Intro to Spatial Ecology

Fall 2022

Lotka Volterra Equations

Prey

$$dN/dt = rN - aPN$$

Predator

$$dP/dt = faP - qP$$

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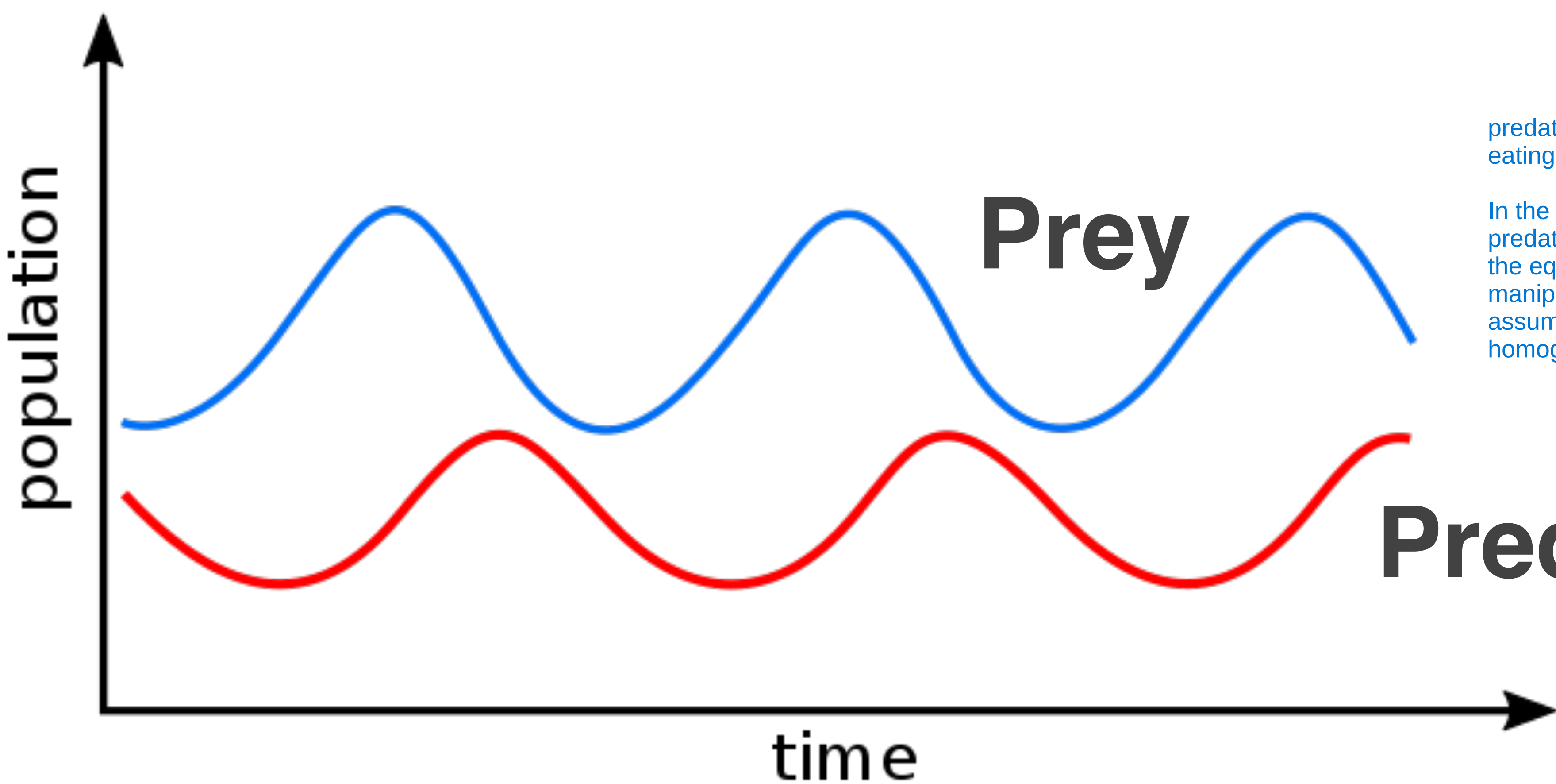
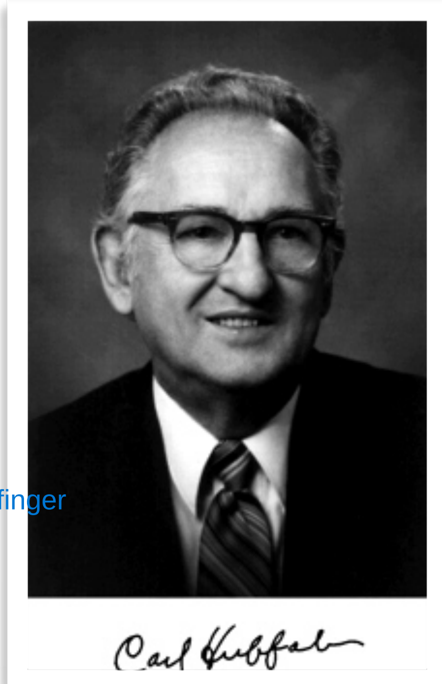
Predator $$dP/dt = faP - qP$$



predator lags the prey because they are eating the prey

In the wild, it's difficult to cause predator-prey dynamics to go extinct but in the equation they go extinct with manipulation easily. This is because the assumption is that there is spatial homogeneity. Actualy the spatial



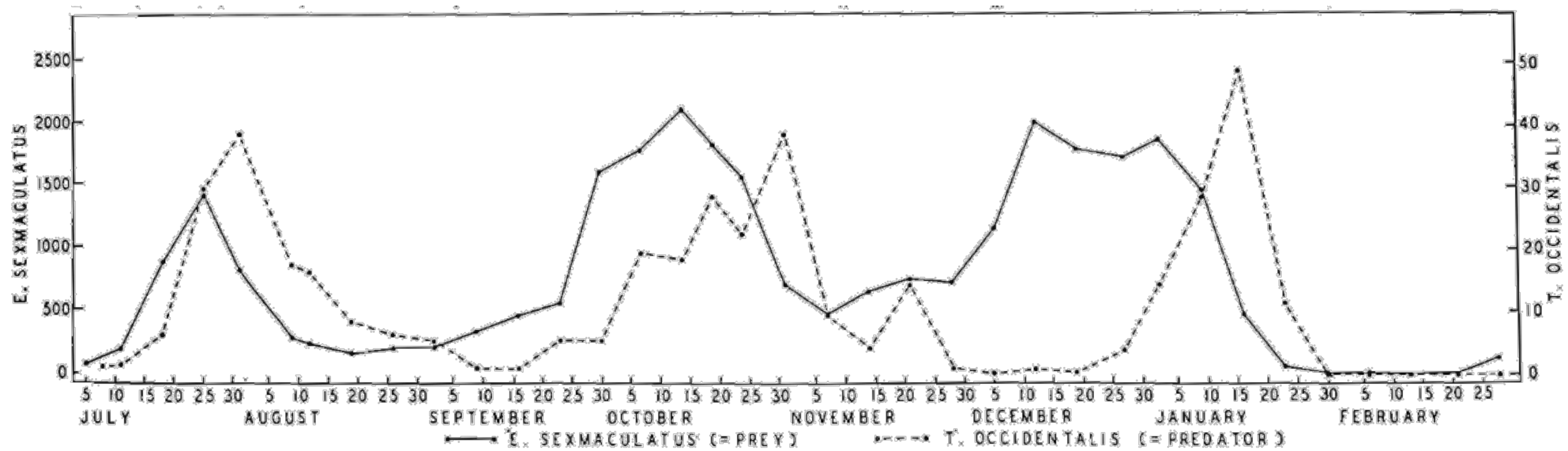
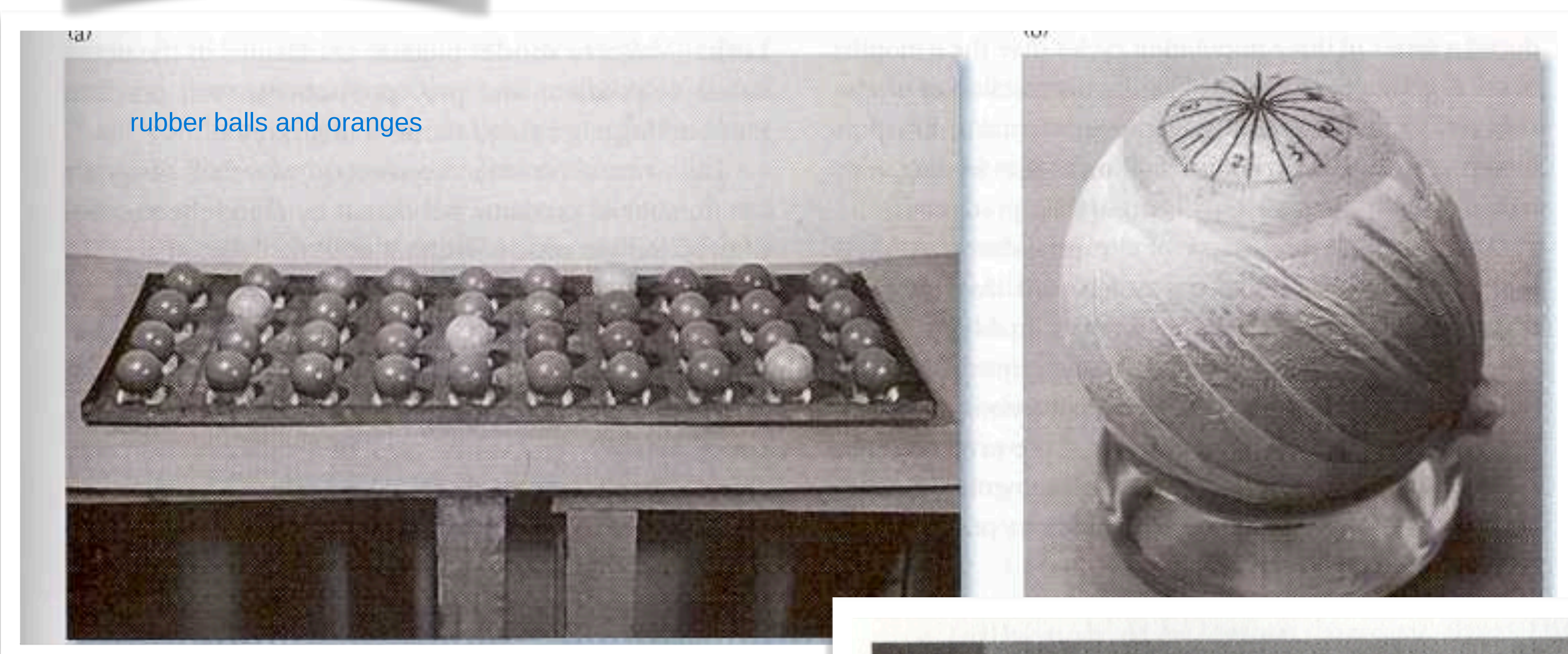


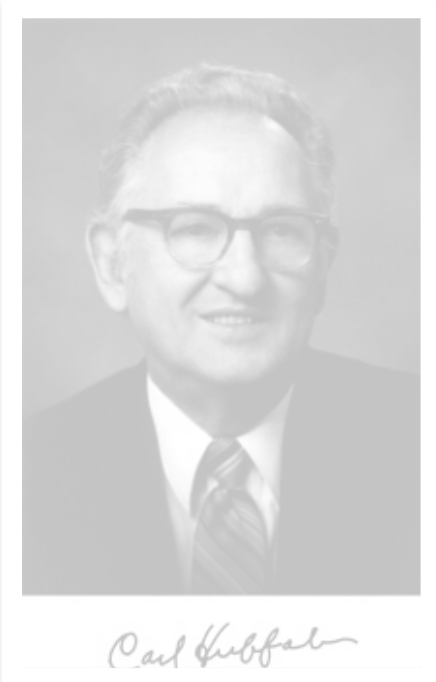
Fig. 18. Three oscillations in density of a predator-prey relation in which the predatory mite, *Typhlodromus occidentalis*, preyed upon the orange feeding six-spotted mite, *Eotetranychus sexmaculatus*.

