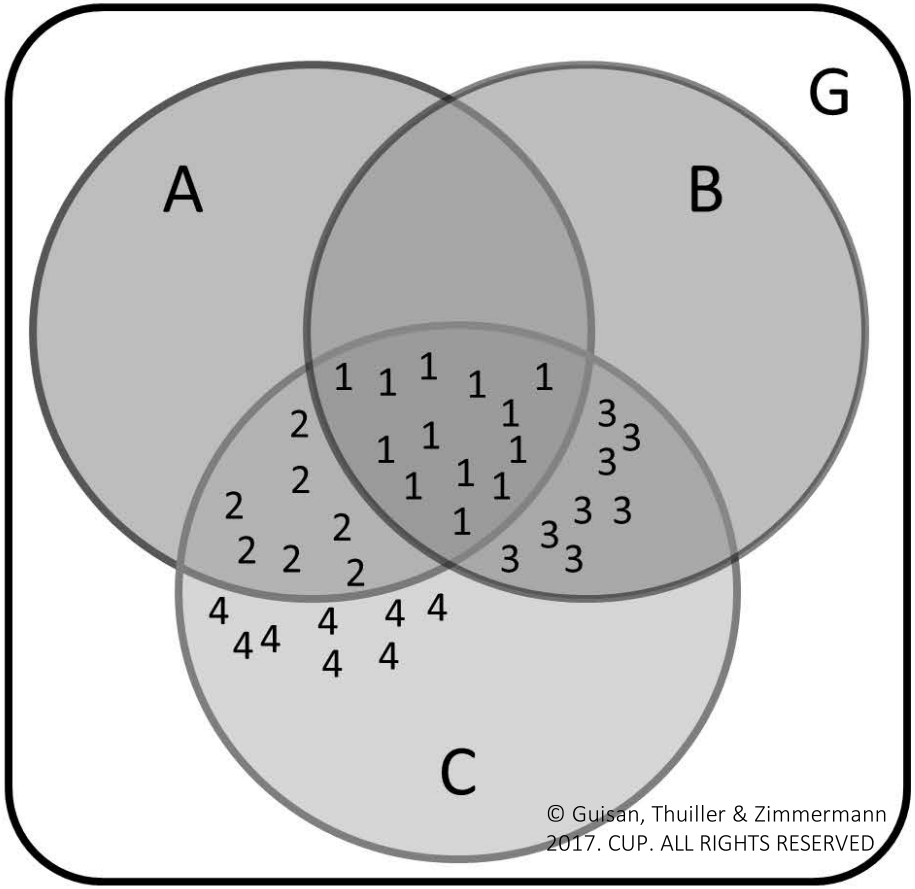
A: Suitable abiotic environment (niche)

B: Suitable biotic environment

C: Dispersal (colonizable range)

C are species where the species can disperse based on the initial environment that they occupy

3 primary factors that determine distribution



1 = ? suitable habitat

2 = ? abiotically suitable and dispersable

3 = ? biotically suitable and dispersable

4 = ? only dispersable

3 primary factors that determine distribution

Ecology Letters, (2007) **10**: 1115–1123 doi: 10.1111/j.1461-0248.2007.01107.x

IDEA AND PERSPECTIVE

Grinnellian and Eltonian niches and geographic distributions of species

Jorge Soberón*
Biodiversity Research Center and Museum of Natural History, University of Kansas Dyche Hall, 1345 Jayhawk Blvd, Lawrence, KS 66045, USA
**Correspondence: E-mail: jsoberon@ku.edu*

Abstract

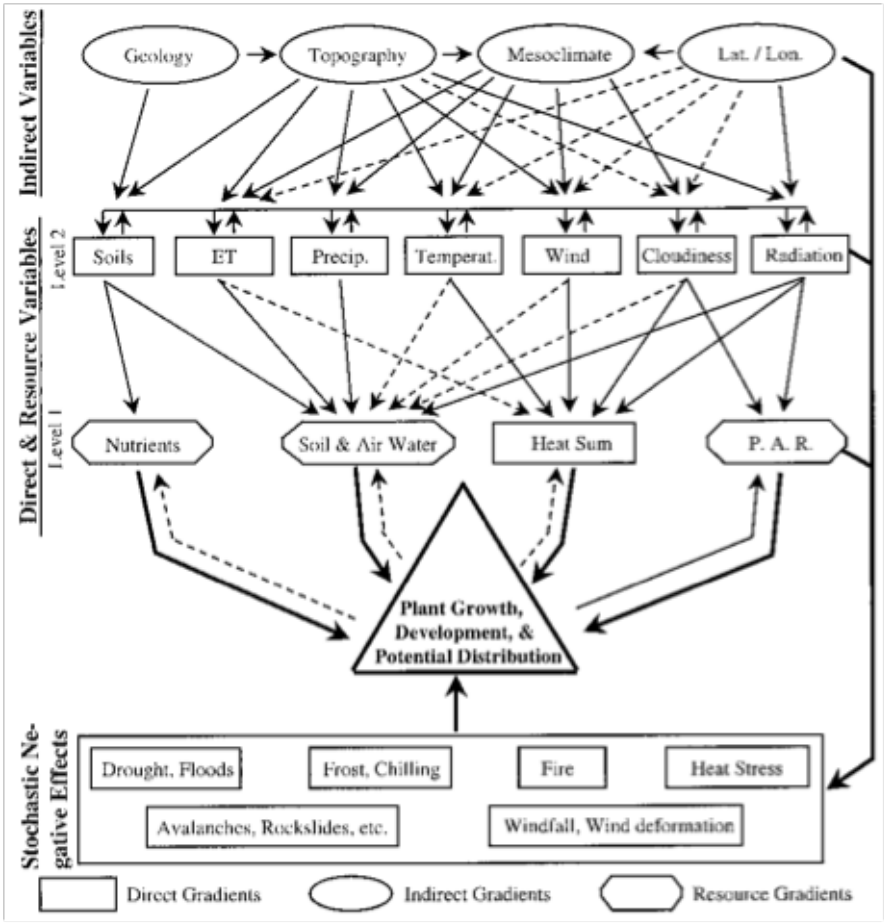
In the recent past, availability of large data sets of species presences has increased by orders of magnitude. This, together with developments in geographical information systems and statistical methods, has enabled scientists to calculate, for thousands of species, the environmental conditions of their distributional areas. The profiles thus obtained are obviously related to niche concepts in the Grinnell tradition, and separated from those in Elton's tradition. I argue that it is useful to define Grinnellian and Eltonian niches on the basis of the types of variables used to calculate them, the natural spatial scale at which they can be measured, and the dispersal of the individuals over the environment. I use set theory notation and analogies derived from population ecology

Variable Selection

ideally don't derive predictors here

Several key concerns:

- Which variables?
- Collinearity
- Indirect versus direct & resource variables
- Only proximal variables drive distribution – distal variables explain through correlation with proximal vars



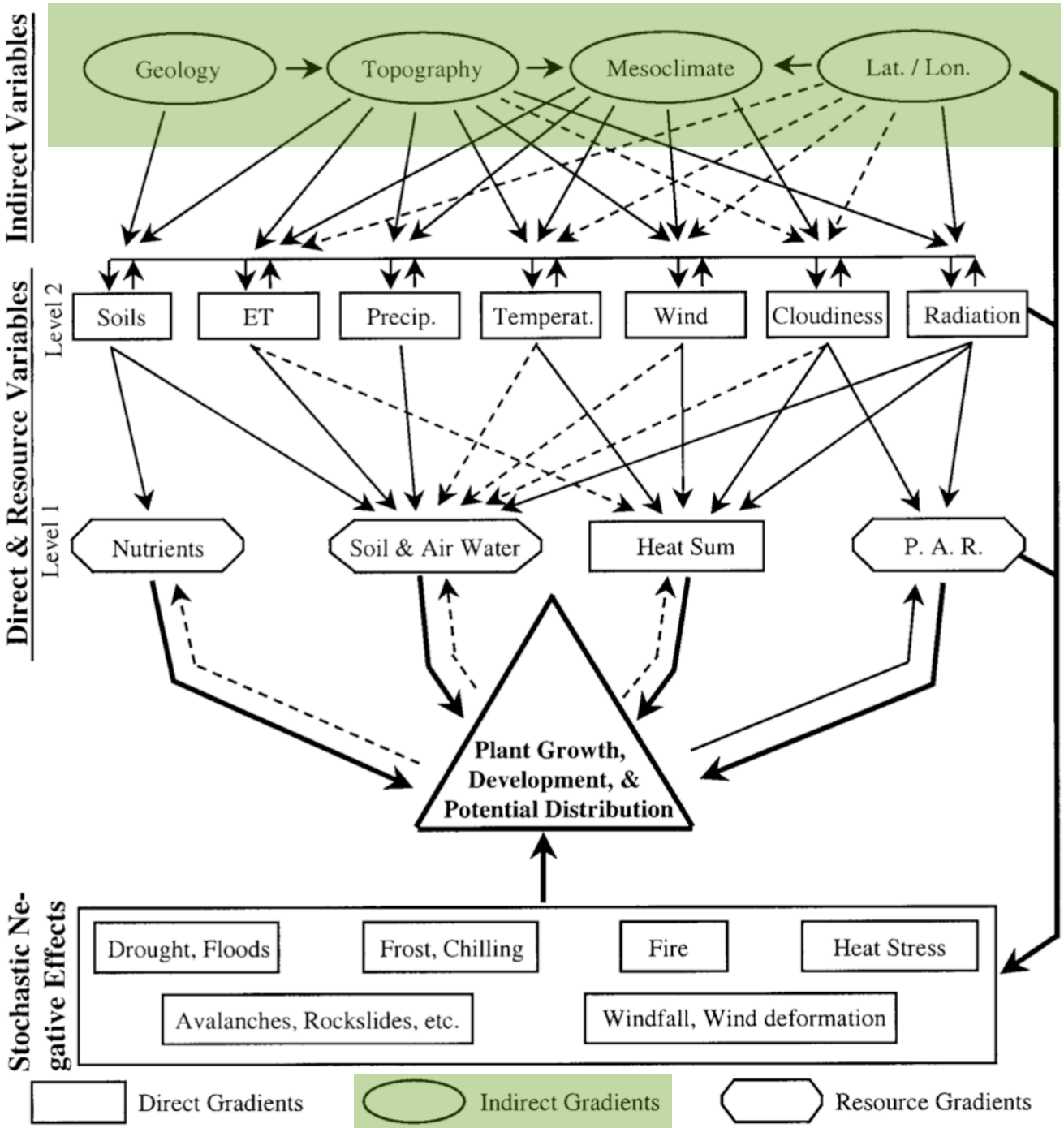
distal

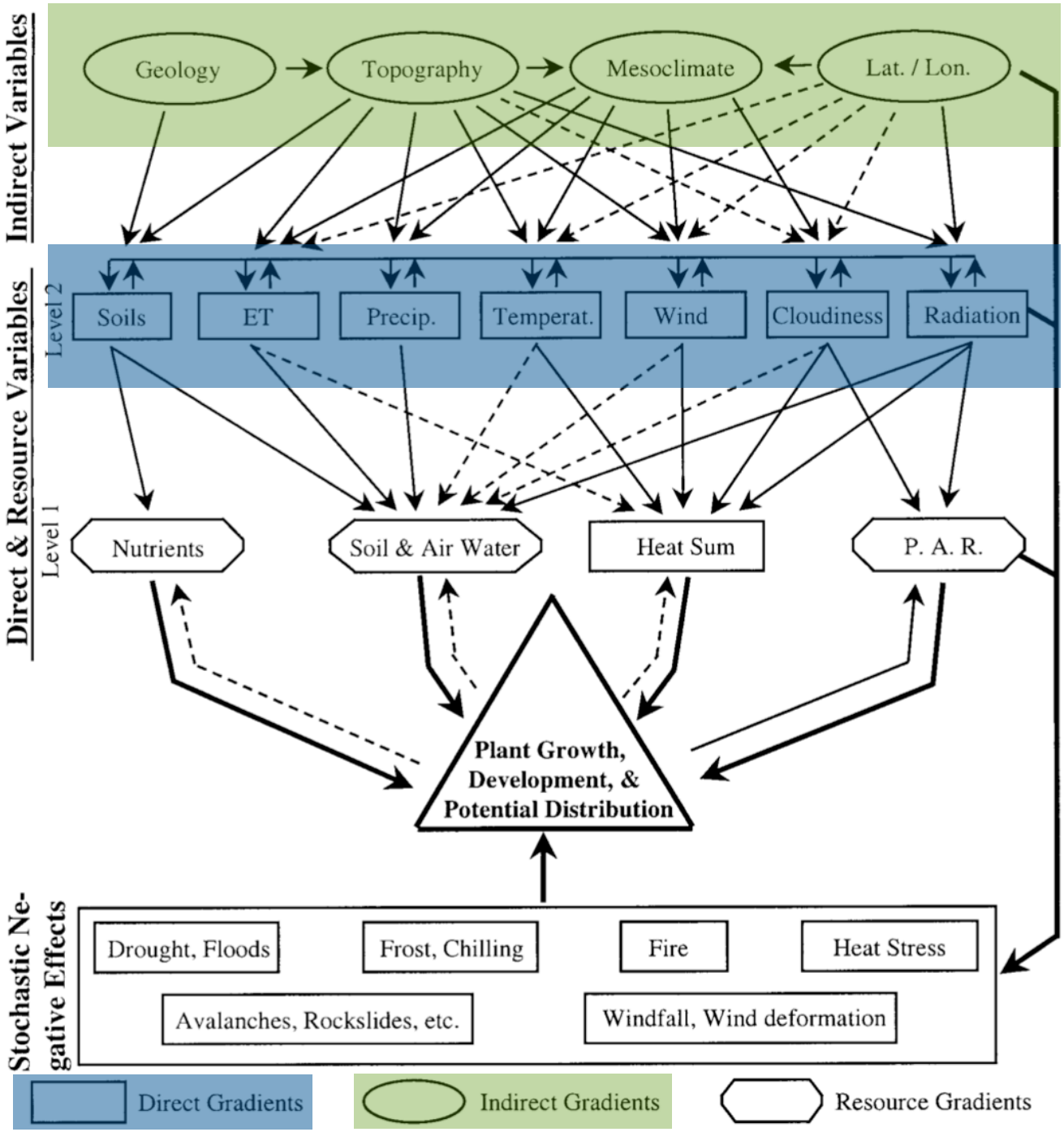
proximal

ideally this is where you should derive your predictors from

Fig. 3. Example of a conceptual model of relationships between resources, direct and indirect environmental gradients (see e.g. Austin and Smith, 1989), and their influence on growth, performance, and geographical distribution of vascular plants and vegetation.

Guisan & Zimmermann 2000


Indirect Variables
Geology
Topography
Mesoclimate
Lat. / Lon.
Direct & Resource Variables
Level 2
Soils
ET
Precip.
Temperat.
Wind
Cloudiness
Radiation
Level 1
Nutrients
Soil & Air Water
Heat Sum
P. A. R.
Plant Growth, Development, & Potential Distribution
Stochastic Negative Effects
Drought, Floods
Frost, Chilling
Fire
Heat Stress
Avalanches, Rockslides, etc.
Windfall, Wind deformation
Direct Gradients
Indirect Gradients
Resource Gradients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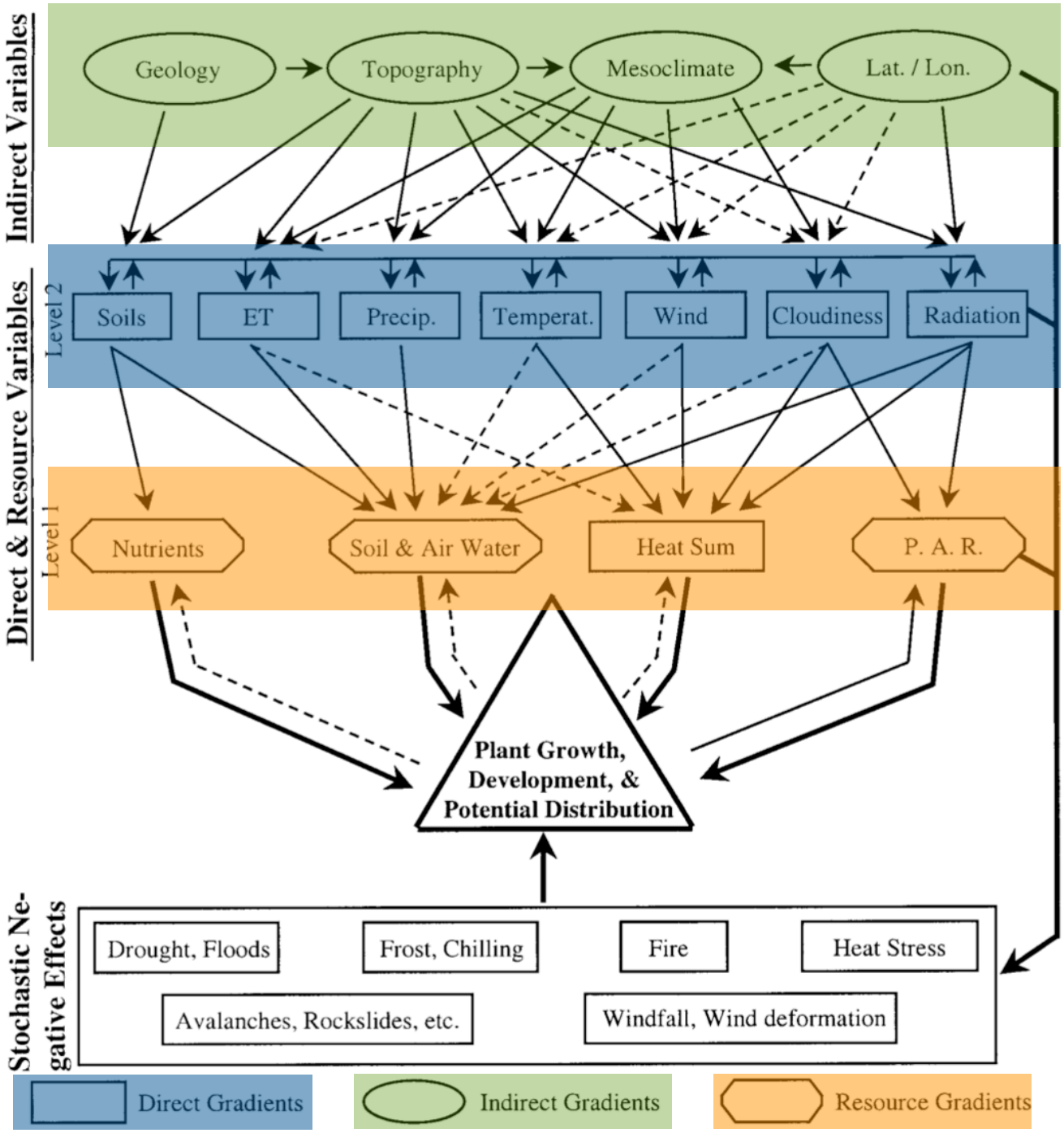
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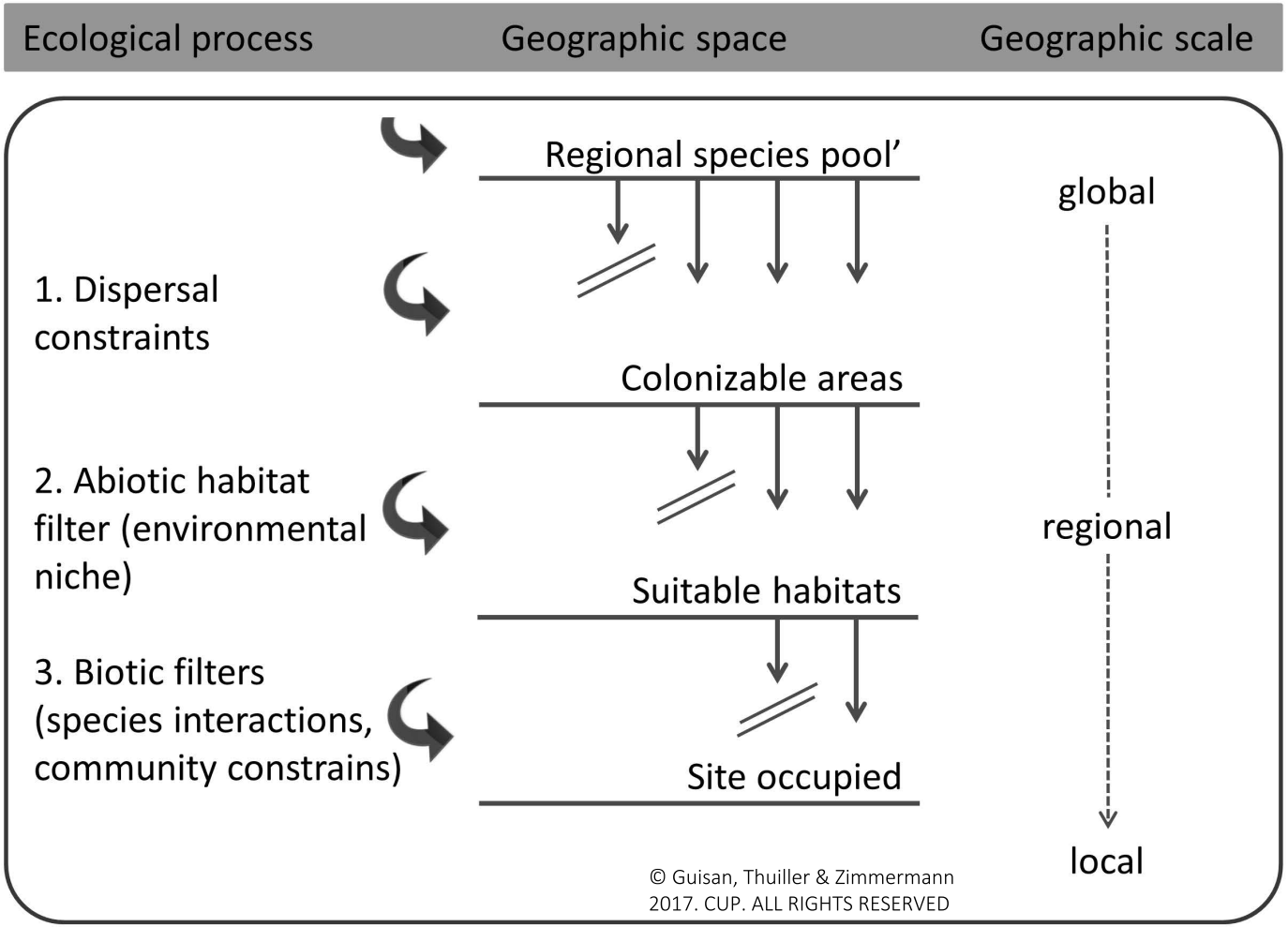
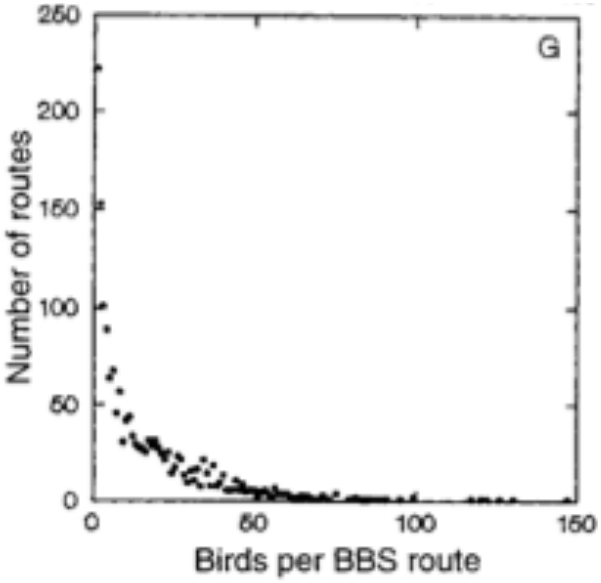
Distributions are limited by factors that operate at different scales (in space and time)

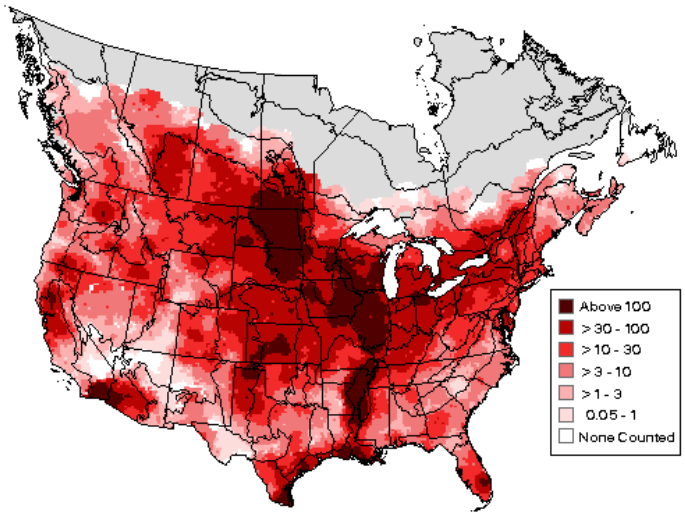


Distributions are complex

- Internal range structure (spatial variation in abundance)
  - Highly abundant at few sites (hotspots), but hotspots occur more rarely than expected by chance

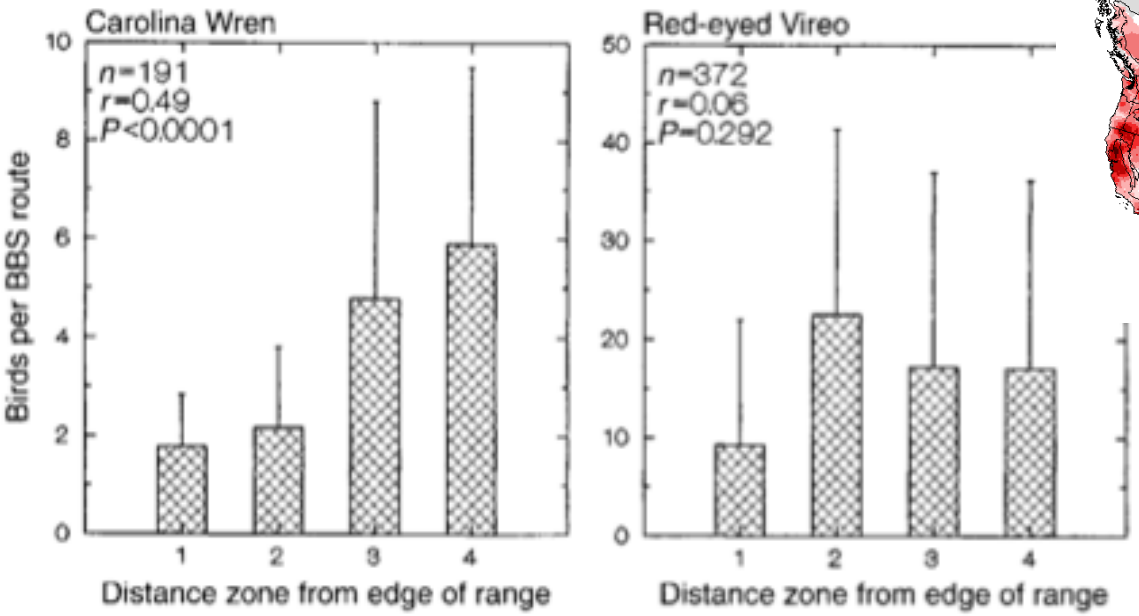


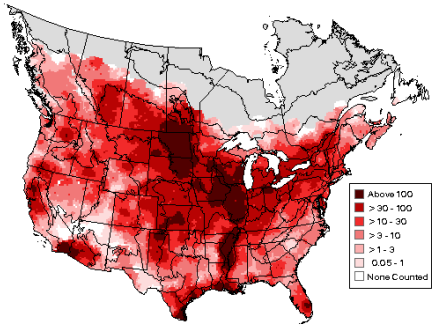
Brown et al. 1995



Distributions are complex

- Internal range structure (spatial variation in abundance)
  - Most abundant in the center of the range?
  - Patchy, low abundance at range margins?

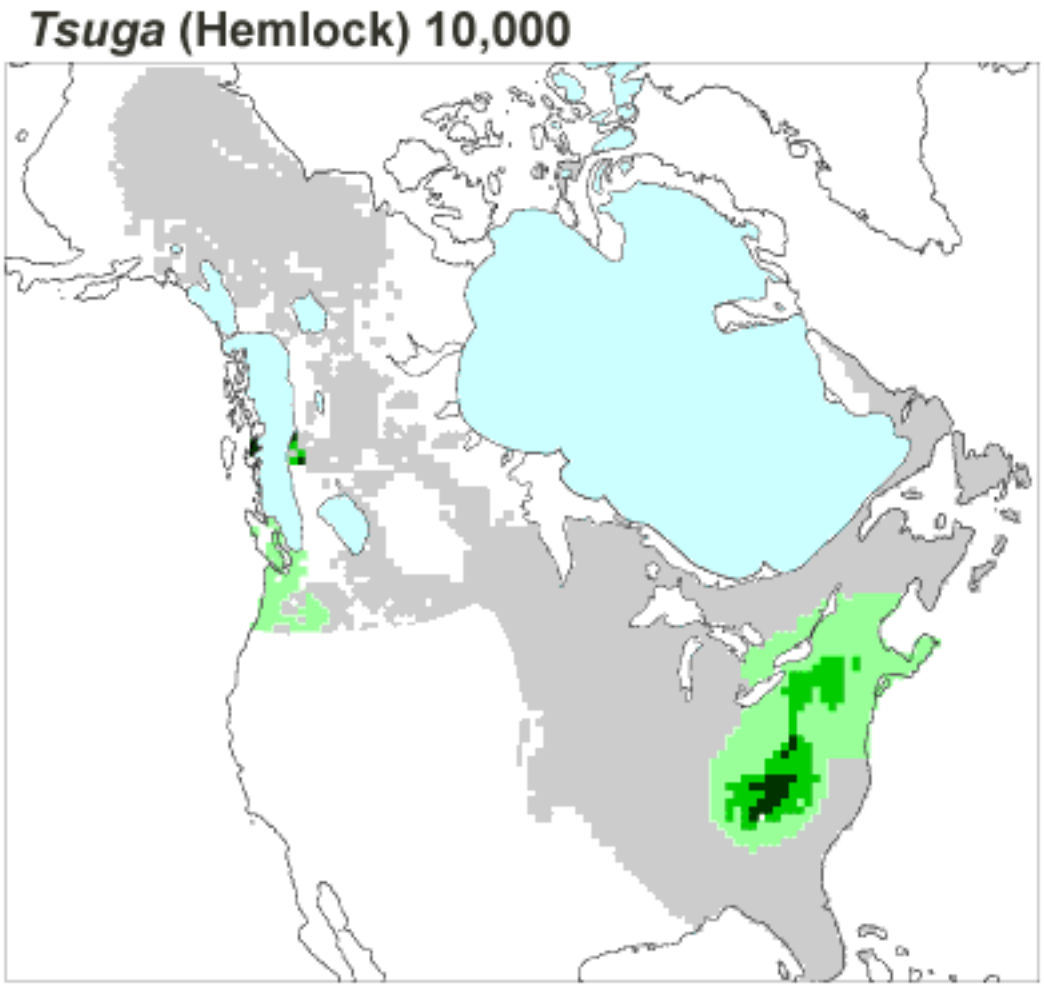




Brown et al. 1995

Ranges are dynamic

- Daily, seasonal, yearly, and millennial changes
- Spatial pattern in temporal variability



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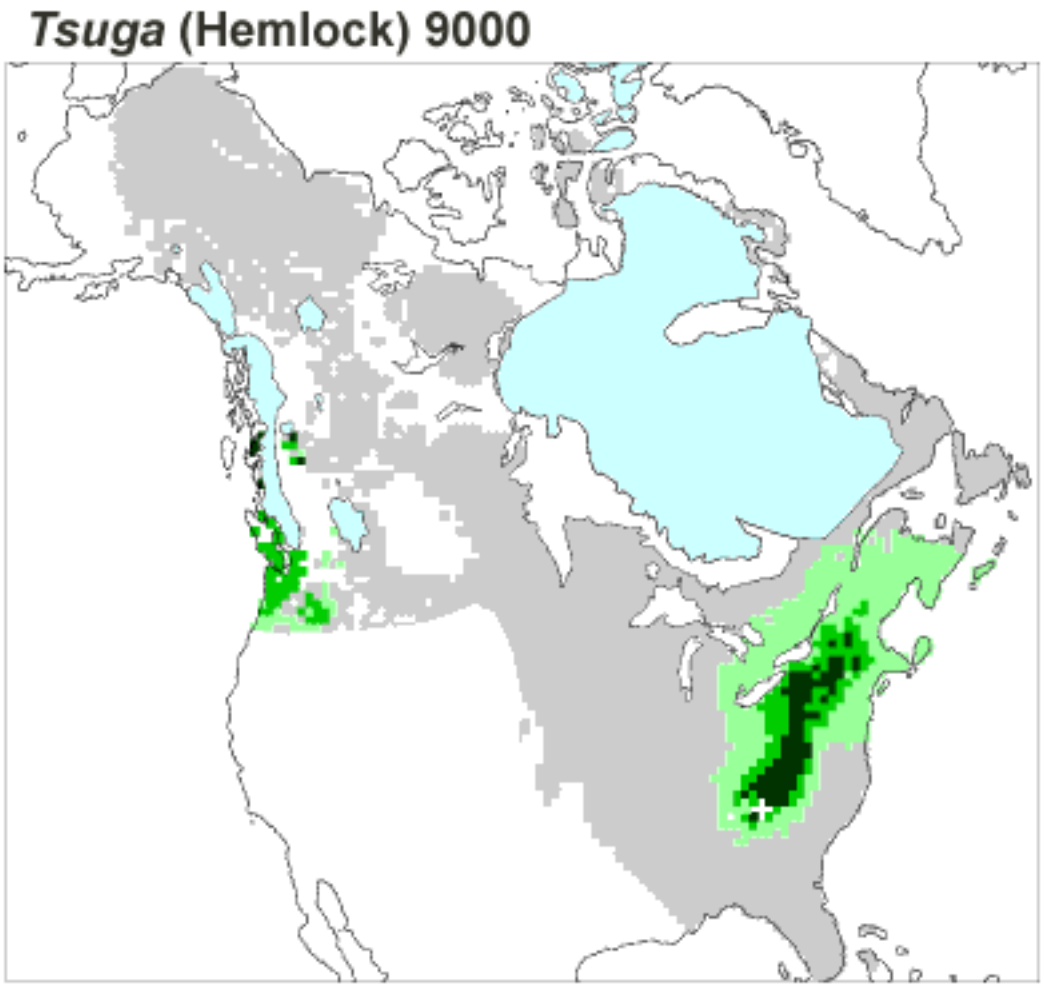