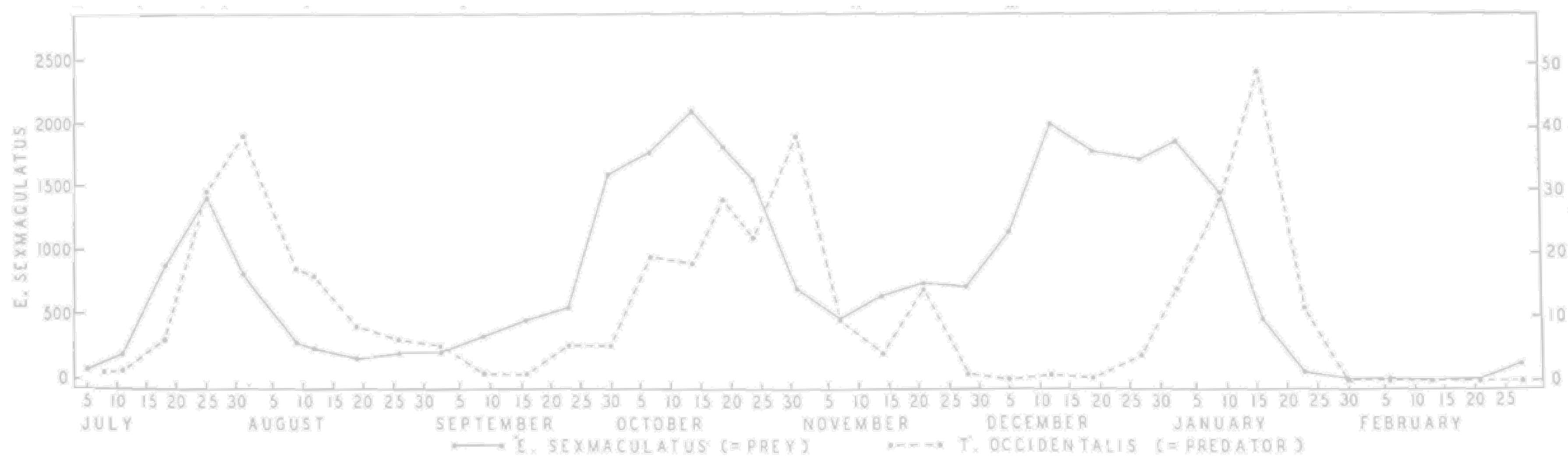


predatory mite feeds on the mite that eats the oranges. Carl changed the orange surfaces (habitats) to introduce spatial heterogeneity. Allowed the surfaces to vary and saw mites move based on it.

Space matters

heterogeneity, movement / dispersal





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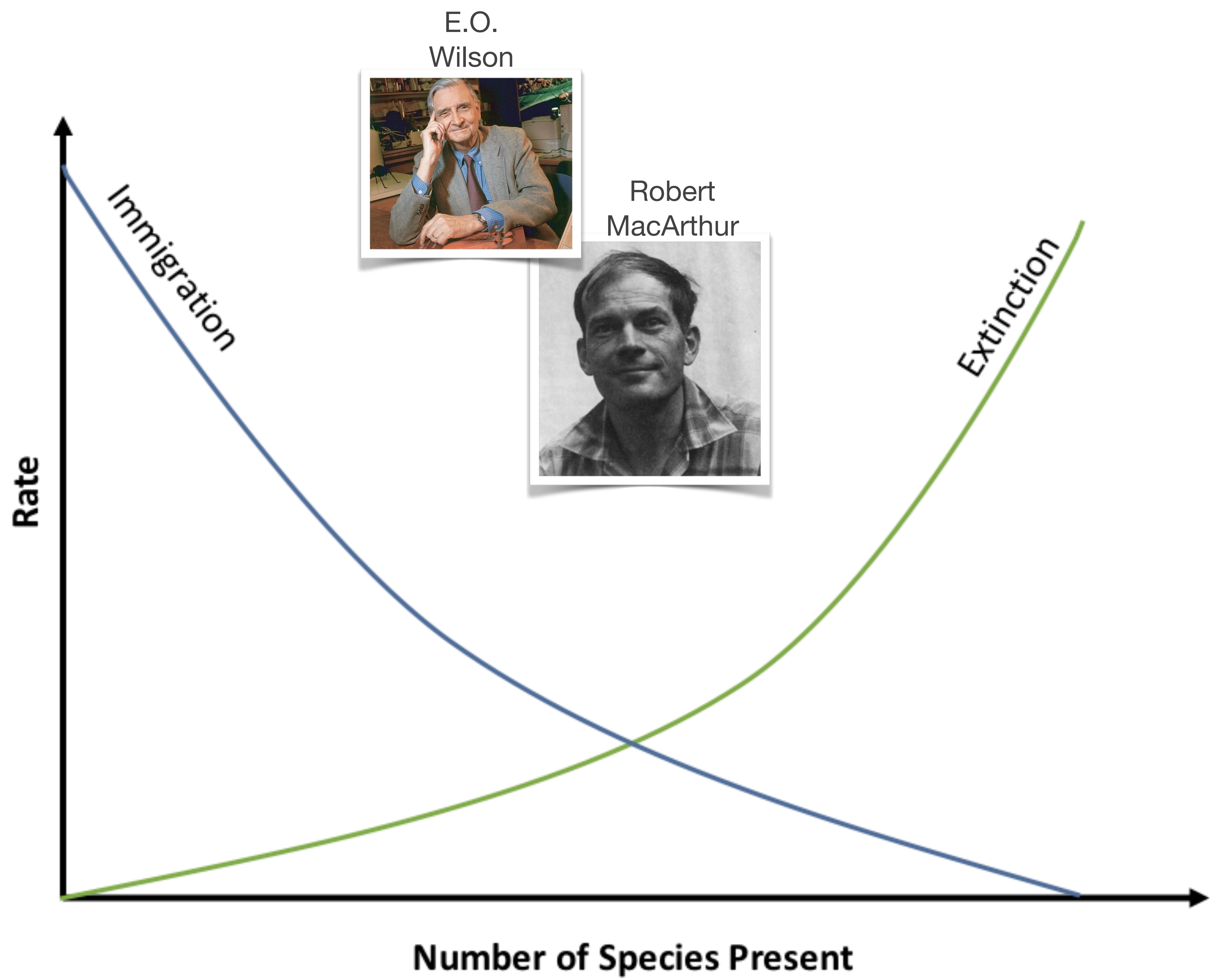
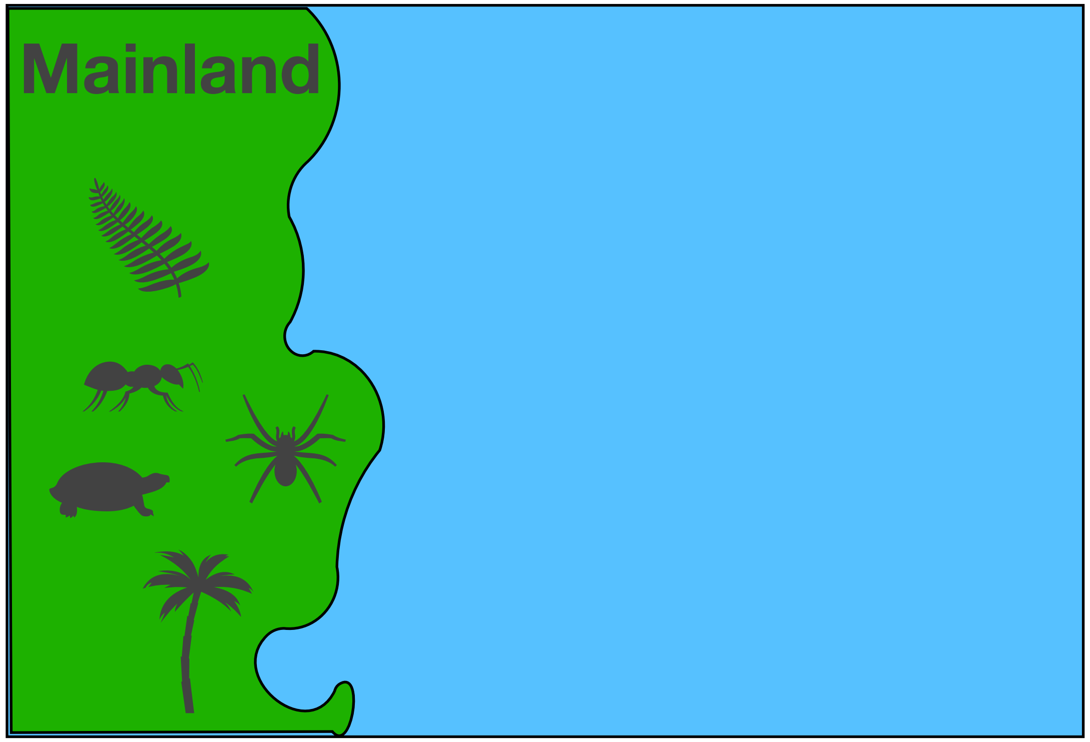
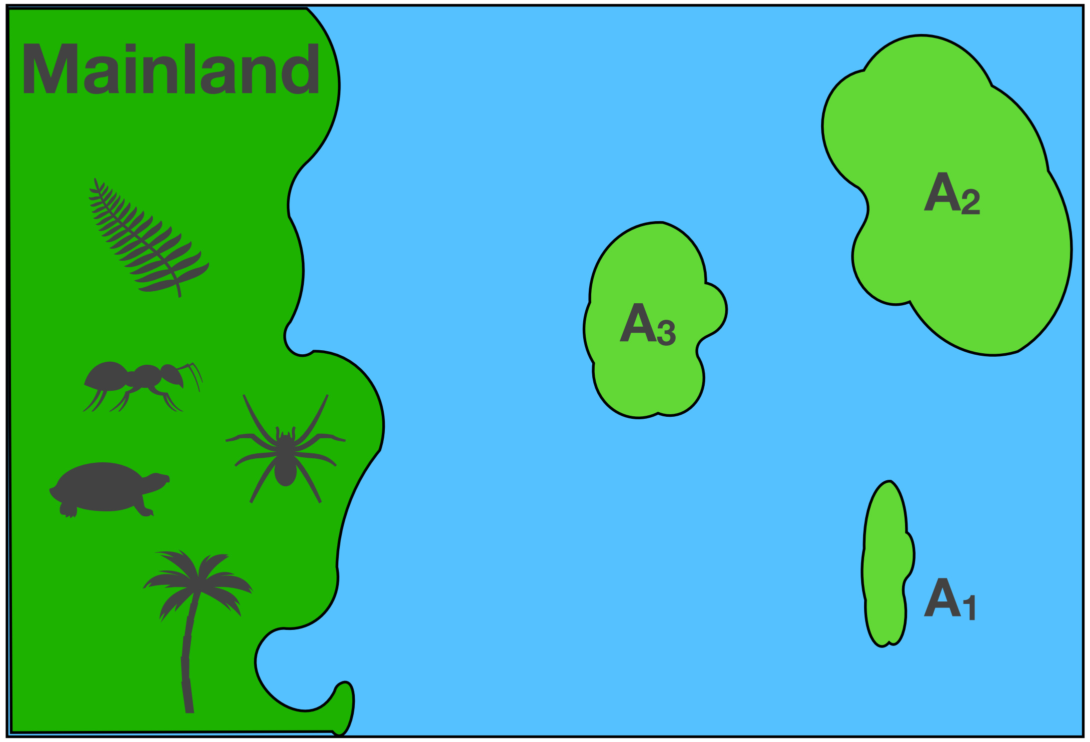
Theory of Island biogeography says there is a mainland with species on it and islands off the shore.