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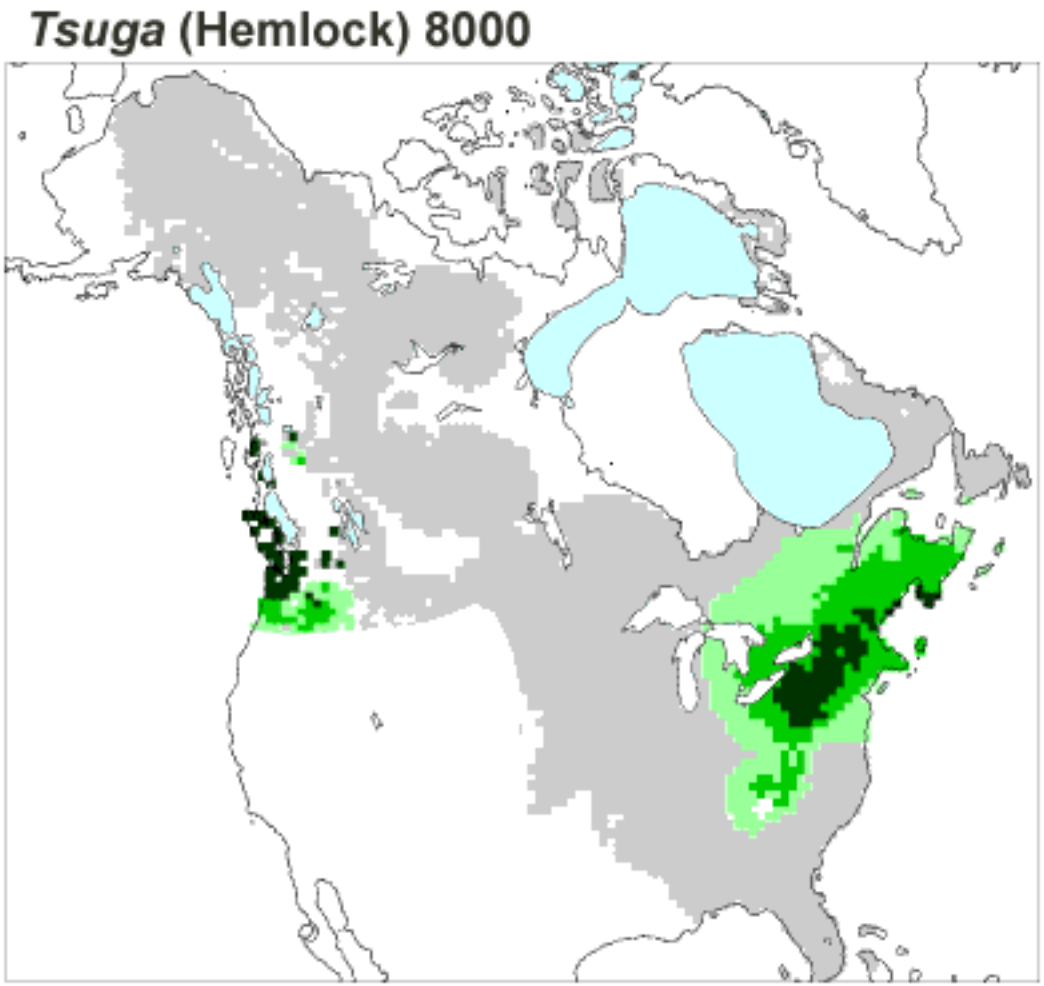

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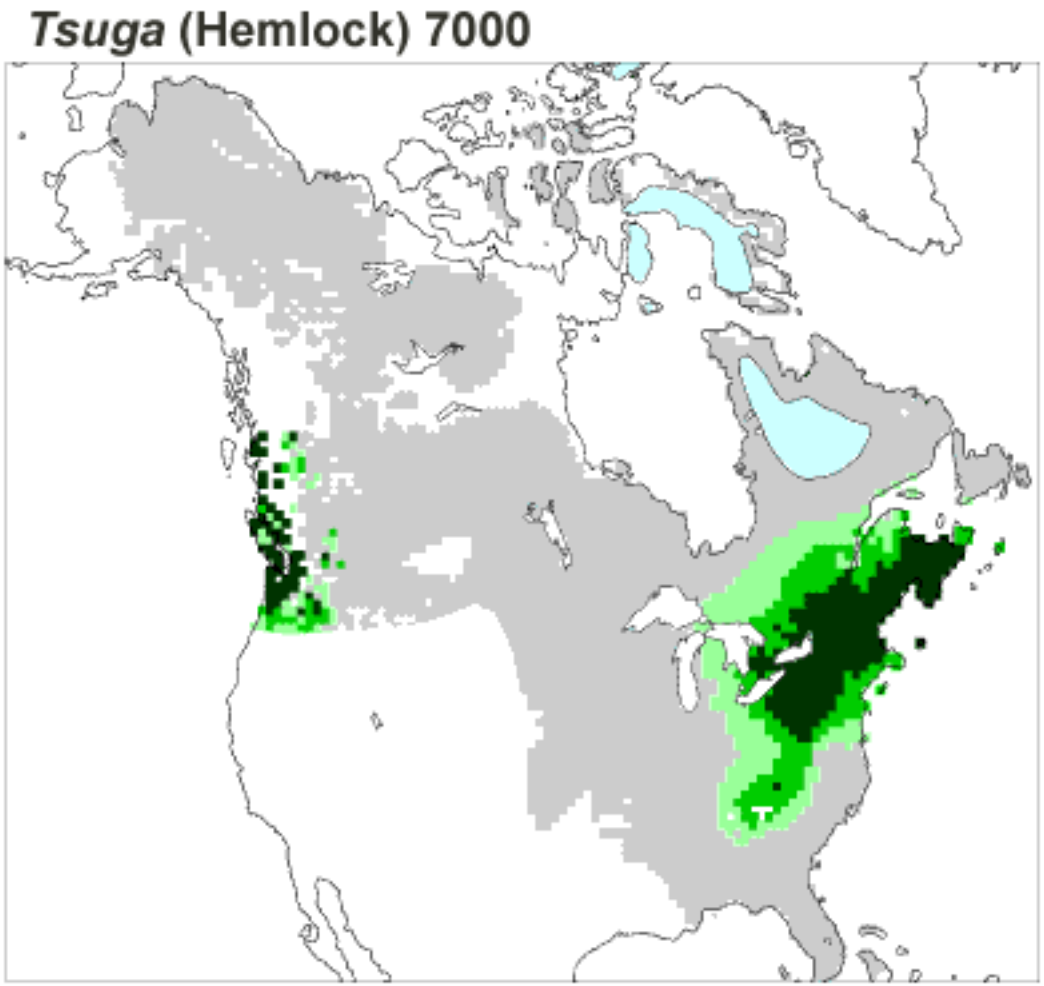

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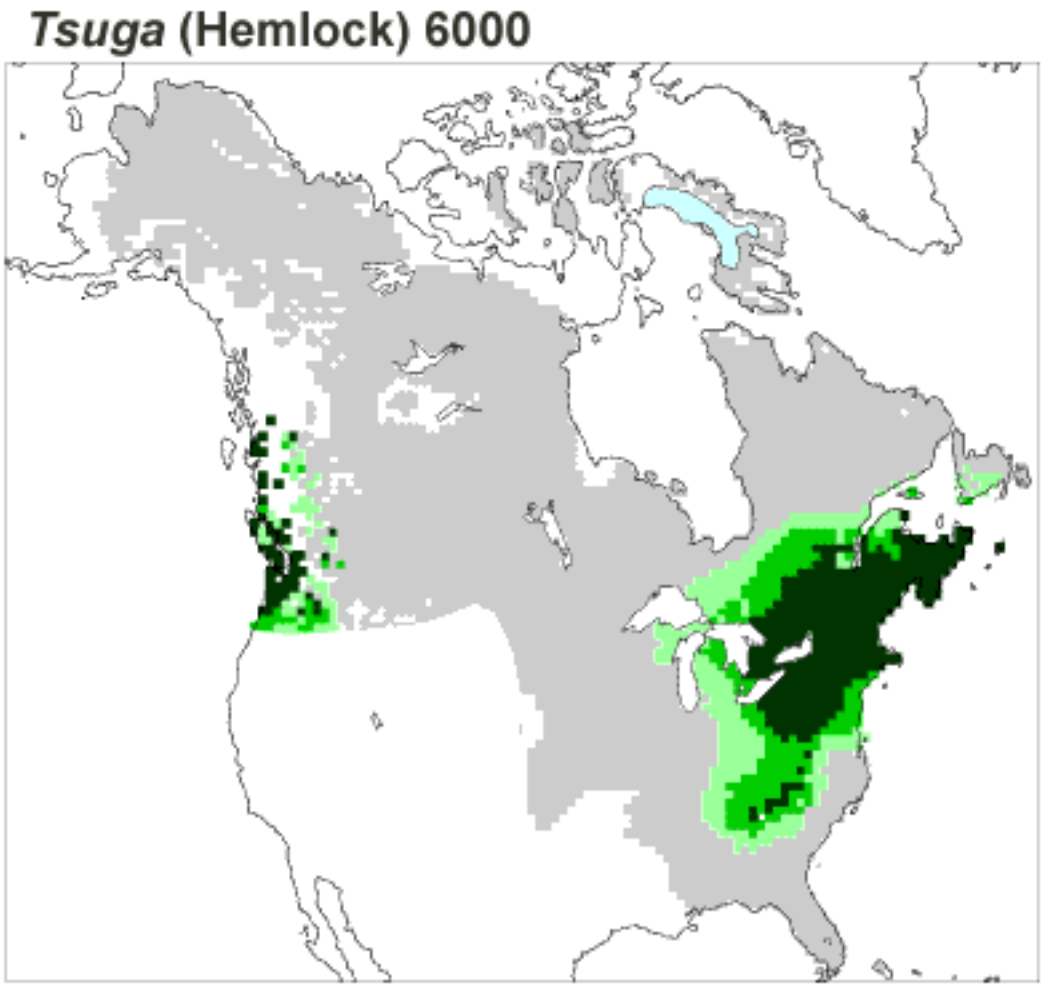

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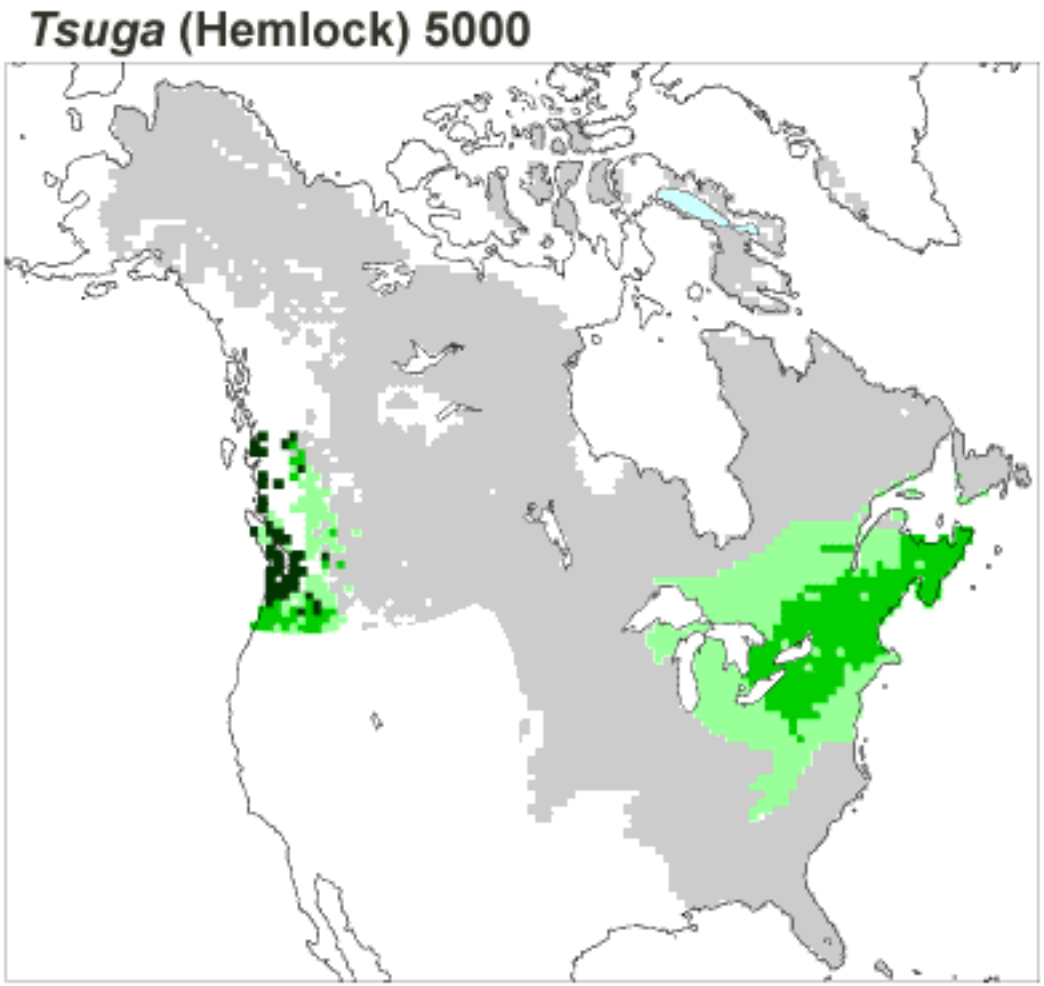