Theory of island biogeography

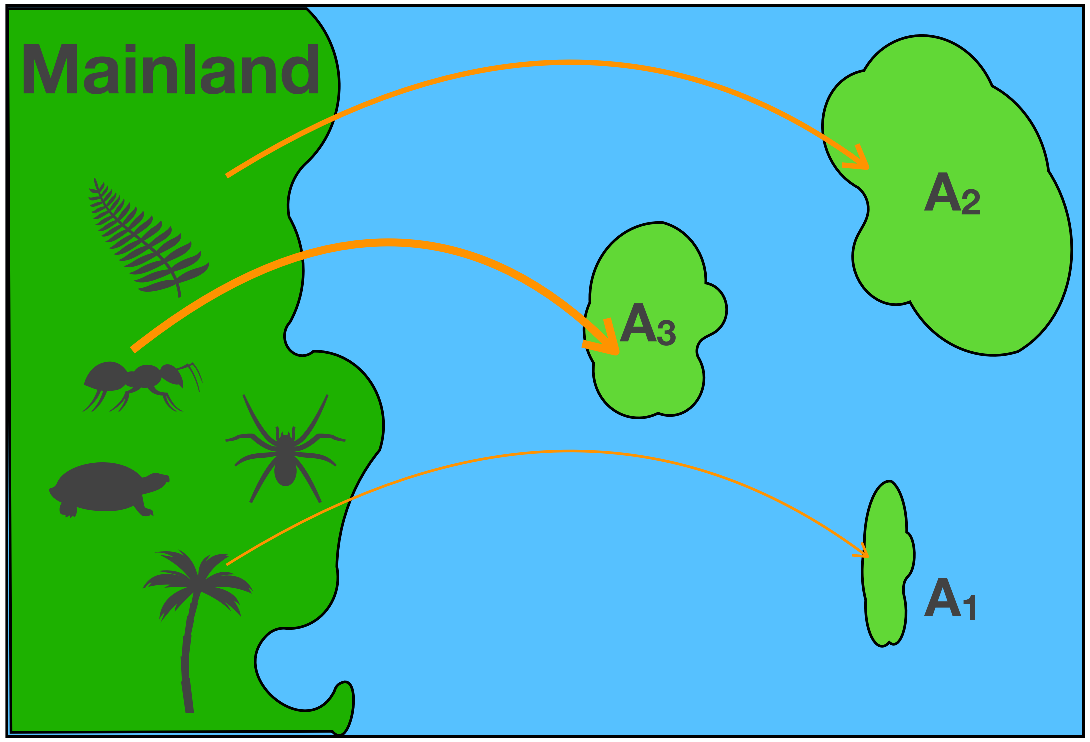


Theory of island biogeography

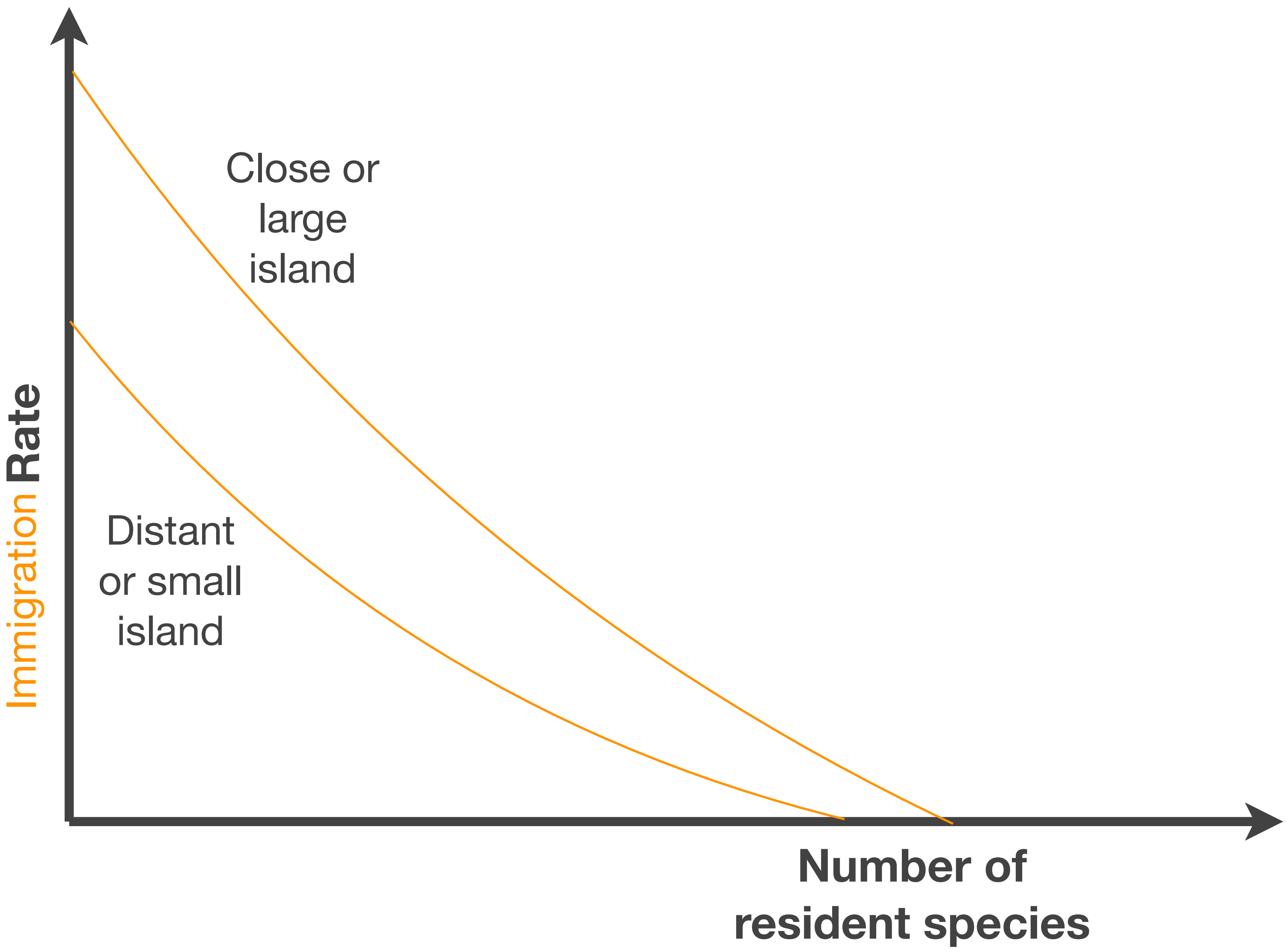


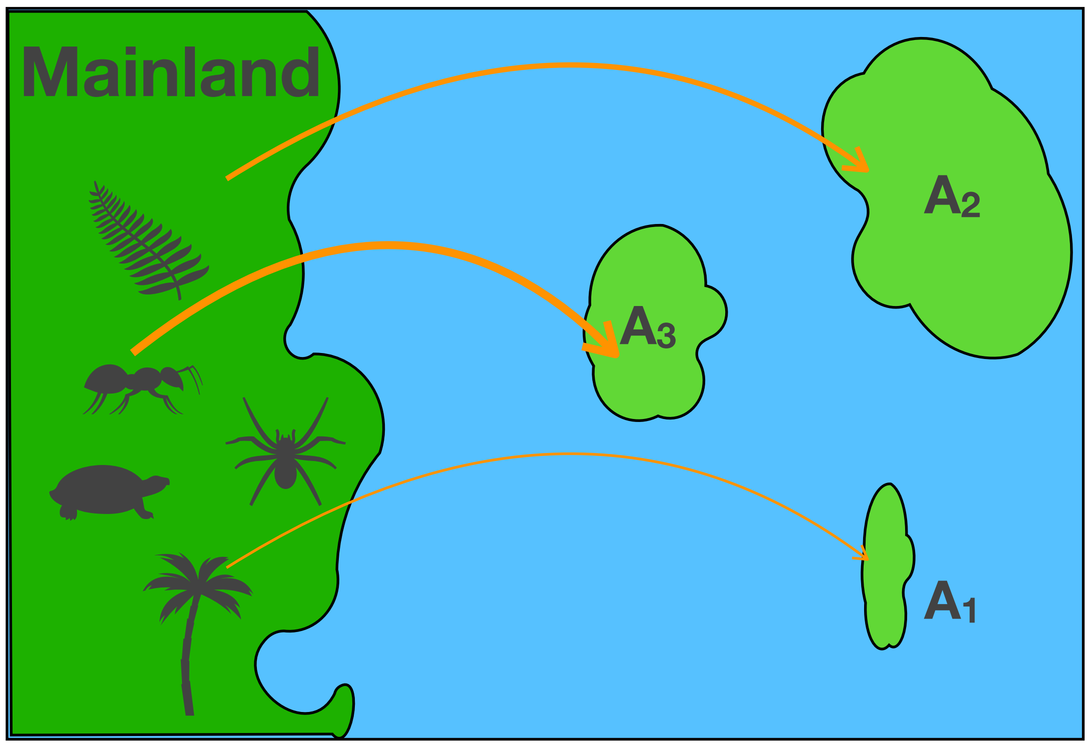
Theory of island biogeography

we expect closer islands to have more individuals due to emigration from mainland to immigration in the islands



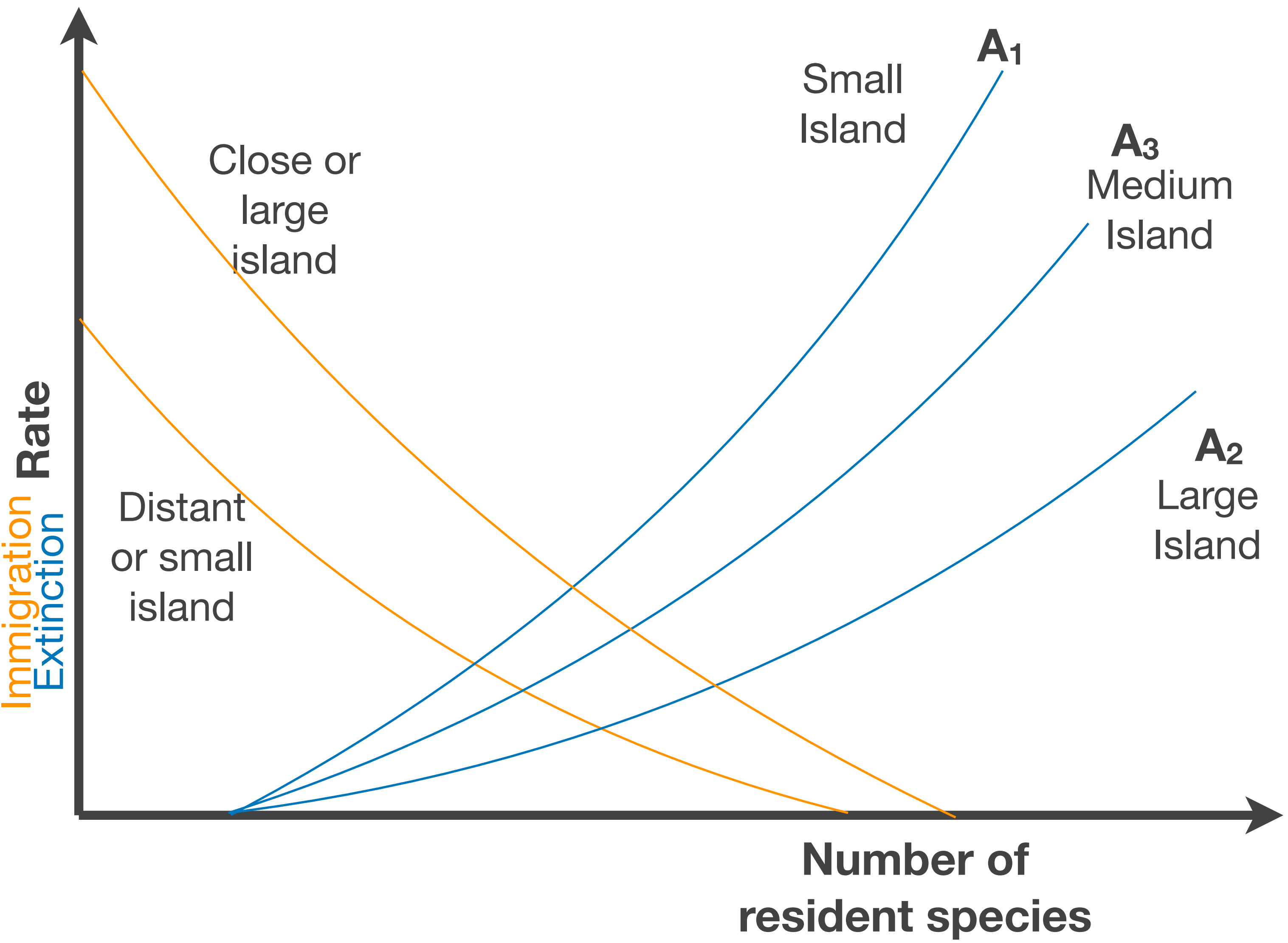
Theory of island biogeography

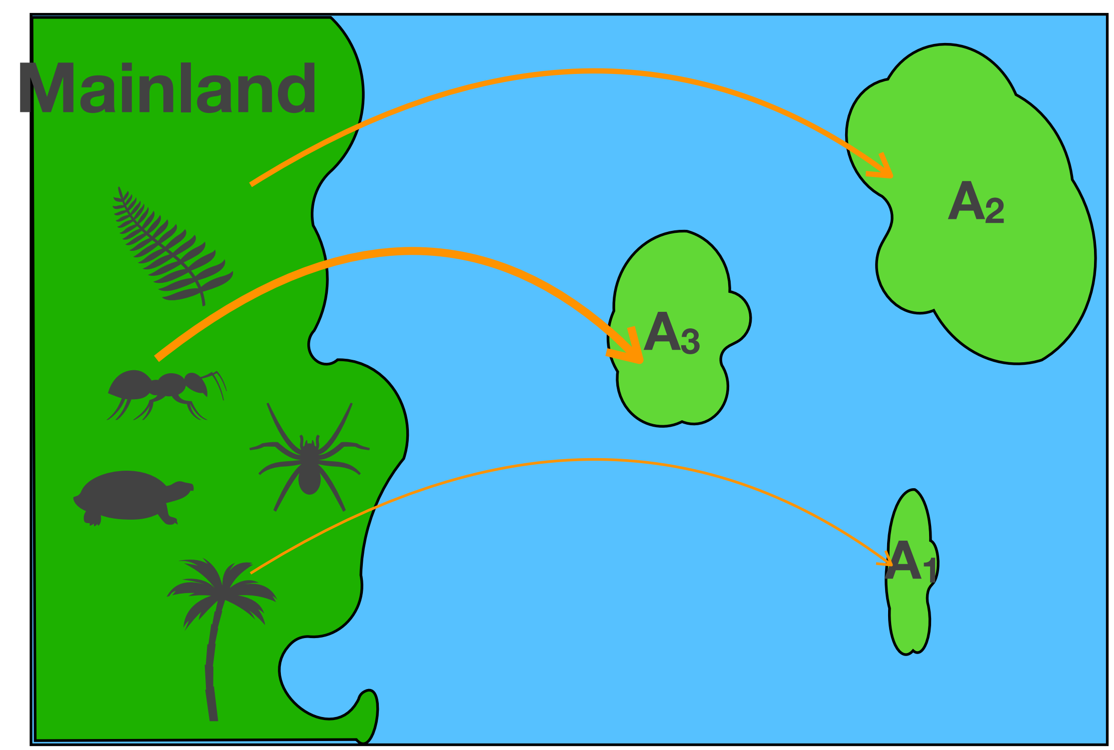




how far away you are and how large you are determines the number of individuals

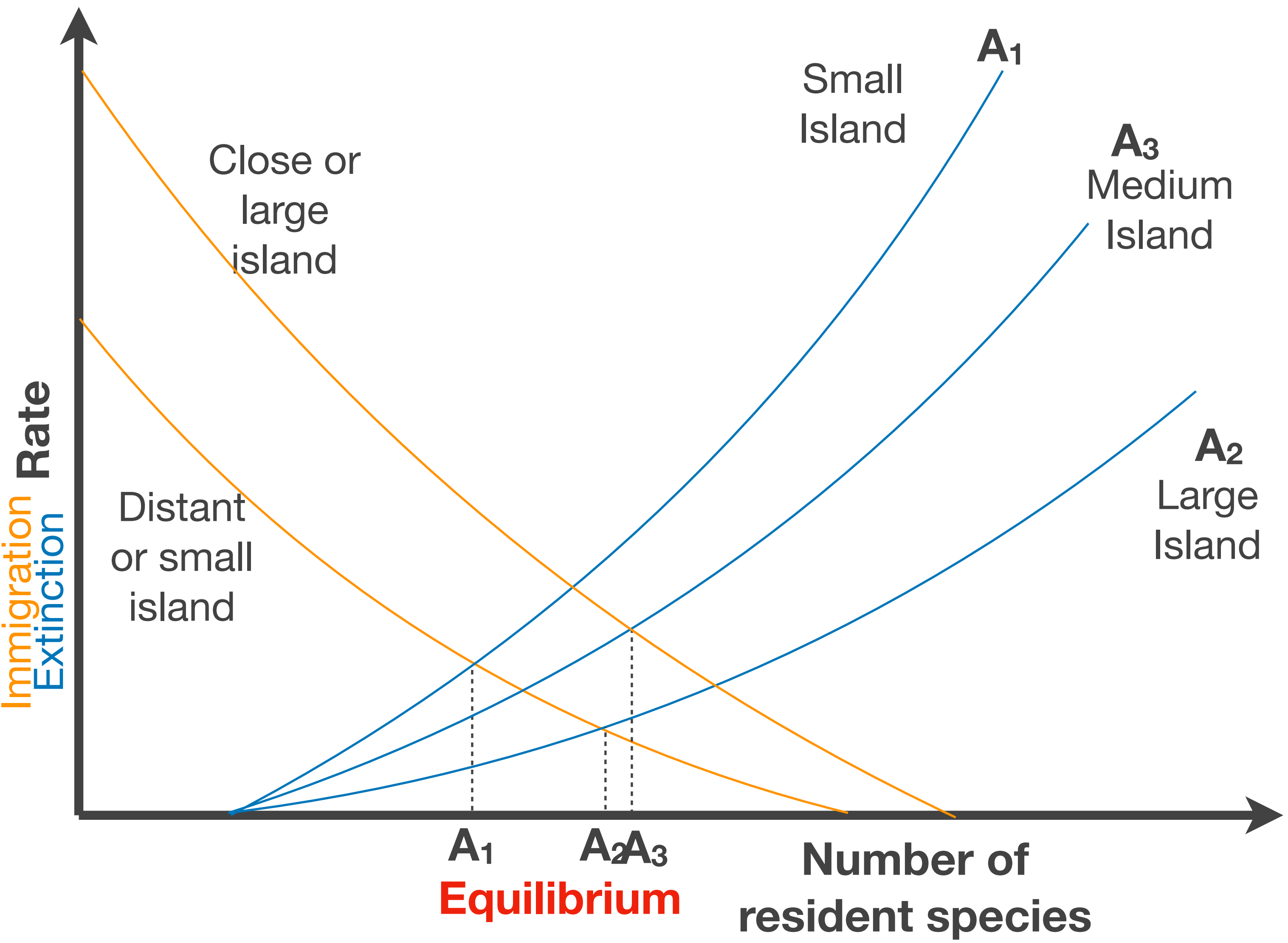
Theory of island biogeography

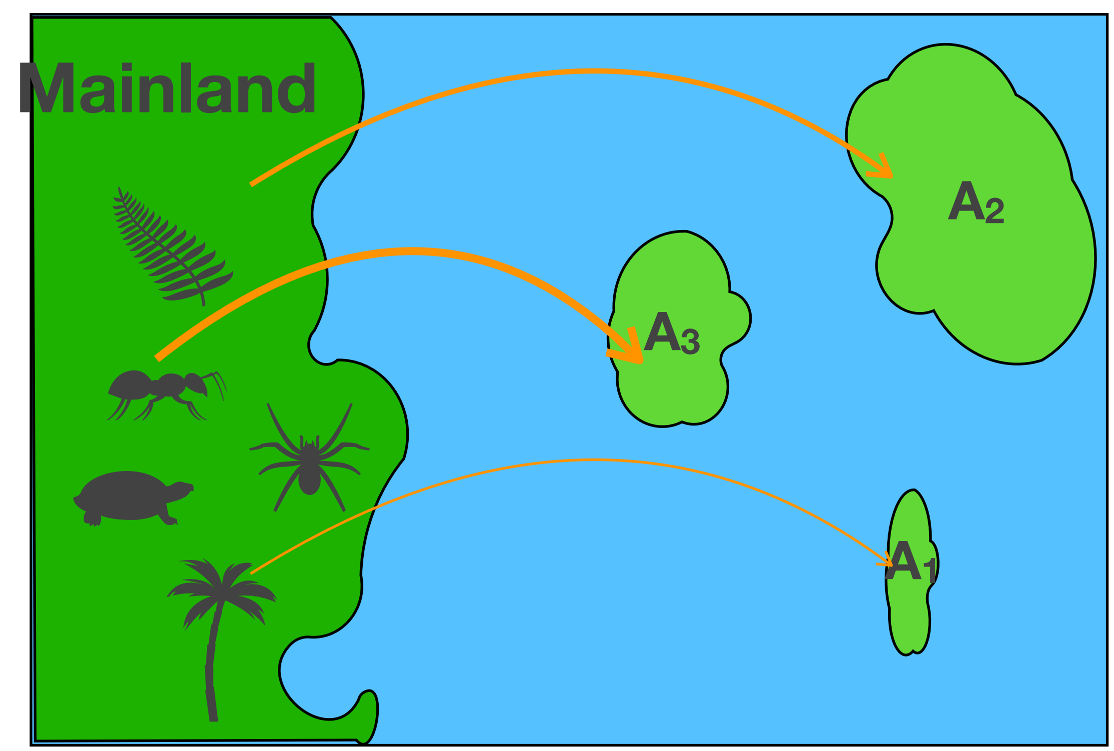




extinction high on small islands because stochastic events have more effect as a function of a small number of resident species.