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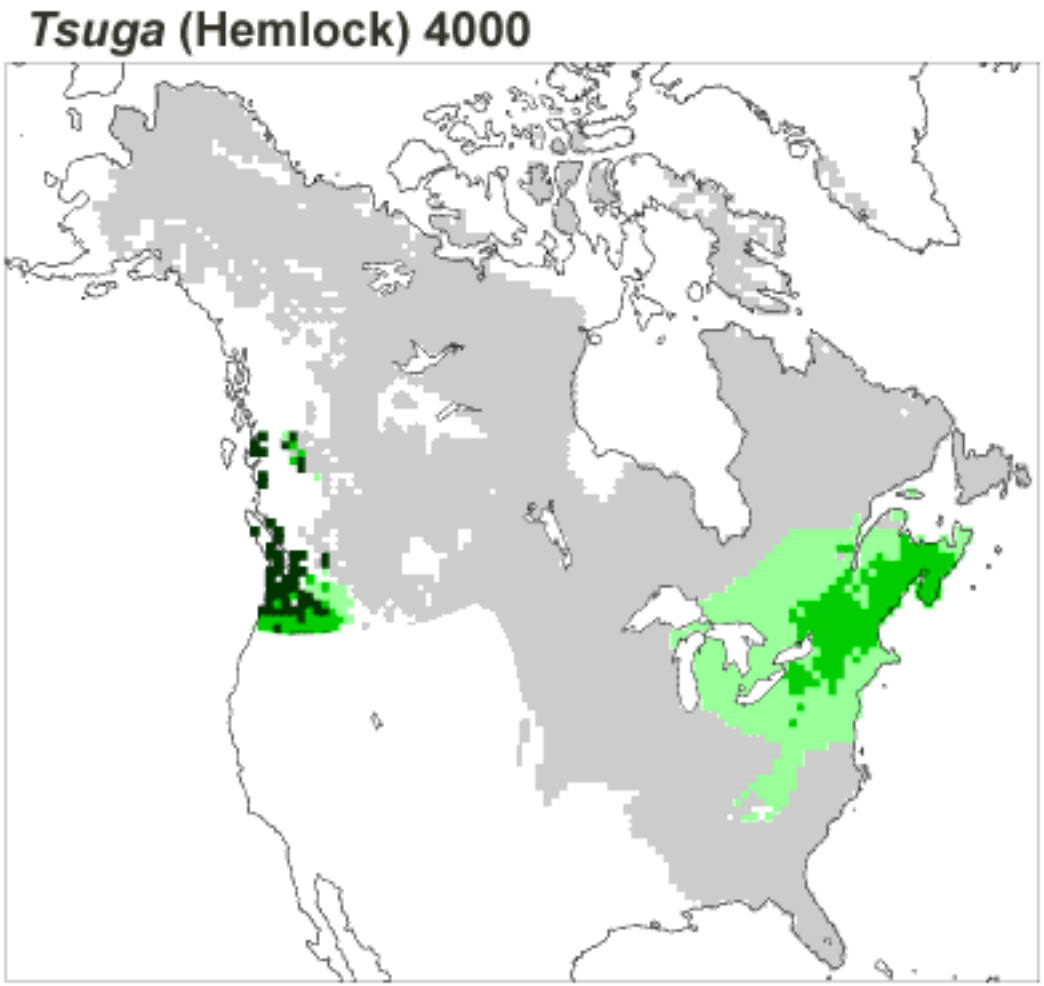

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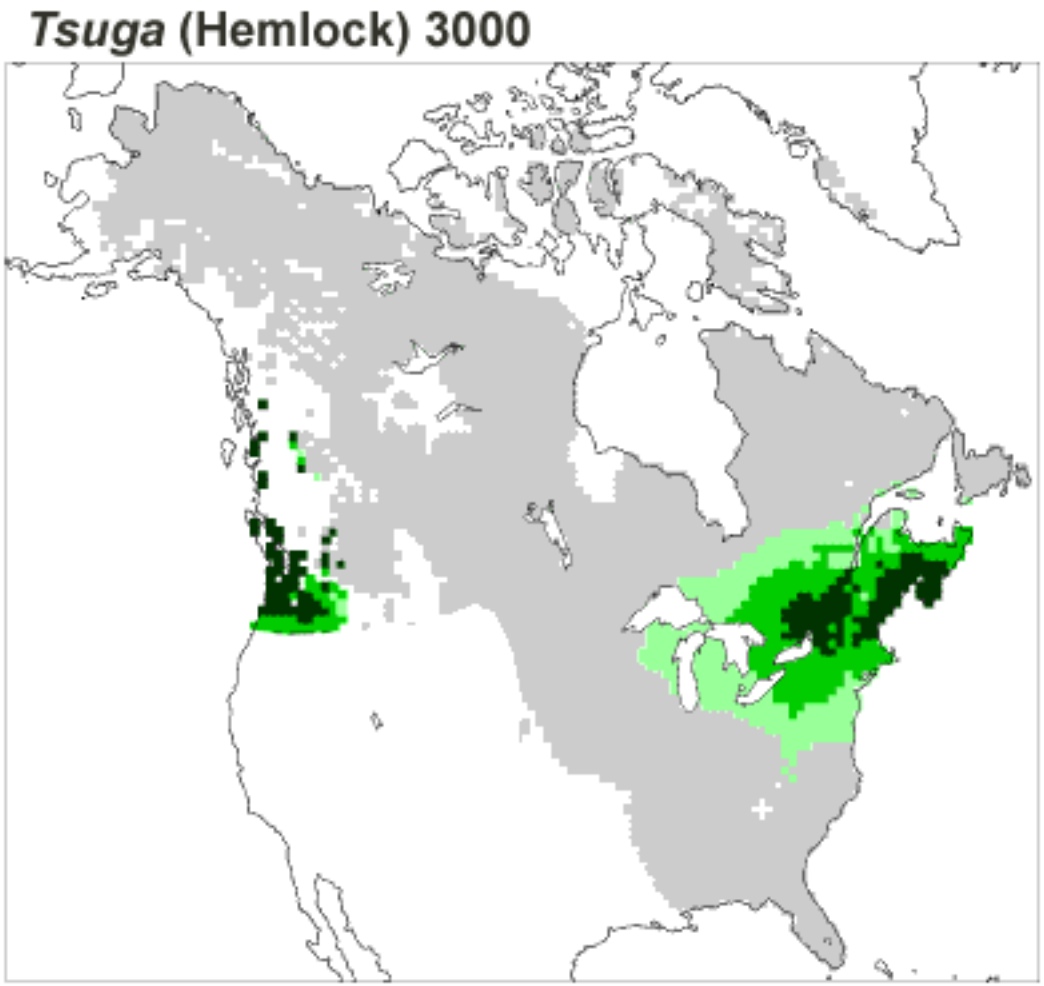

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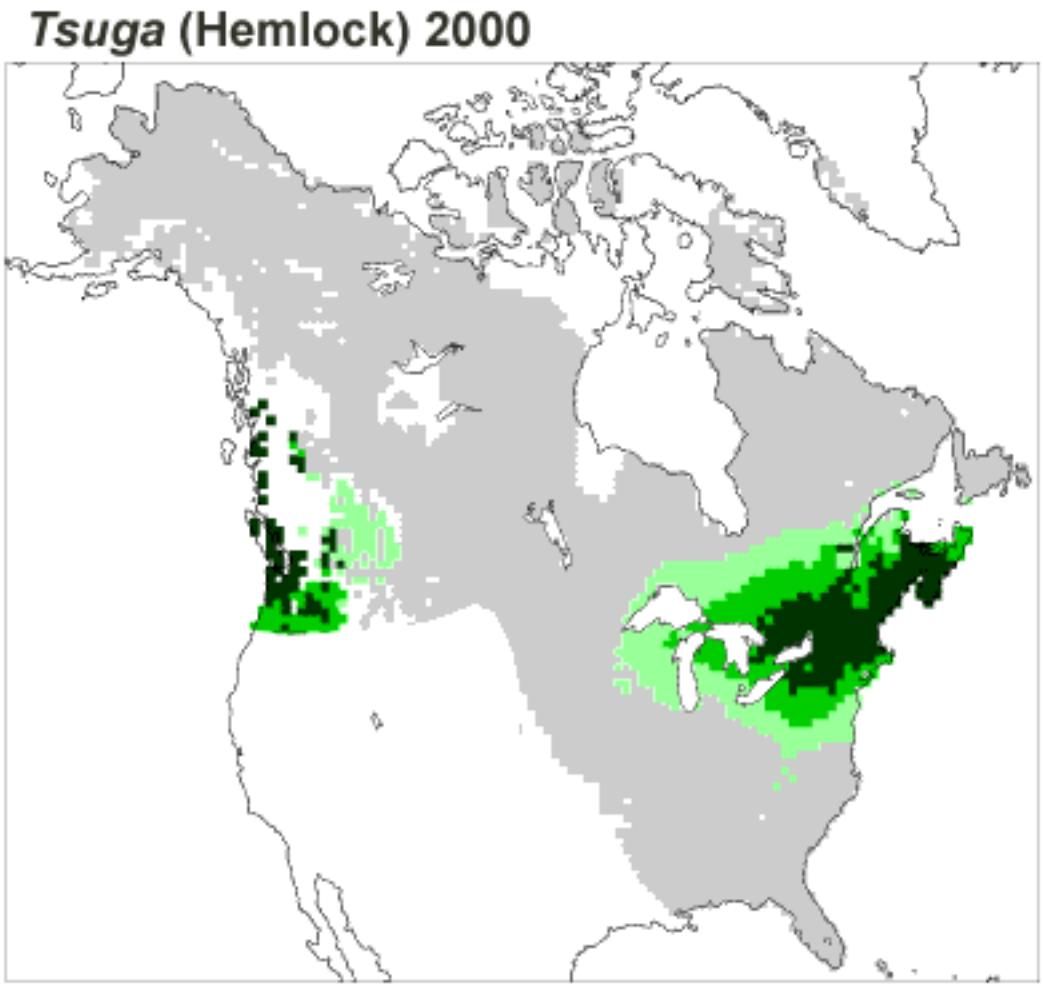

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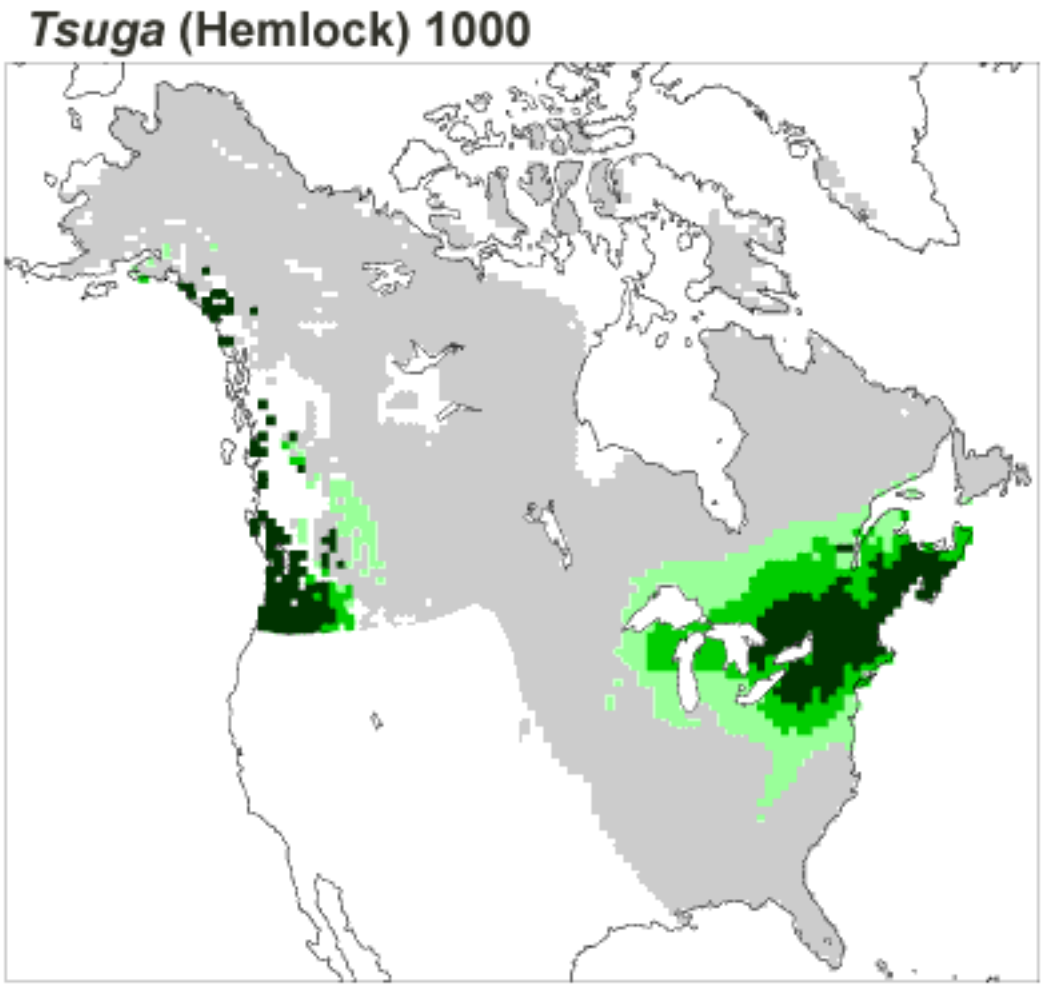

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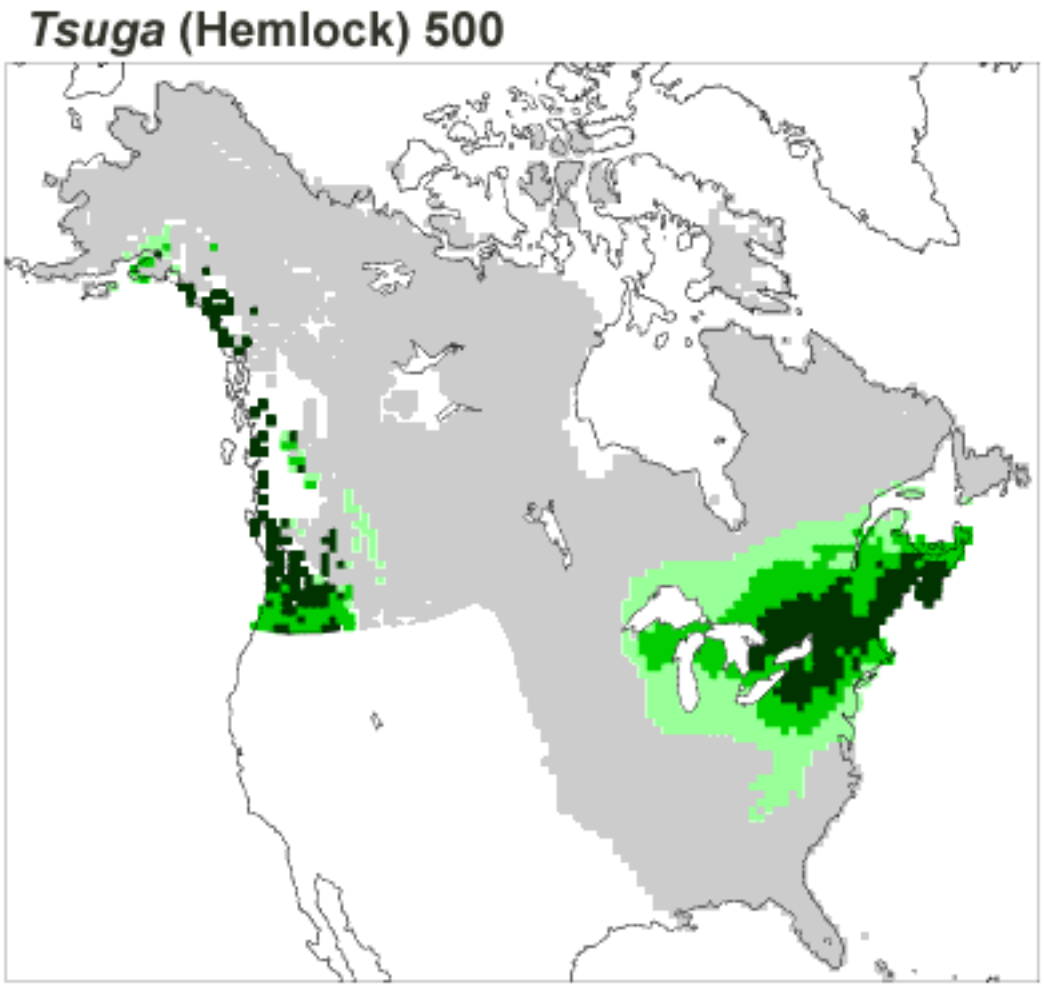

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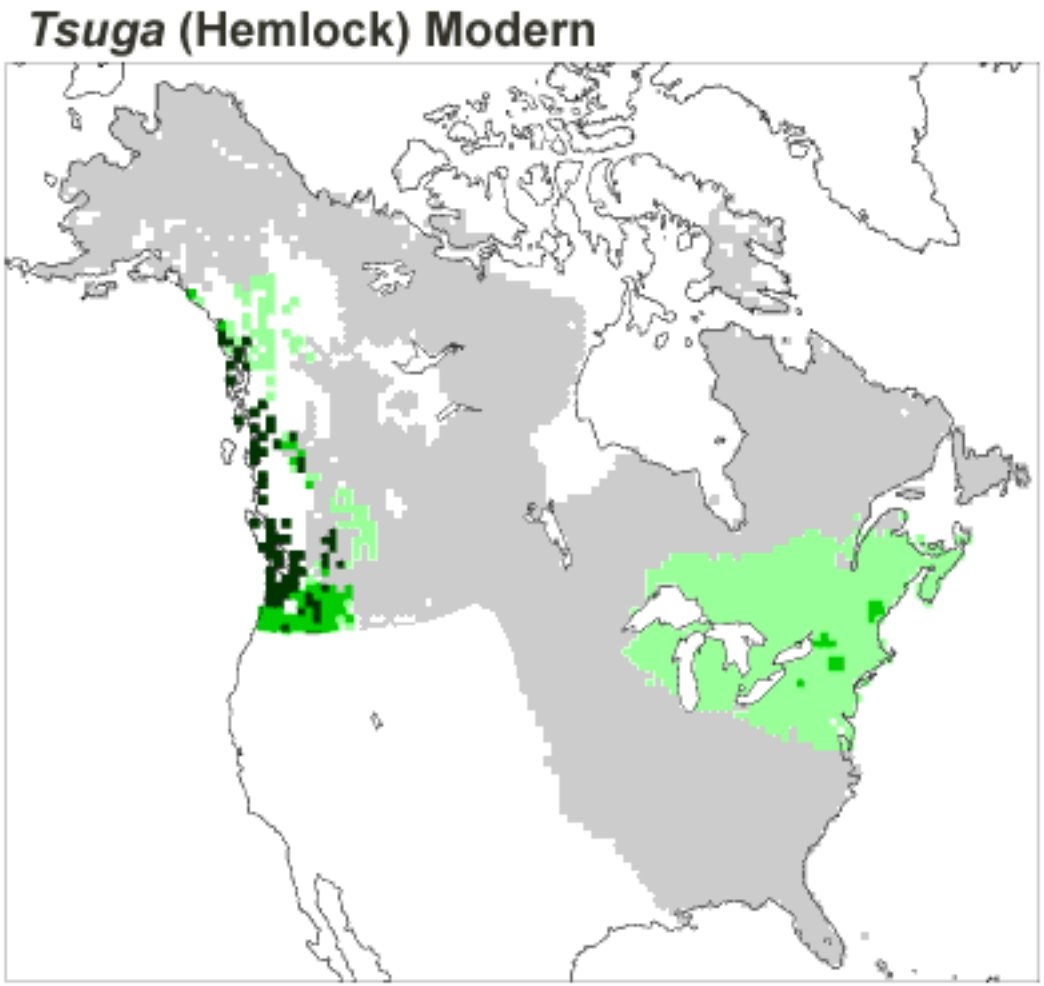
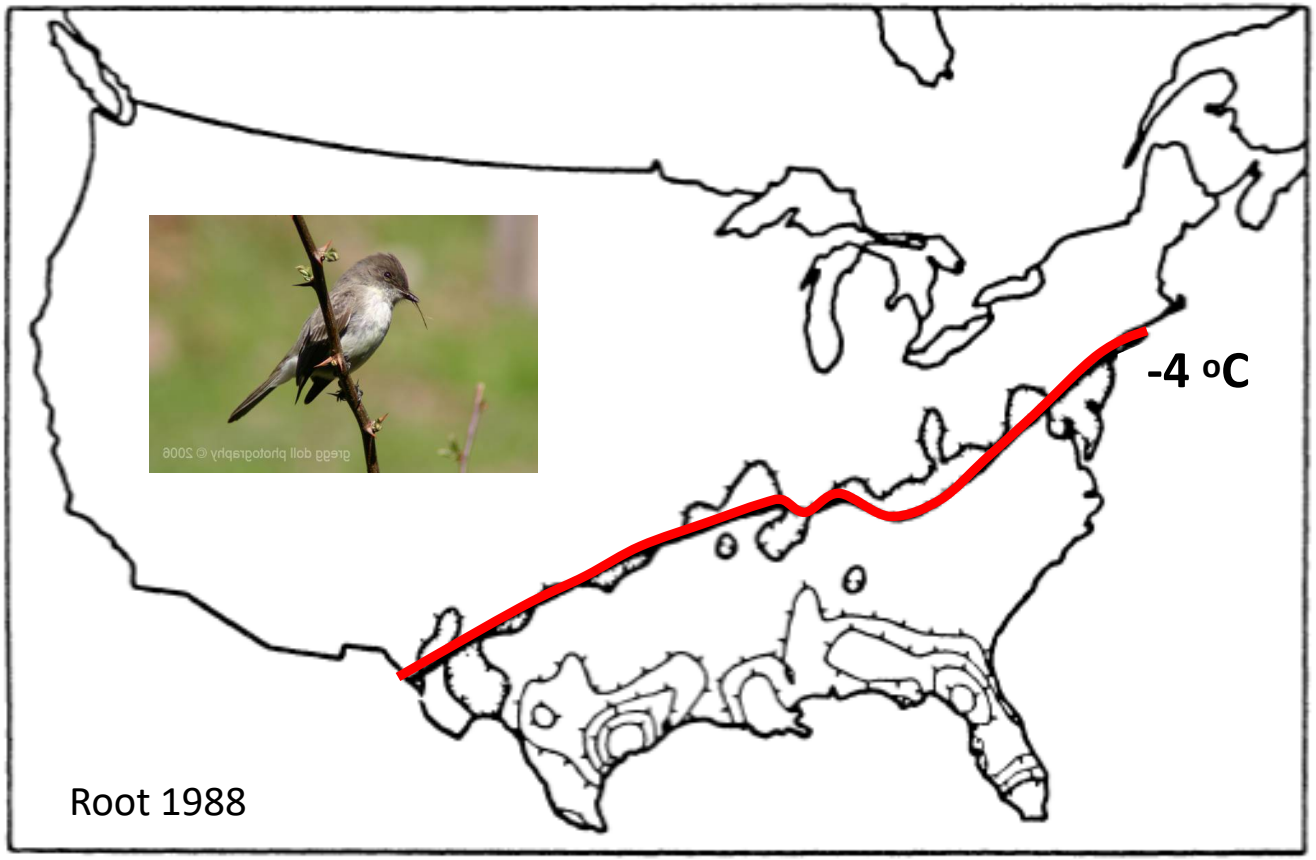
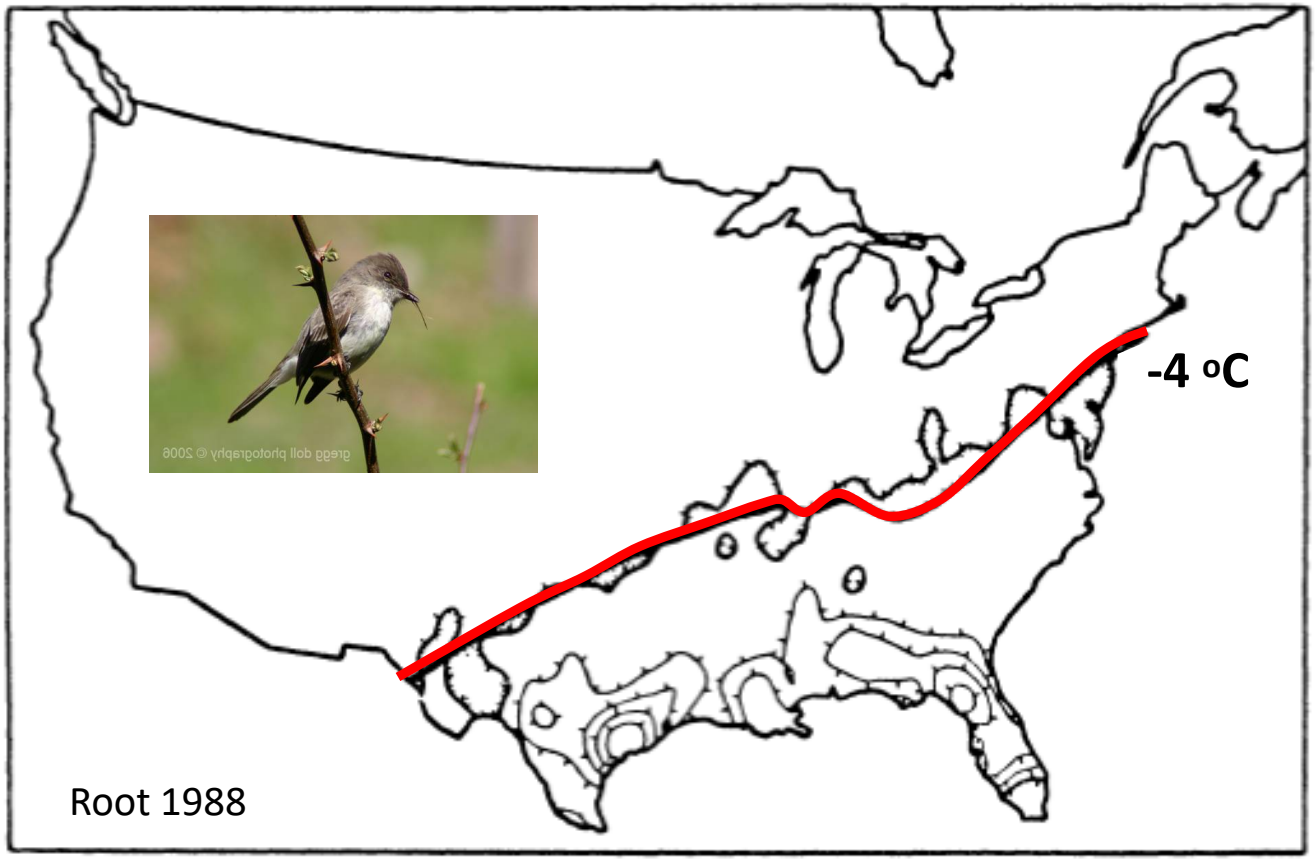


Polar range margins ~ climatic, often well defined & relatively stable



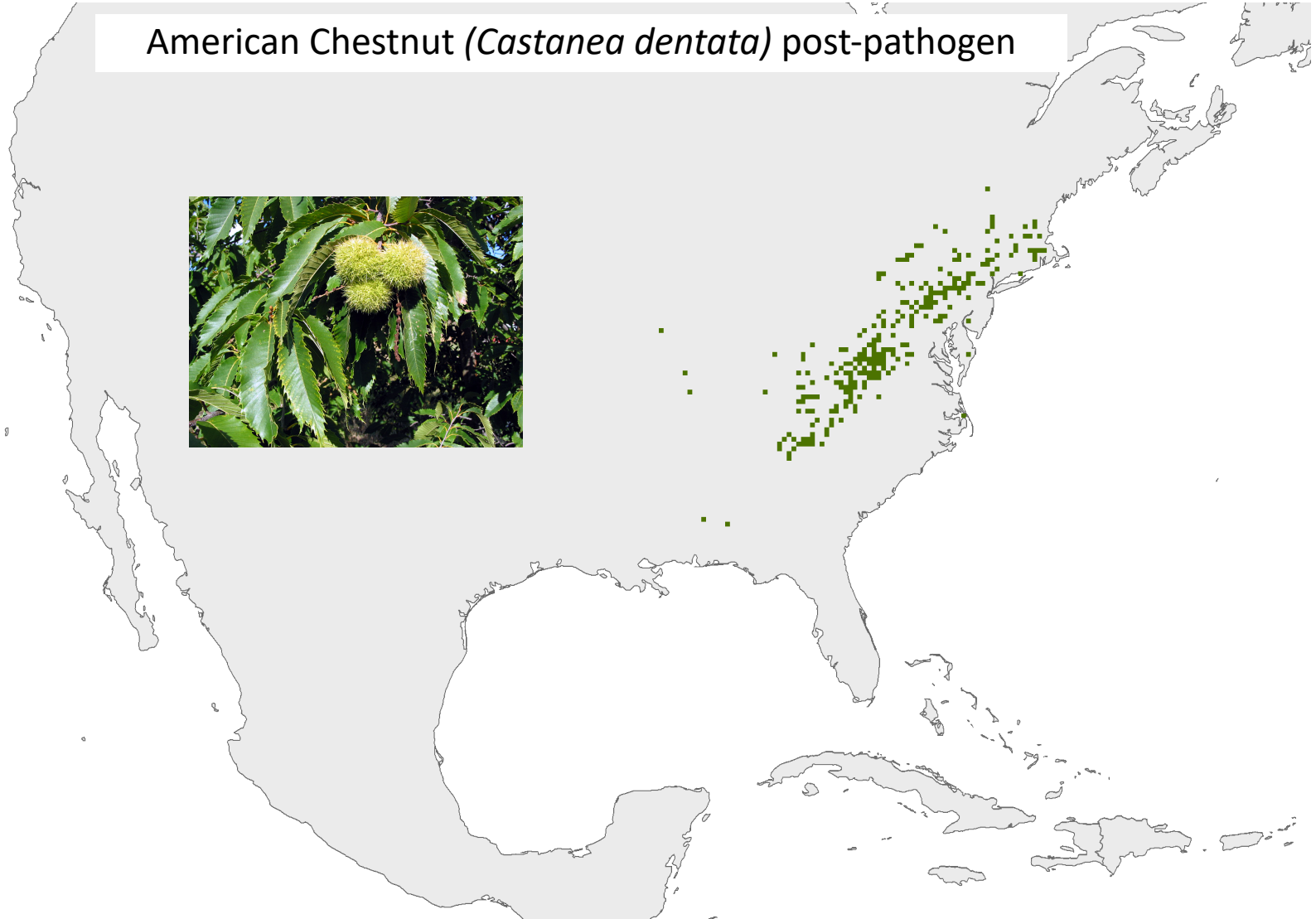
Equatorial range margins ~ biotic, often diffuse, potentially unstable



Biotic factors also influence geographic ranges

American Chestnut *(Castanea dentata)* pre-pathogen

Biotic factors also influence geographic ranges



Biotic factors also influence geographic ranges

ECOLOGY LETTERS

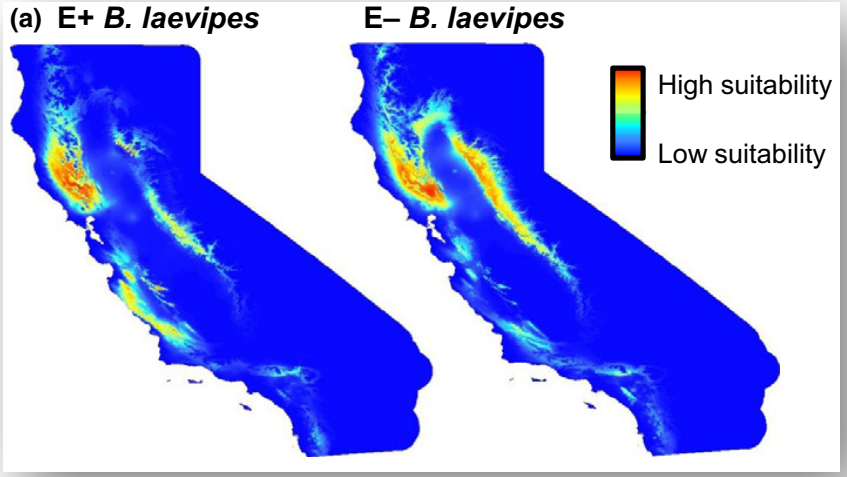
Ecology Letters, (2014) **17**: 1265–1273 doi: 10.1111/ele.12332

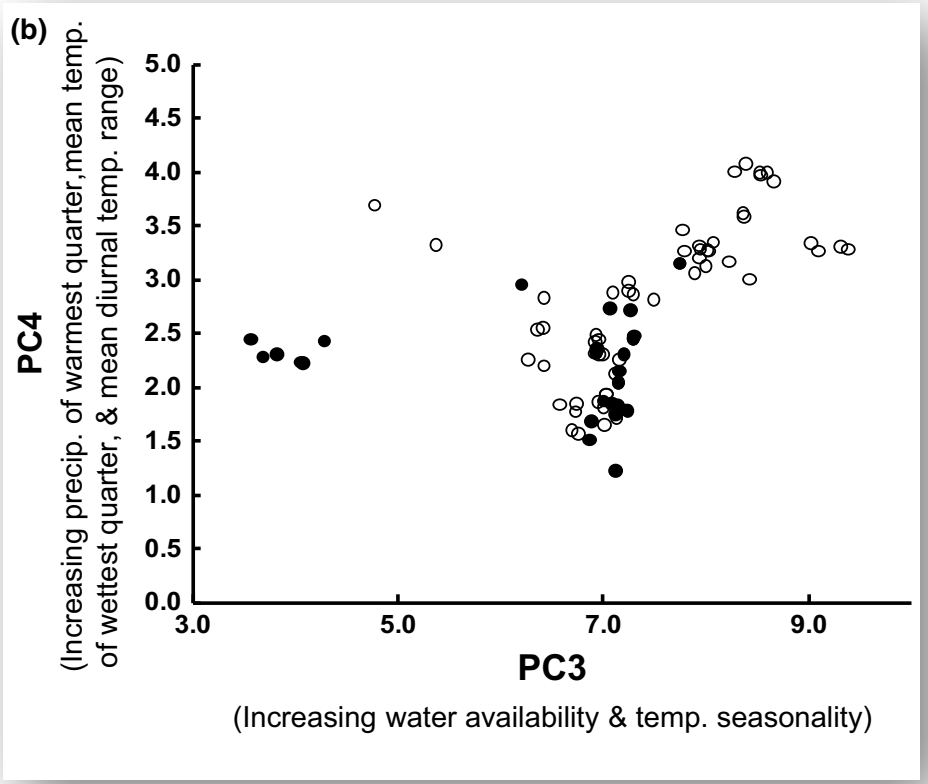
LETTER

Mutualist-mediated effects on species' range limits across large geographic scales