Theory of island biogeography

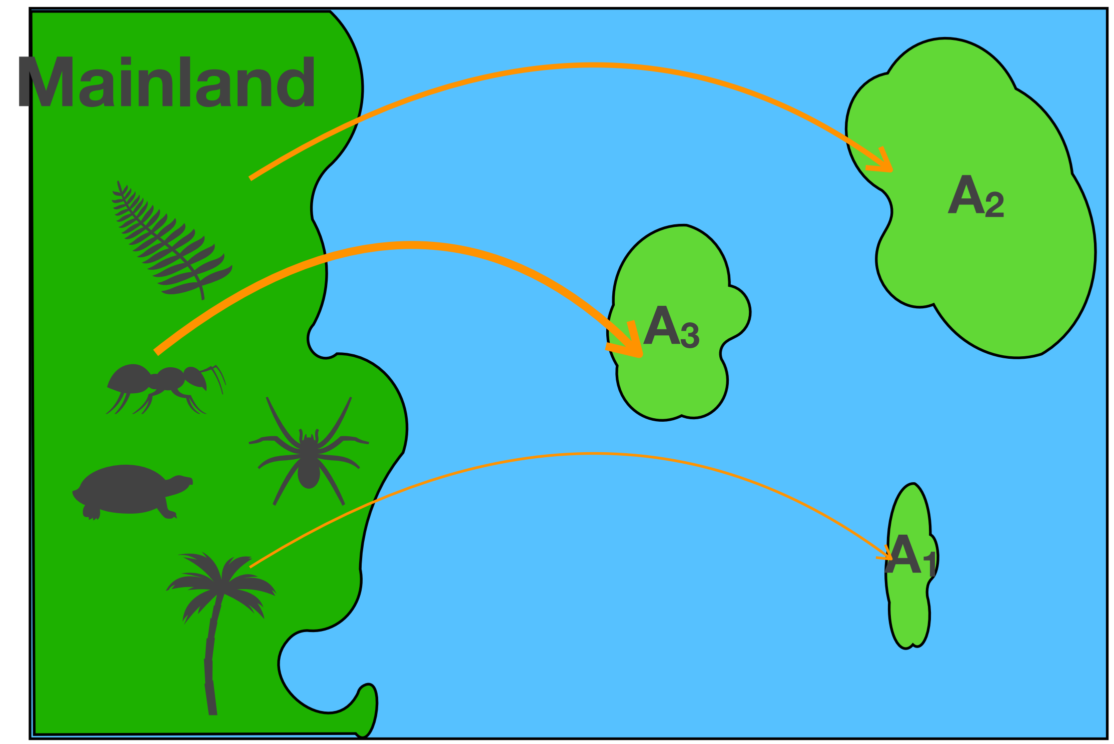




Equilibrium when same number emigrants and immigrants

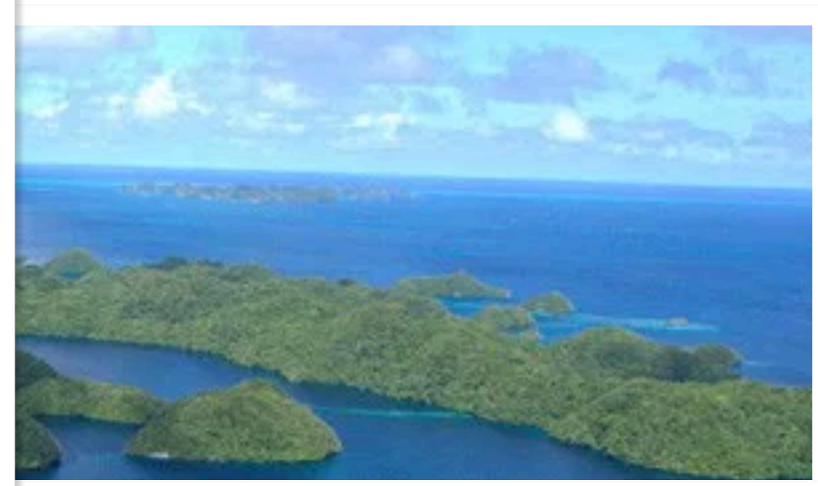
Theory of island biogeography

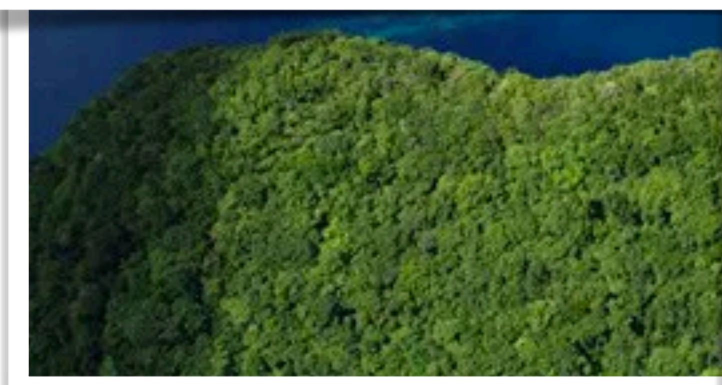
- General theory to predict the number of species expected on oceanic islands
    - Large island should have more species than small islands
    - Species numbers decline with increasing remoteness from the mainland
- Greatly influenced how ecologists think about organisms and spatial patterns