Michelle E. Afkhami,* Patrick J. McIntyre and Sharon Y. Strauss

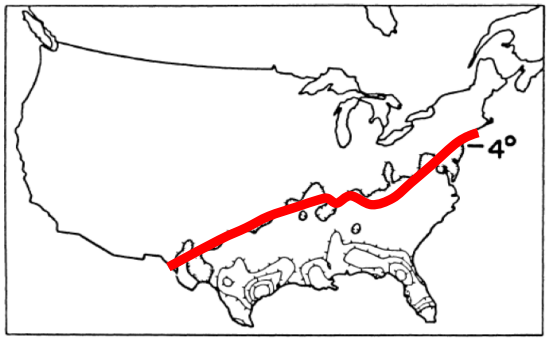
Closed circles = E+





Equilibrium vs non-equilibrium range limits

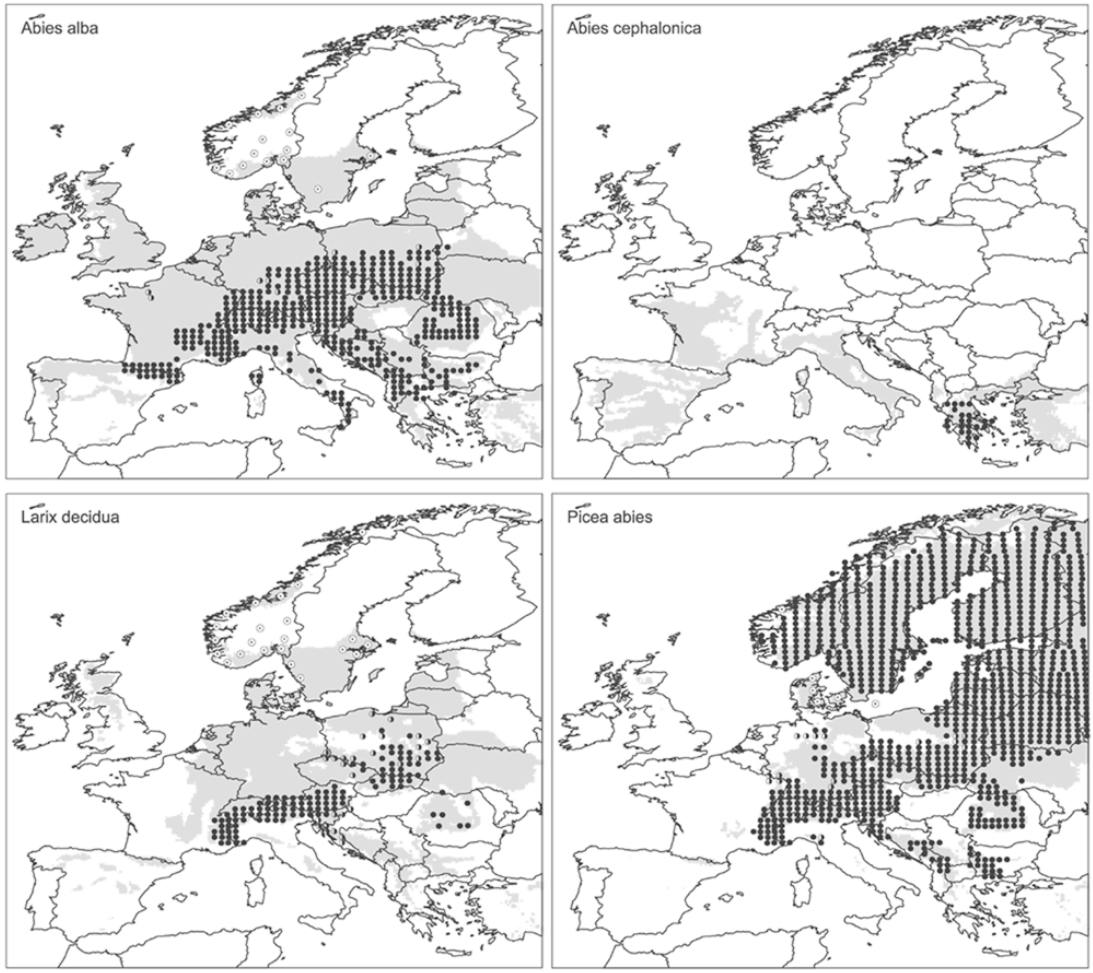
- **Equilibrium** – range limits set by current climatic (abiotic) conditions



Equilibrium vs non-equilibrium range limits

- **Non-equilibrium** – species fail to occupy suitable habitat due to biotic constraints (dispersal)

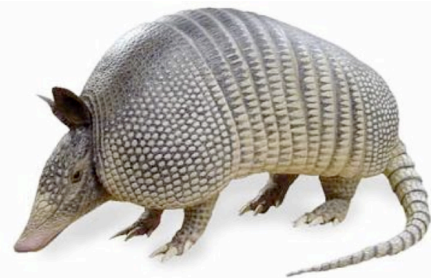
Post-glacial recolonization lags in European trees



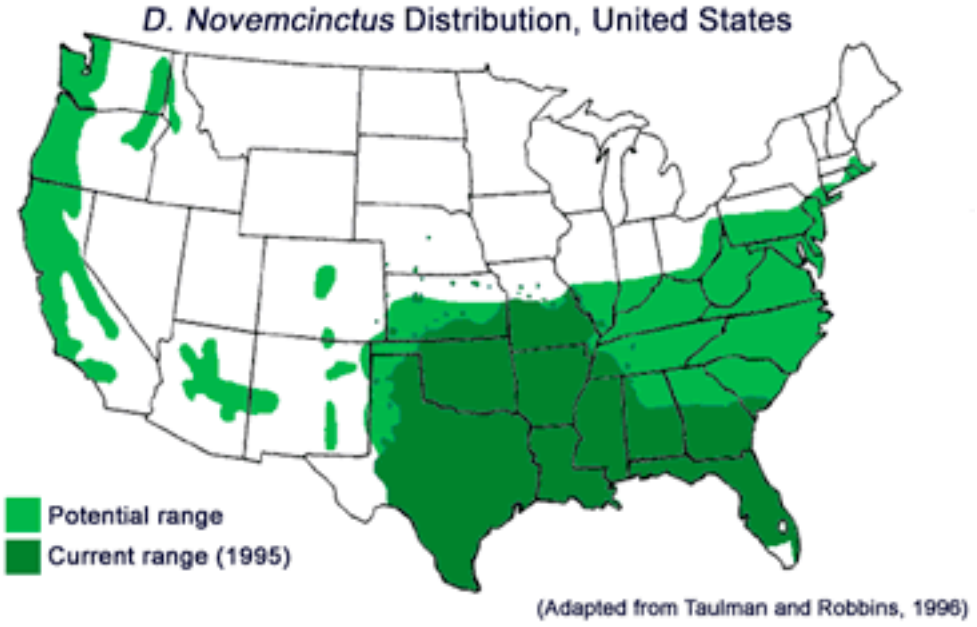
Svenning & Skov 2004.

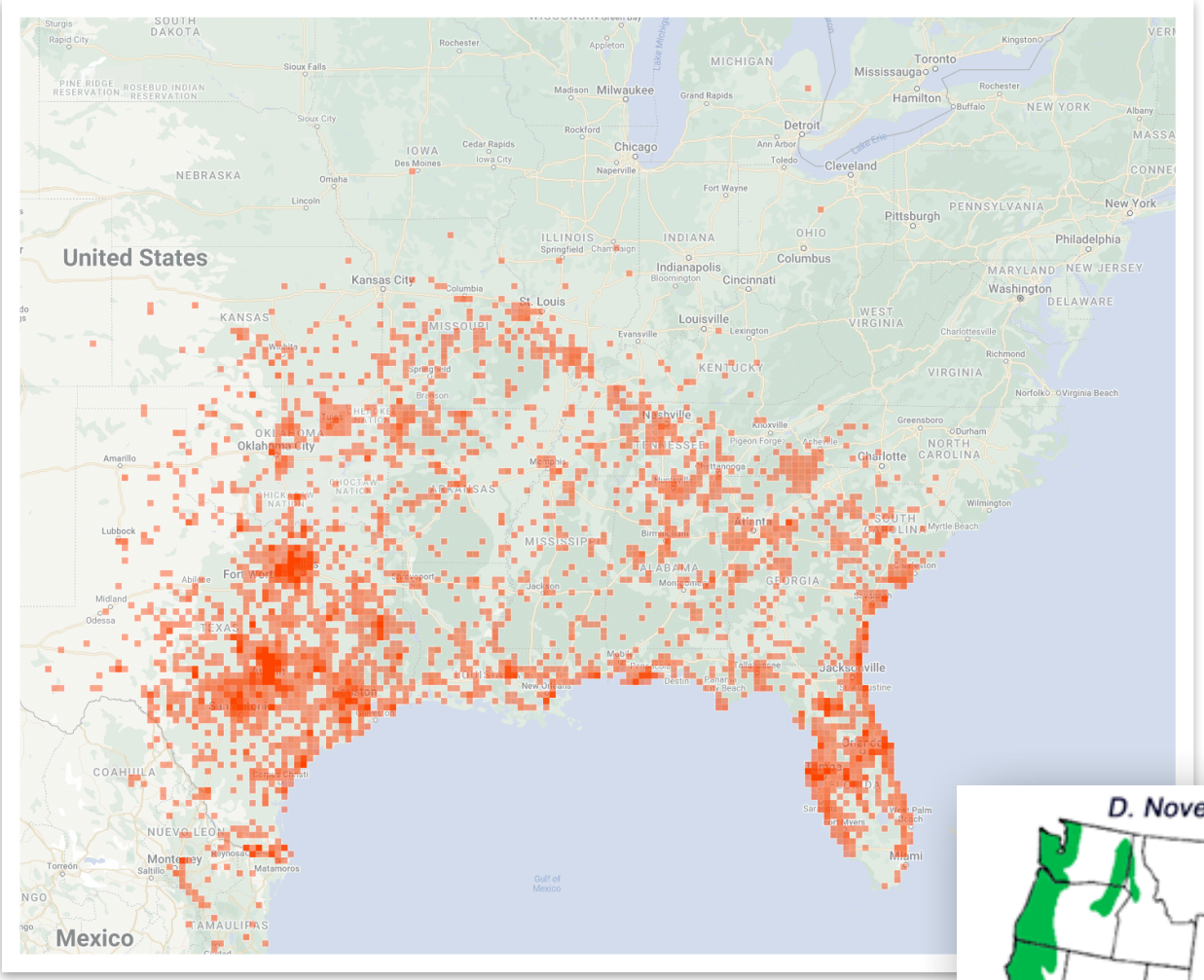
Equilibrium vs non-equilibrium range limits

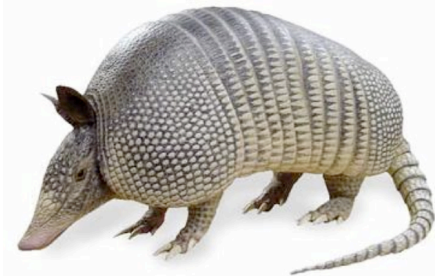
- **Non-equilibrium** – species fail to occupy suitable habitat due to biotic constraints (dispersal)

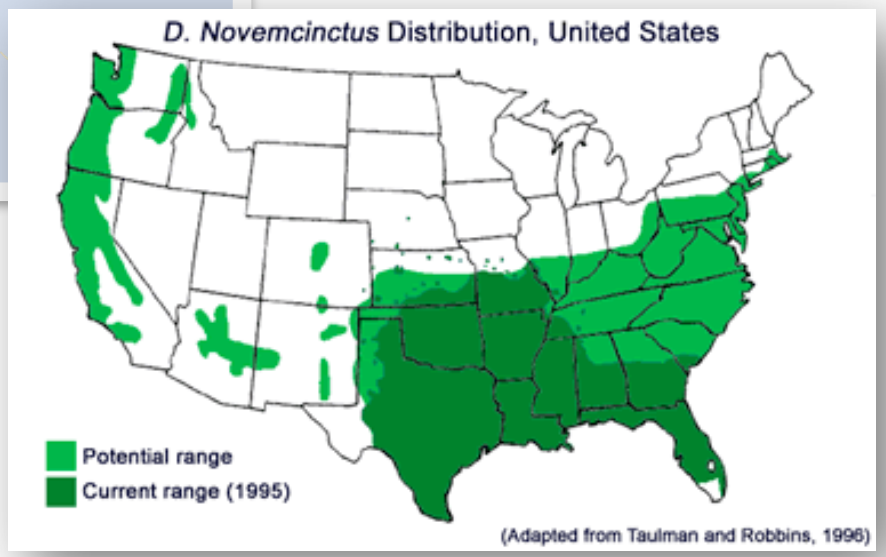


Actively spreading native and invasive species

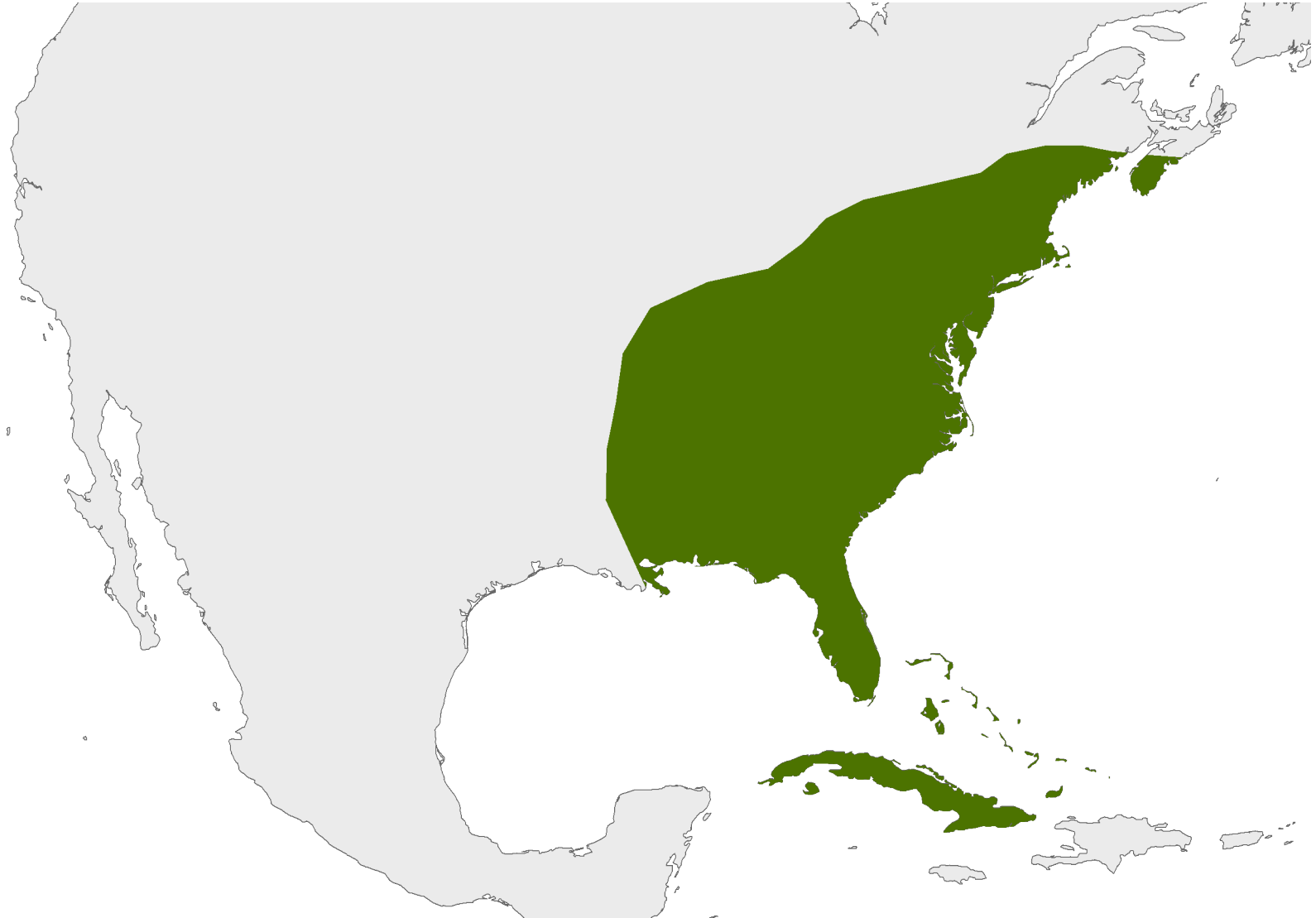



United States
Mexico

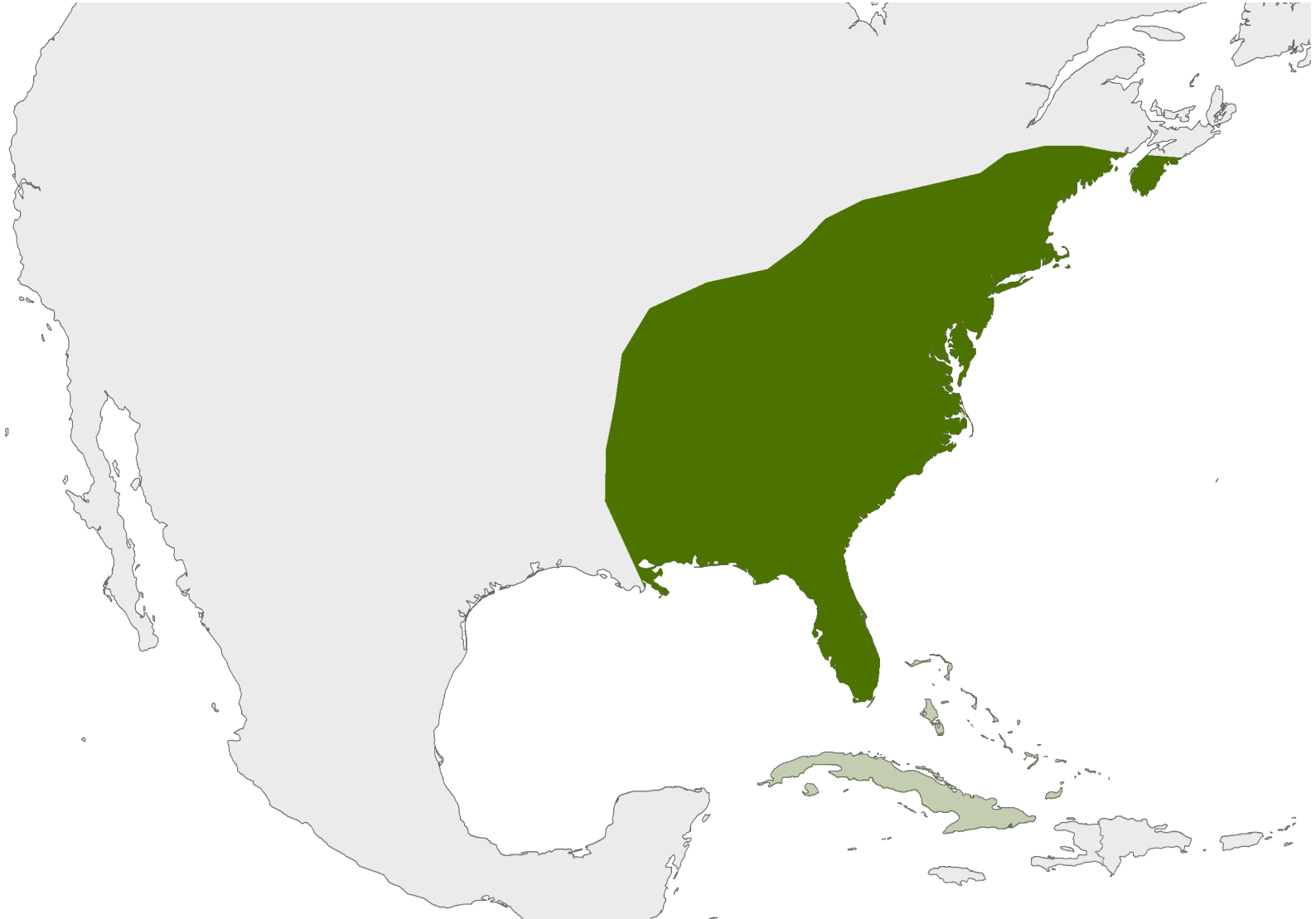



D. Novemcinctus Distribution, United States
Potential range
Current range (1995)
(Adapted from Taulman and Robbins, 1996)

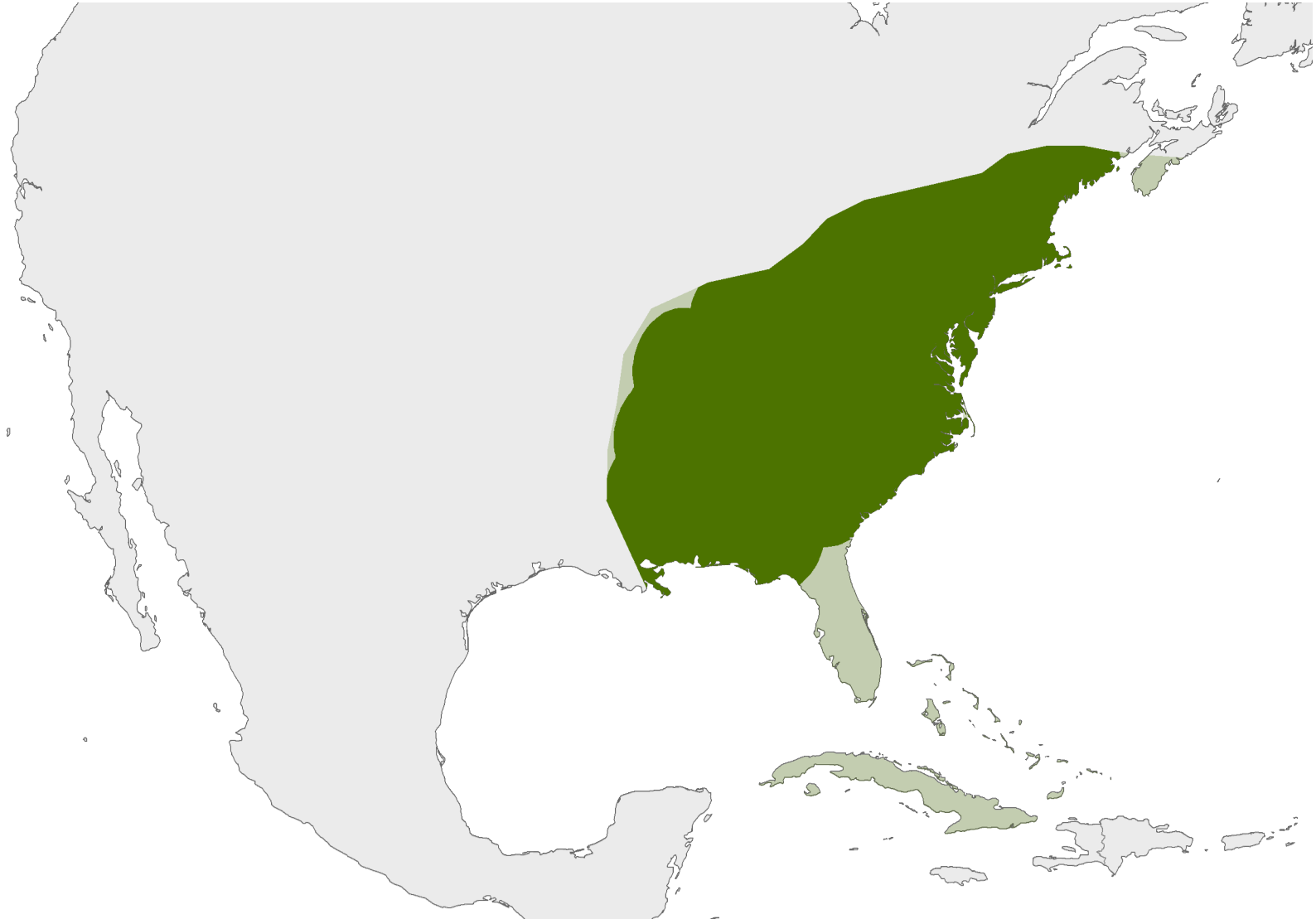
Potential geographic range (fundamental niche mapped in space) limited by climatic tolerances only



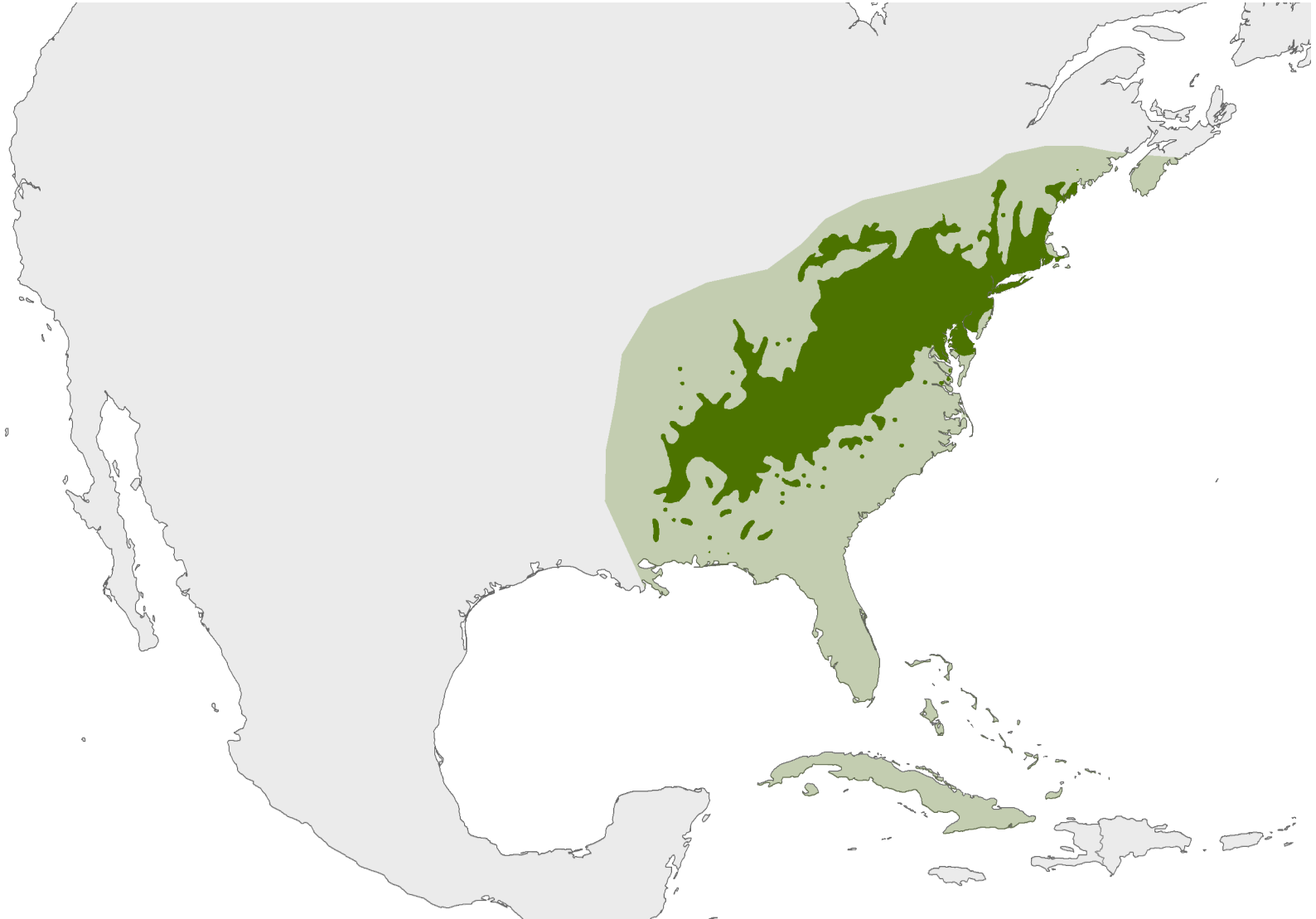
Dispersal limitation…



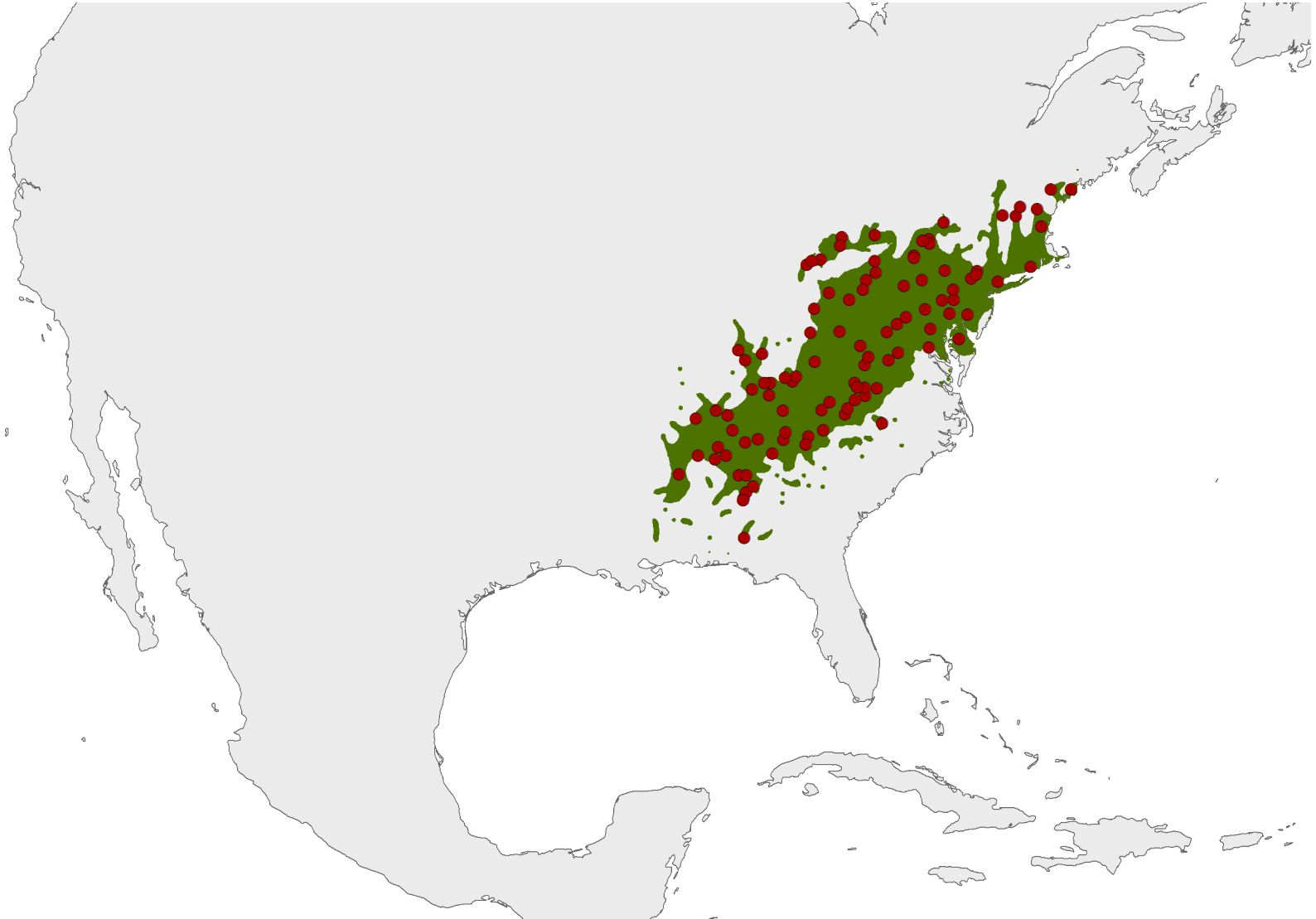
Disturbance….