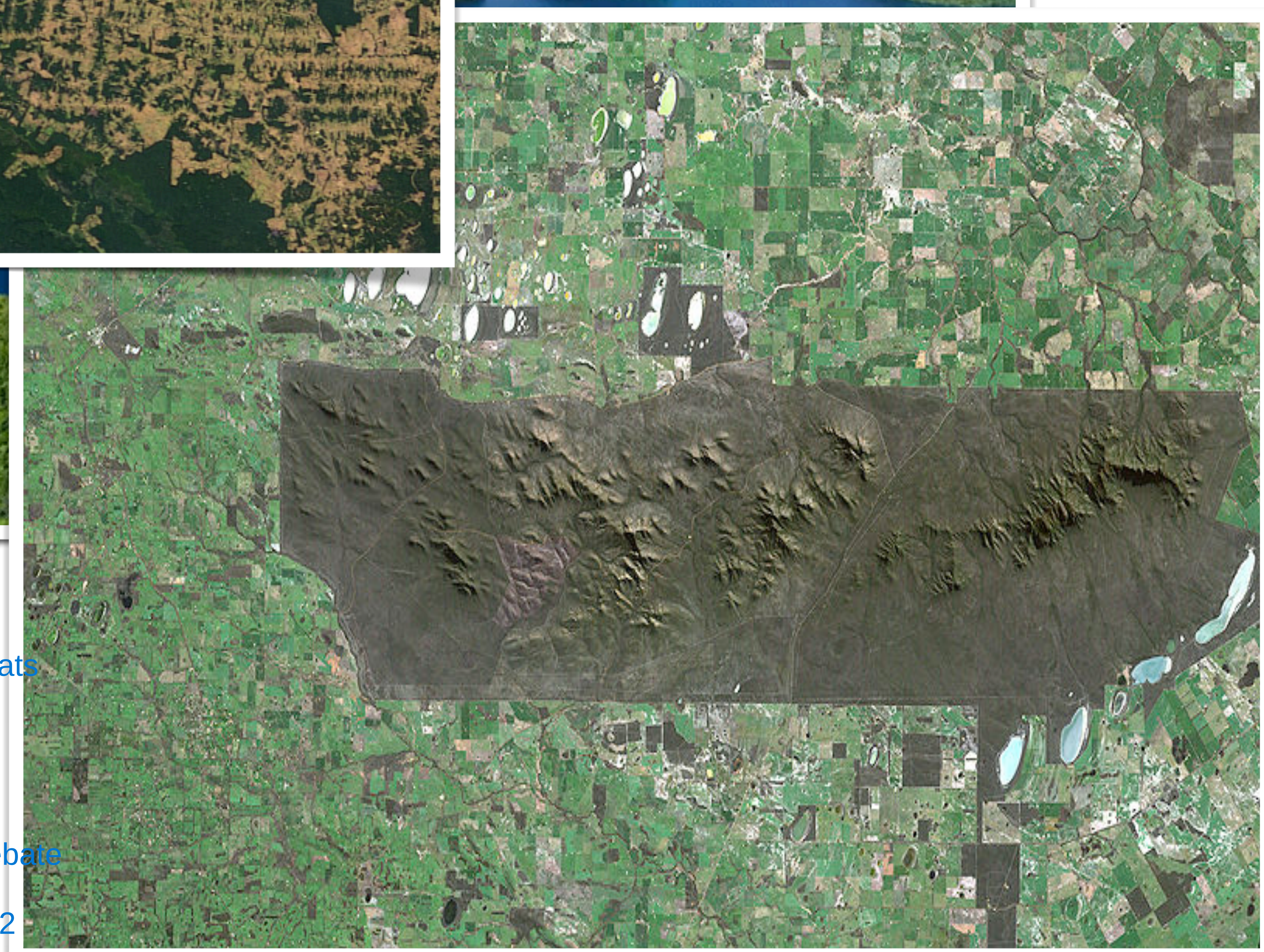


assumption: habitat in between islands is inhospitable

space, configuration, movement are all important





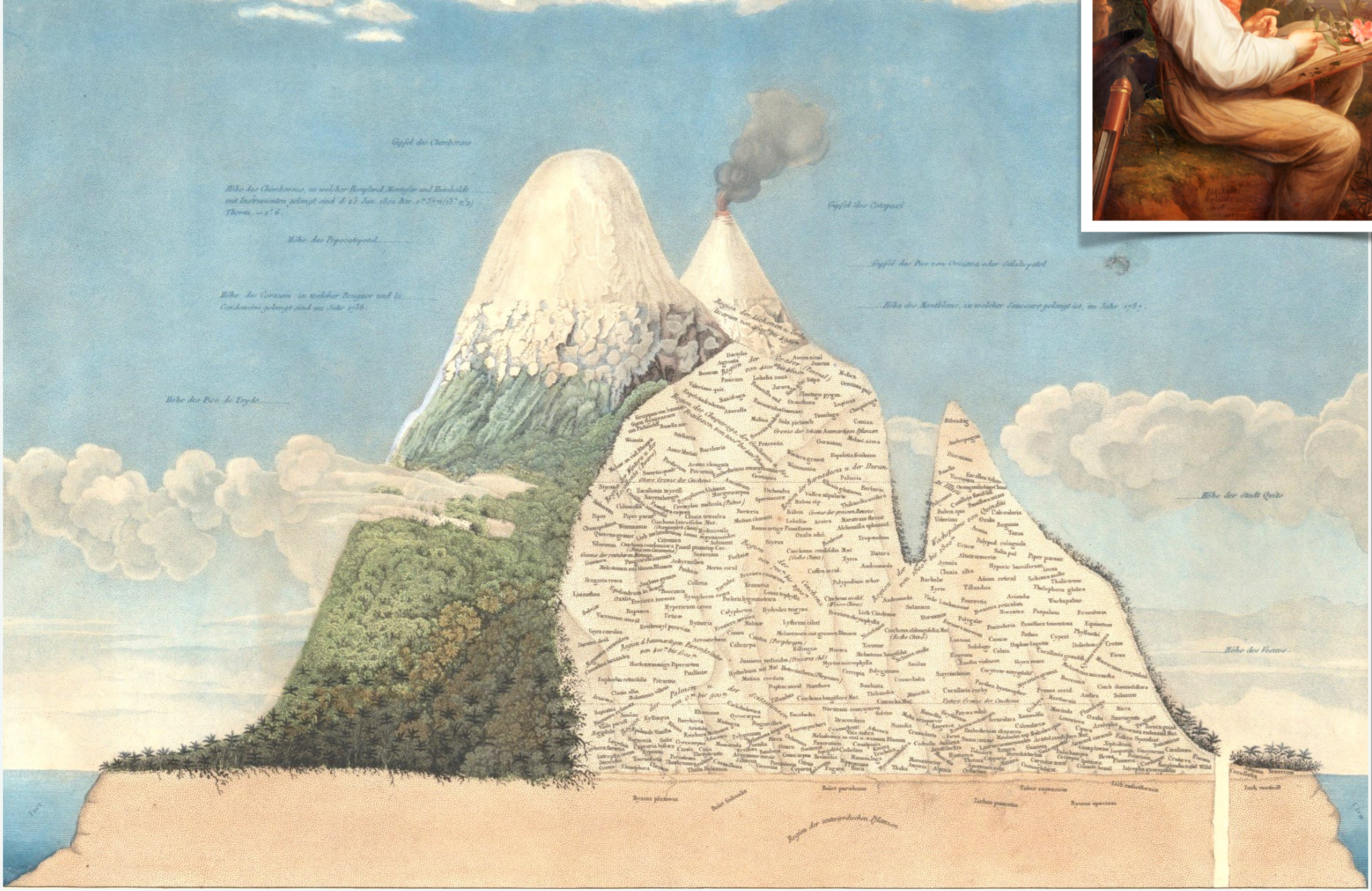


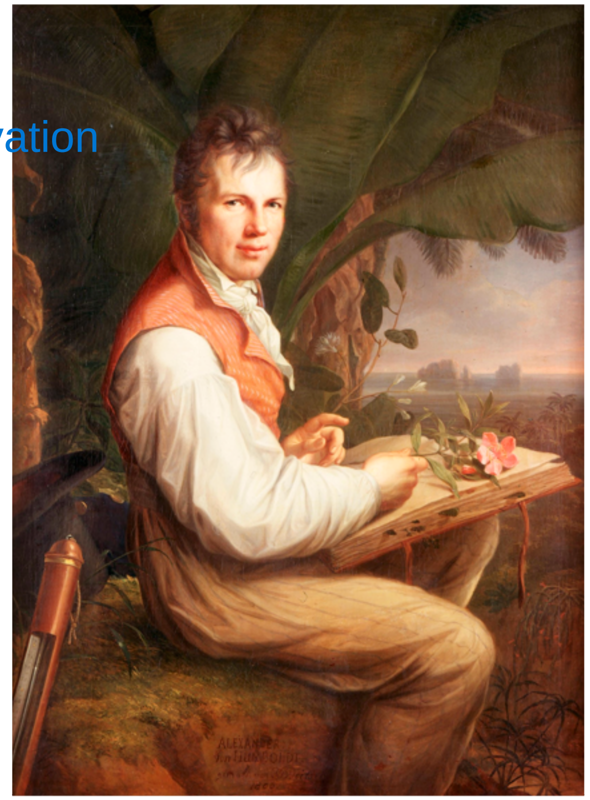
application to real life: we are
losing species due to chopping up habitats
(ie. deforestation, agriculture, trapping
of endemic species in small areas

SLOSS debate:
Single large or several small reserve debate
which one is better?
Article: https://doi.org/10.1111/brv.12792

Precursors

Alexander Von Humbult was a German Scientist that noticed species vegetation changes as elevation changed over the course of a mountain.

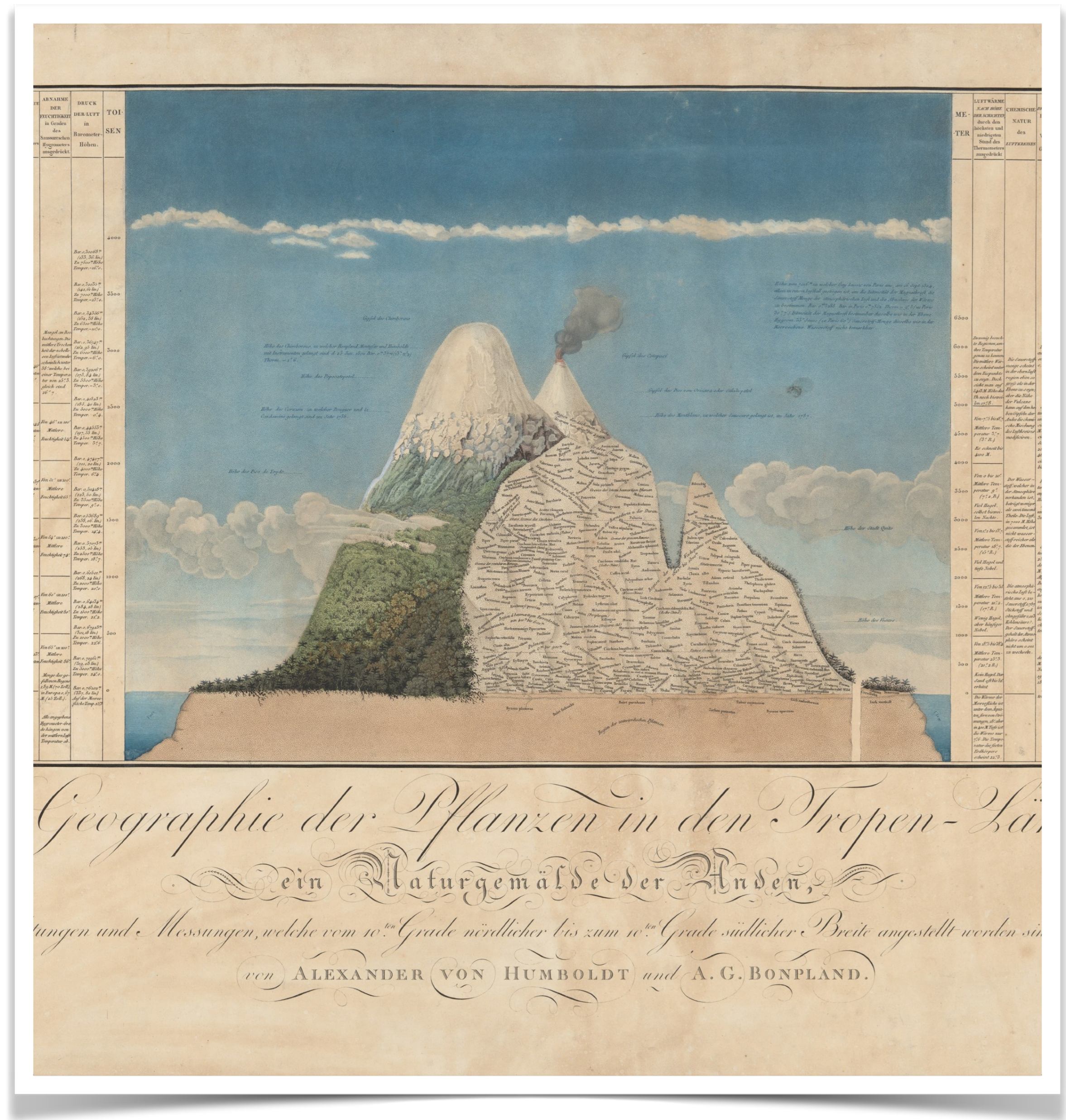




Focus on vegetation

- Well established that ecological systems interacted with spatially distributed environmental factors to form distinct spatial patterns
    - Vegetation types change with elevation / latitude / other env. gradients
    - North vs. south facing slopes

difference in rainfall leads to differences in species



Precursors in the U.S.

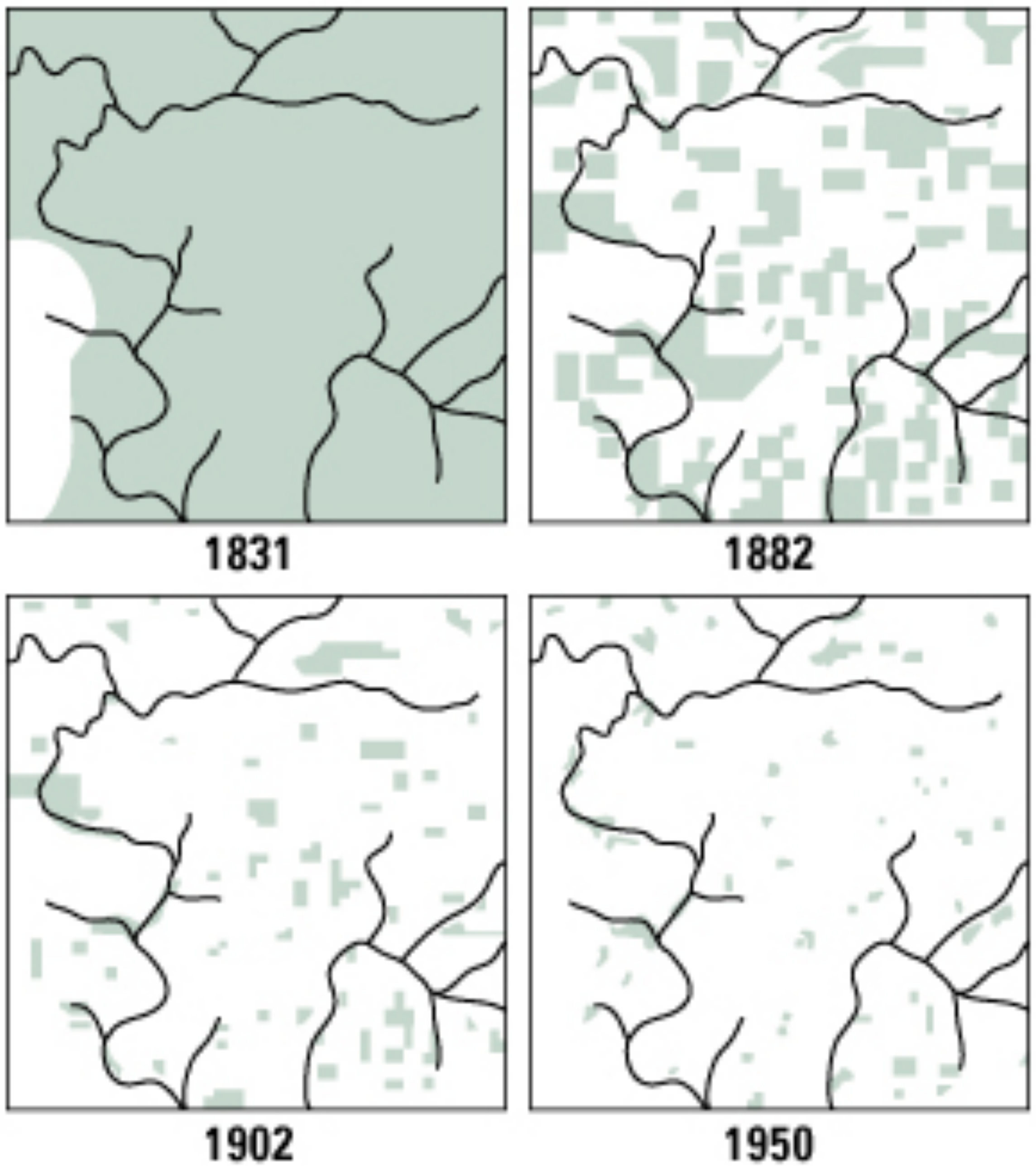


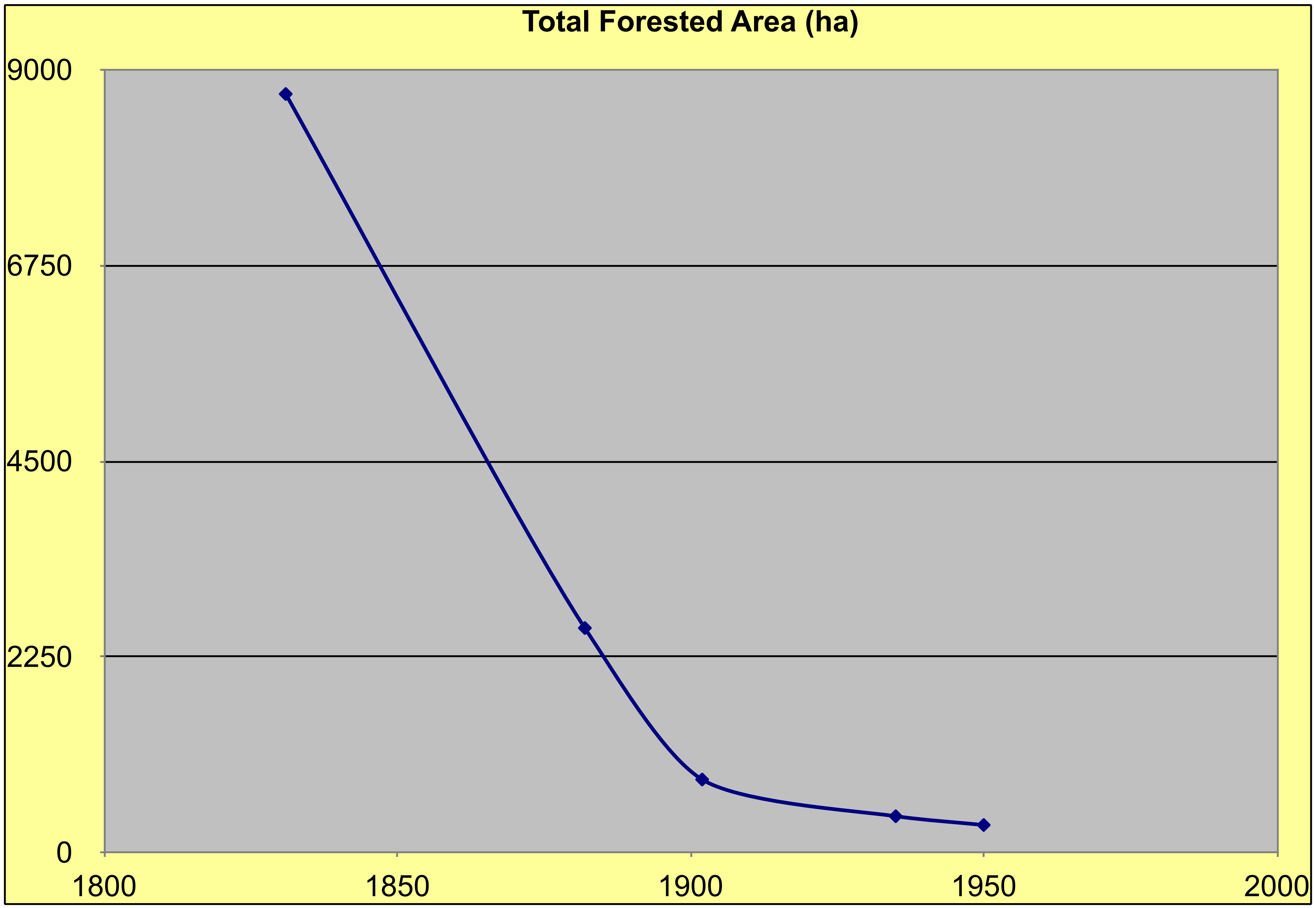
Fig. 1-1. Changes in wooded area of Cadiz Township, Green County, Wisconsin, during the period of European settlement. The shaded areas represent the land remaining in, or reverting to, forest in 1882, 1902, and 1950. (From Curtis 1956, by permission of the University of Chicago Press.)

Land use change in Cadiz Township

Curtis (1956)

change from natural forest habitat to predominantly agriculture with few forested areas

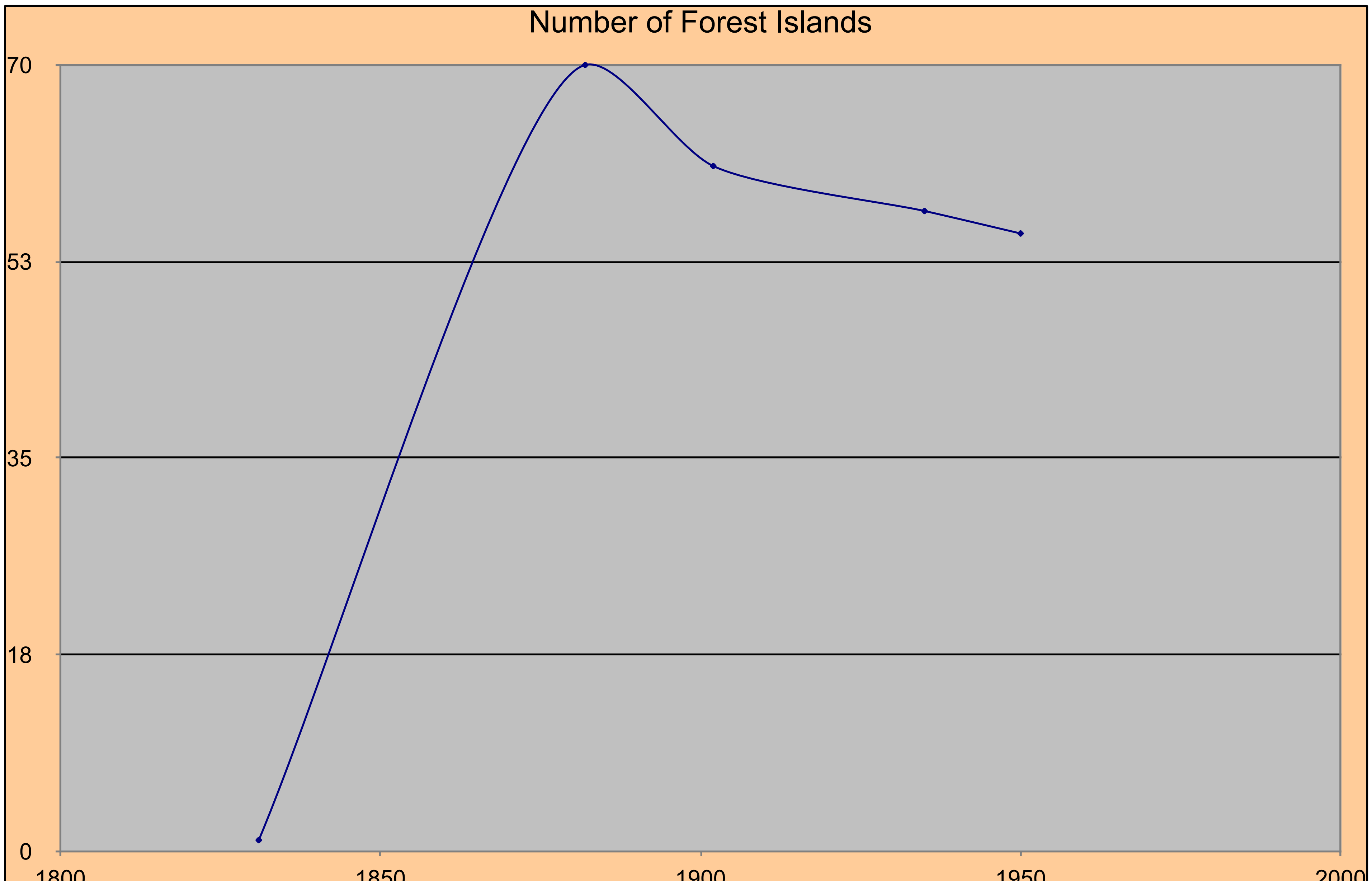
Cadiz Township - Revisited



Forest Island Dynamics in Man-Dominated Landscape

Burgess & Sharpe (1981)