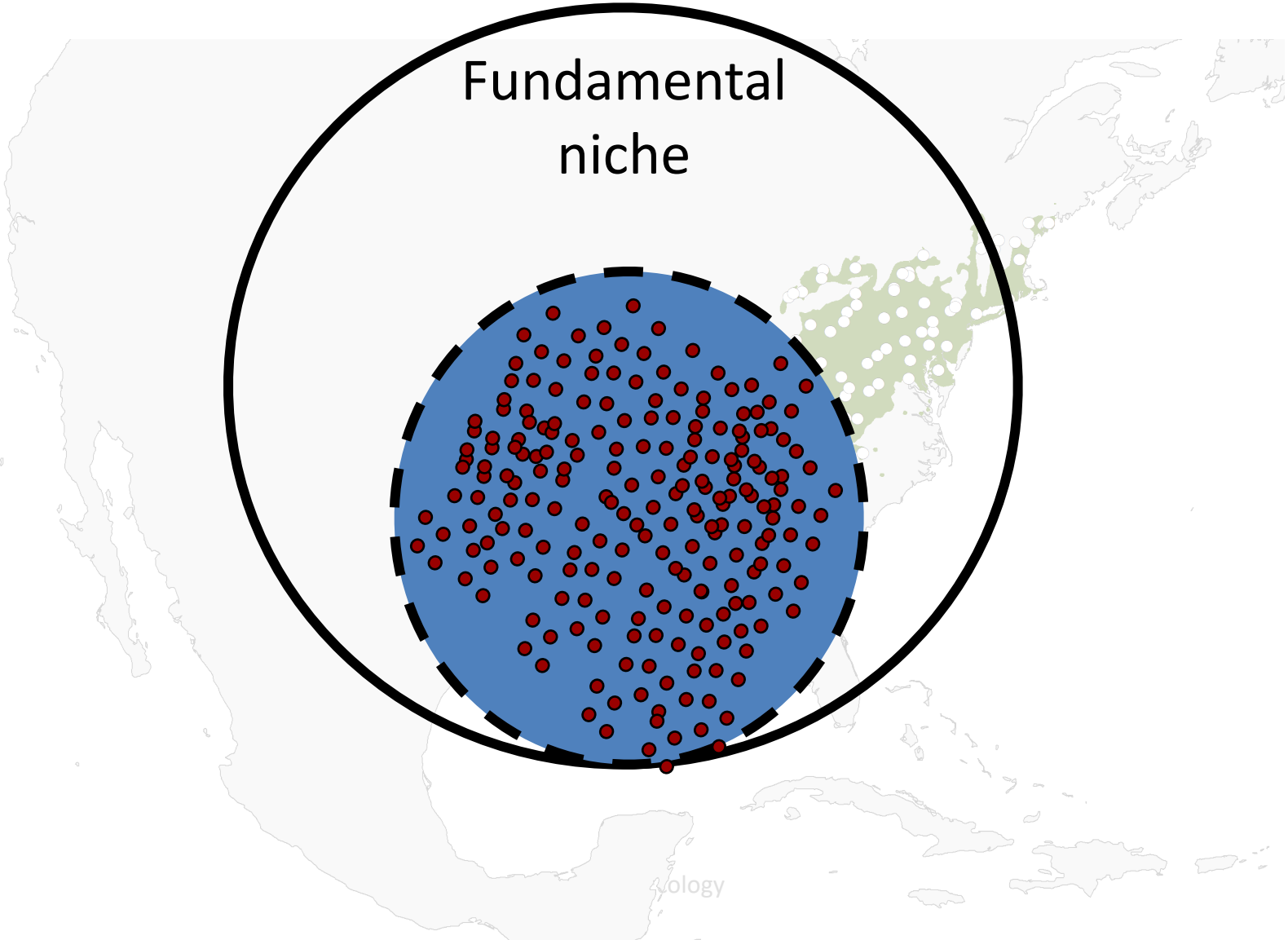
Biotic interactions & land use…



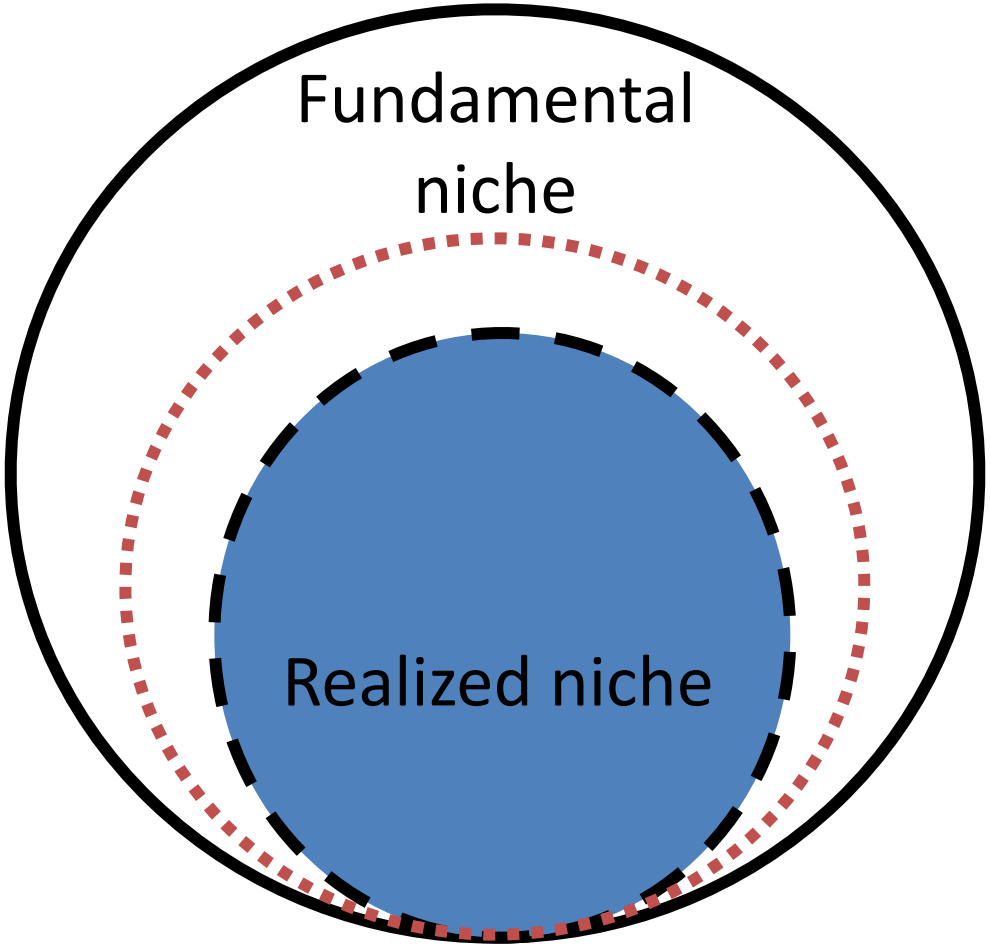
The fundamental niche cannot be sampled!



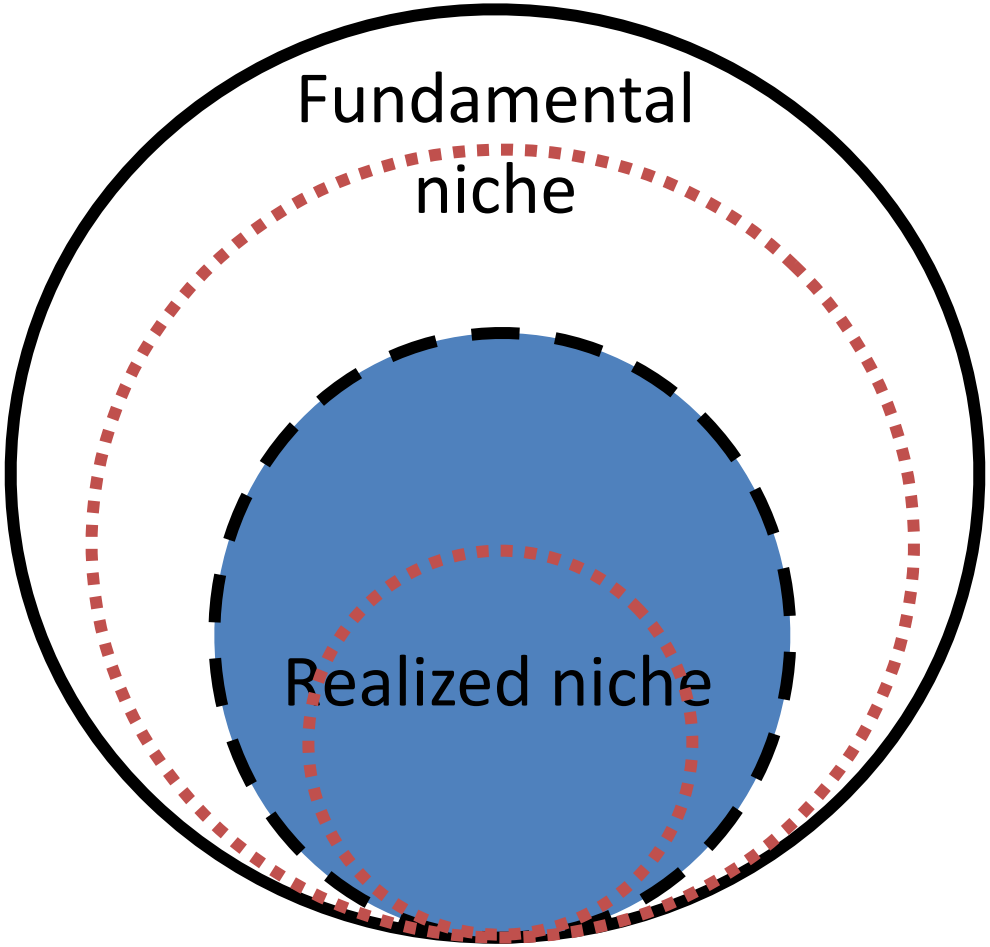
Distribution represents a subset of conditions the species can tolerate…



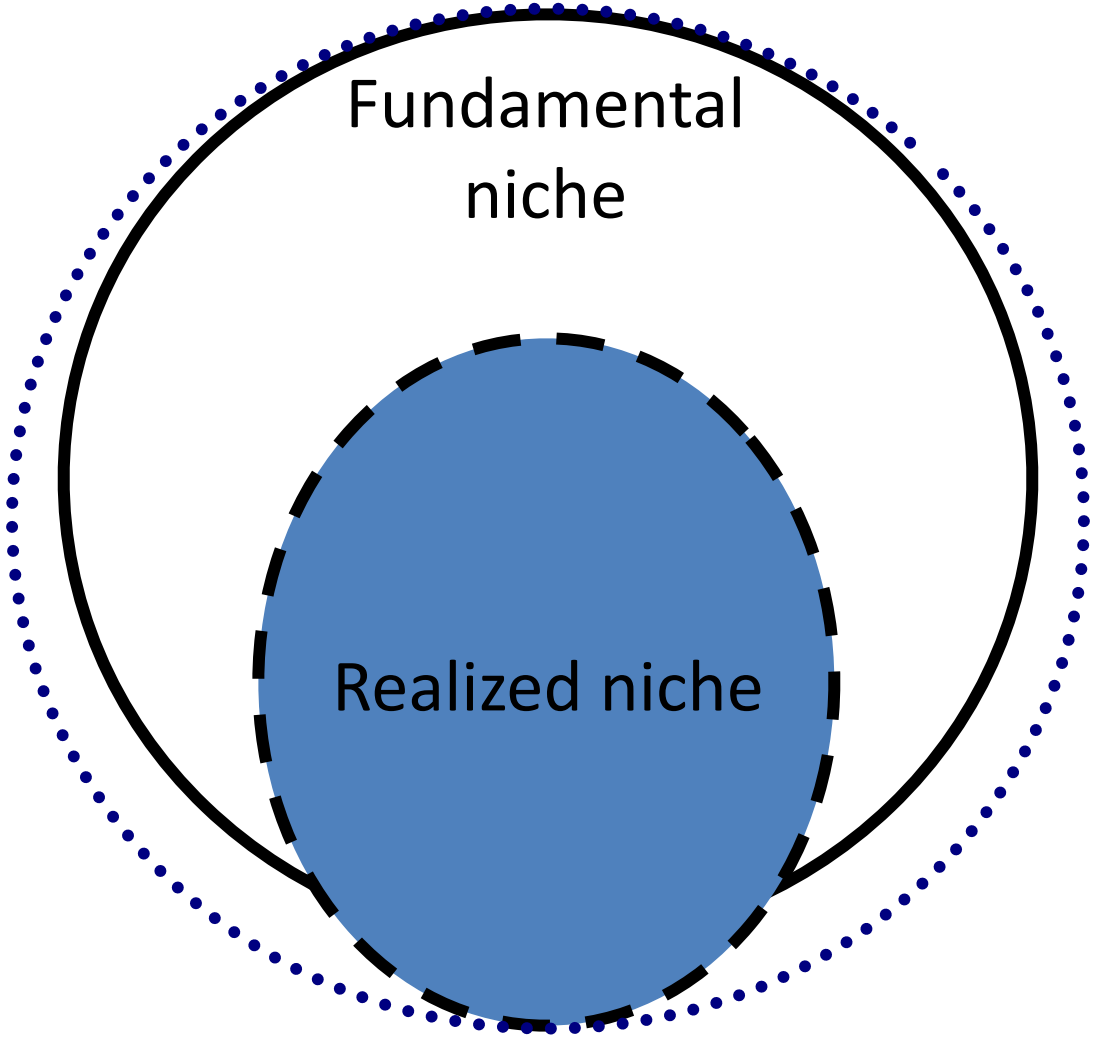
Environmental change can alter species interactions



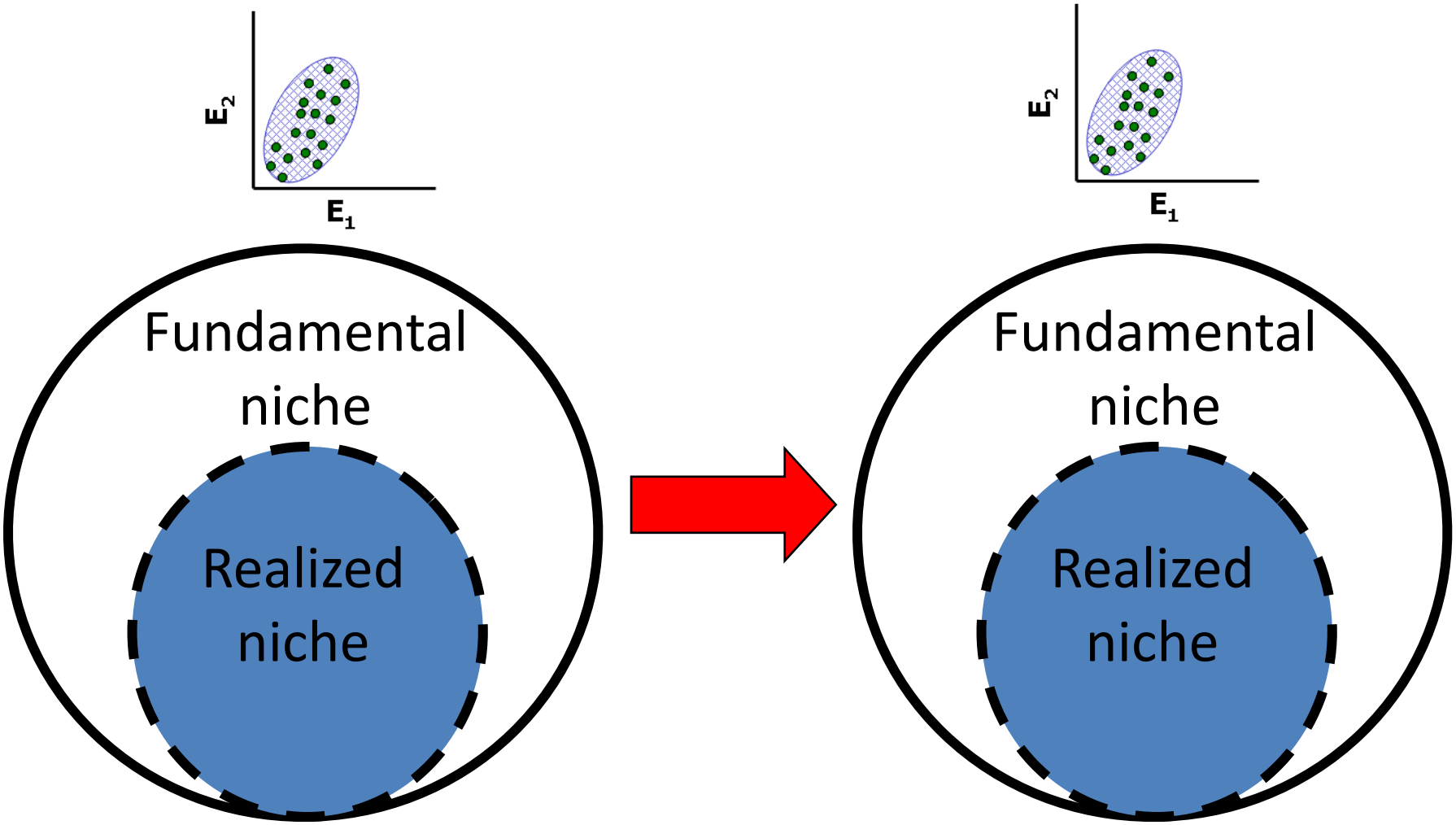
Dispersal can influence fundamental/realized niche relationships



Adaptation can alter the fundamental niche



Key assumption: 'Niche conservatism'



Present Range

Past/Future Range

Key Assumptions: Theoretical

- Species is in pseudo-equilibrium with its environment
- Species-environment relationships are stable through time (niche conservatism)
- Important abiotic constraints are included in the model at the correct scale
- Species occurrence records correctly capture habitat requirements (e.g., source / sinks)

Key Assumptions: Methodological

- Appropriate statistical method is used for model fitting
- Predictors are measure without error
- Species data are unbiased and independent (spatial autocorrelation)