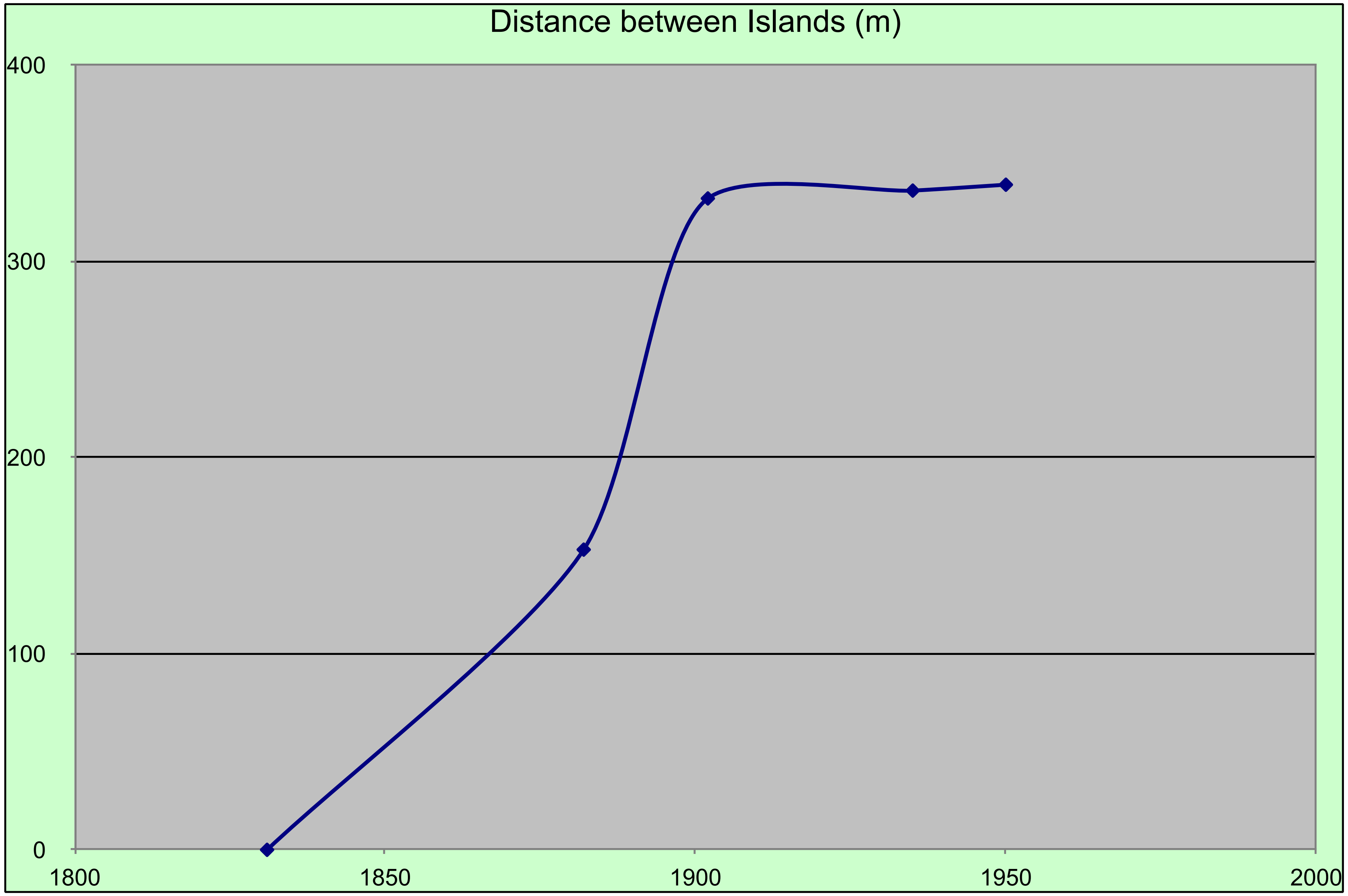
Cadiz Township - Revisited



number of forest islands increase due to fragmentation of the original forest until decreases as forest islands die off

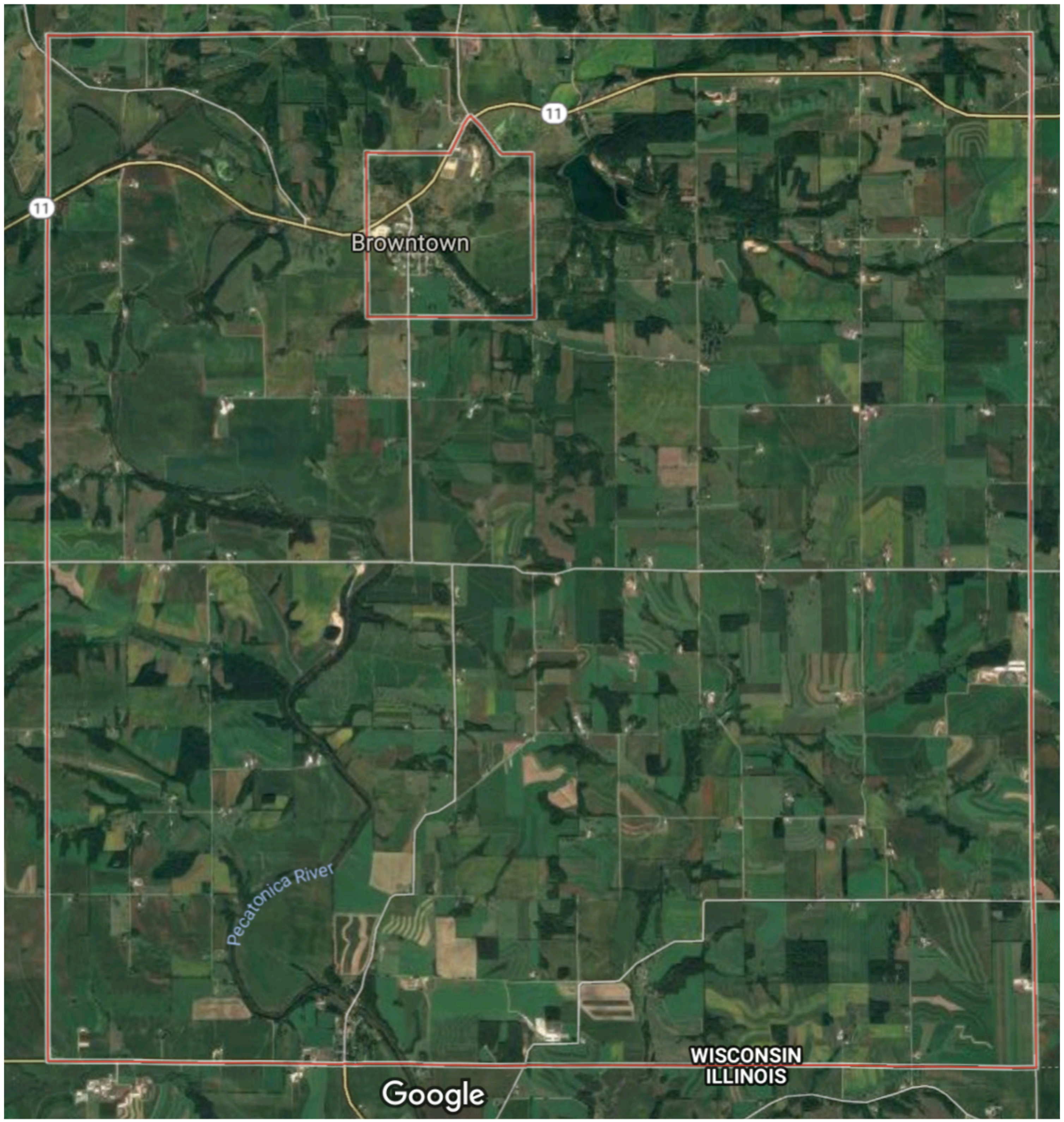
Burgess & Sharpe (1981)

Cadiz Township - Revisited

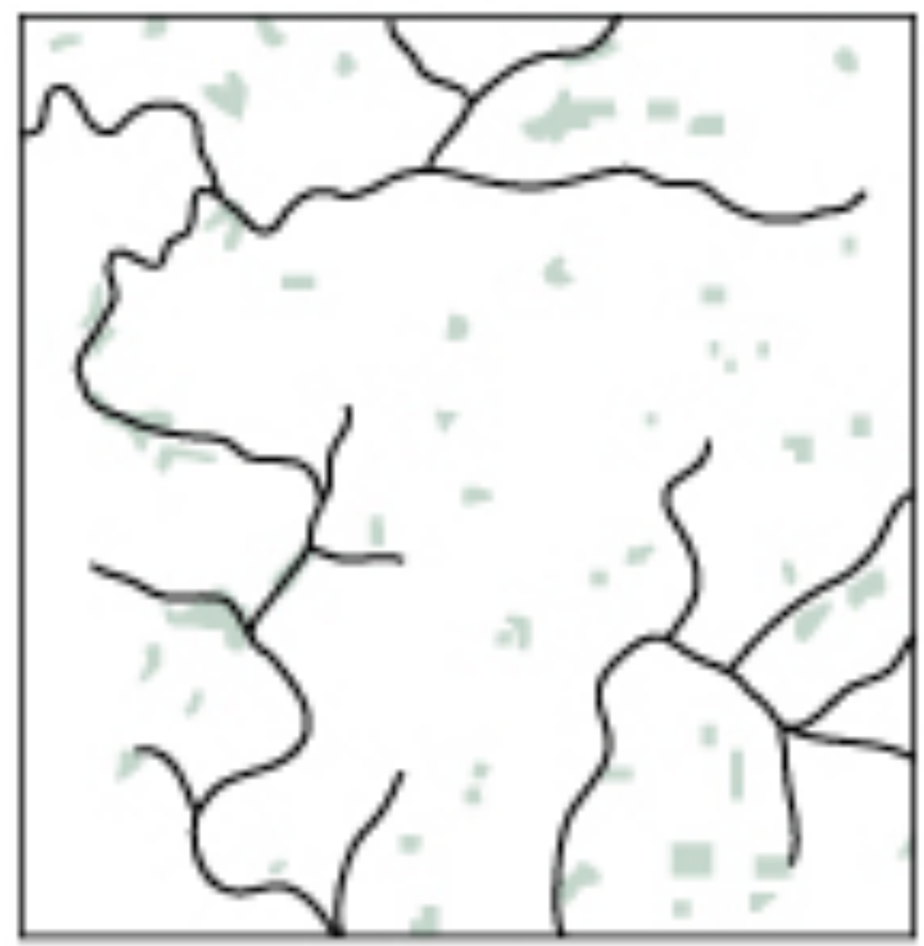


Burgess & Sharpe (1981)

Cadiz township today



viewing the world in high resolution space shows it's not as simple as a binary (1: habitat, 0: not habitat). There is a lot of ecology that was glossed over.



1950

led to different metrics such as examining edges, volume, etc.

Changing Views

Paradigm shifts:

- from the “equilibrium” view of ecosystems to a “dynamic” view (e.g., where disturbance is part of the natural process)
- from viewpoint of “closed” to “open” systems
  - cannot be understood without consideration of energy & material flows across ecosystem boundaries
- from “natural” to “human-dominated” conditions
- The overriding importance of scale (scale dependent vs. independent phenomena)

Advent of New Technologies

- Remote sensing and images from space (observations)
  - visualization of change (awareness of extreme events, disturbance)
- Technology for display & interpretation
  - GIS, etc
  - NDVI, etc
- Computer memory and speed - facilitated simulation and synthesis of complex models & large datasets

Some key ideas

1. **Space matters**

    - Ecological process play out across space and through time

    - Environments are heterogeneous

    - How entities are arranged (proximity, arrangement, etc) influence ecological processes

    - Ecological process generate spatial patterns

Some key ideas

2. **Spatial patterns infer the existence of underlying processes**

   - We can characterize spatial pattern, using appropriate statistics and/or identify scales at which key processes seem to be operating

   - Develop hypotheses on the nature of the underlying process producing the pattern

   - Use ecological theory to derive hypotheses about spatial patterns that can be tested using either (i) statistical analyses of *observations* from appropriate systems or (ii) *spatial simulation models*

Key ideas

3. **Importance of spatial _configuration_ (i.e., of habitat patches) for ecological process**

    - How much and how it is arranged (e.g., forest patches in an agricultural matrix)?

    - Patch arrangement (a landscape mosaic) affects ecological systems in ways that would be different if the mosaic composition or arrangement were different

    - Until the mid-1980s, most ecological theory / analyses / experiments avoided explicit consideration of space & had implicitly assumed an ability to average or extrapolate over spatially heterogeneous areas (e.g., Lotka-Volterra, Huffaker)

Key ideas

4. **Focus on spatial extents that are much larger than those traditionally studied in ecology**

    - Landscape / regional scale where human effects most evident & fine-grained ecological studies are insufficient

    - History, economics, ecological dynamics interact at broad spatial extents

        - Fragmentation of habitat, erosion, sedimentation, biogeochemical processes, cumulative effects (non-point source water and air pollution)

    - Scale is ultimately determined by ***spatial heterogeneity*** and the question (organism) of interest (and funding / data)

Key challenges

Requires quantification of many variables

Uniqueness of regions (N=1)

Pseudoreplication

Simultaneous (correlated) changes

Often beyond experimentation

These all can lead to low confidence levels associated with predictions