# Scale and Hierarchy Theory

## Scale

"The problem of pattern and scale is the central problem in ecology, unifying population biology and ecosystems science, and marrying basic and applied ecology. Applied challenges ... require the interfacing of phenomena that occur on very different scales of space, time, and ecological organization. Furthermore, there is no single natural scale at which ecological phenomena should be studied; systems generally show characteristic variability on a range of spatial, temporal, and organizational scales."

Simon Levin 1992

## Theories of Scale

Value of Scale Theories:

Heuristic value

Focus measurement

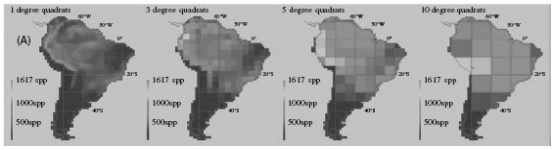
Model Parameterization

Management - Range of Natural Variation

## Temporal and Spatial Scales in Ecology

Different patterns may emerge at differing scales of investigation of almost every aspect of every ecological system.

Early example were species-area curves, which showed that nonlinear patterns existed, and that study area size must be accounted for when interpreting results of studies of species richness.




Source: Rahbek Ecology Letters 2005

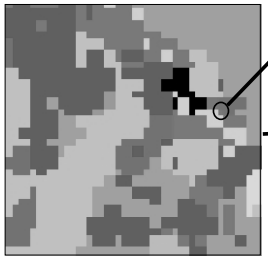
## Temporal and Spatial Scales in Ecology

Different patterns may emerge at differing scales of investigation of almost every aspect of every ecological system.

**Local scale**: red pine is declining and may disappear from the Boundary Water Canoe Area

**Landscape scale**: red pine is thriving in Superior Nt'l Forest due to active management.

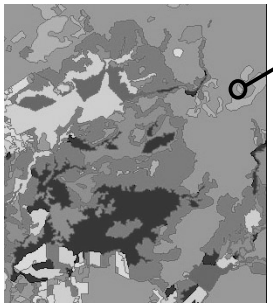
## Ecological scaling: definitions



**Grain** = minimum resolution of the data, defined by the cell size (for raster data) or minimum polygon size (vector data).

**Extent** = the scope or domain of the data, defined as the size of the landscape or study area under construction.

## Ecological scaling: definitions



**Grain & Vector Data**

**Grain** = minimum resolution of the data = minimum mapping unit.

Is Grain a relevant concept for vector data?

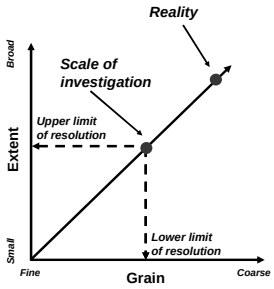
Yes, because:
a) Grain influences both area and length.

b) You must be aware of the grain when combining or using multiple data sets.

## Ecological scaling: notes and rules

- Grain and extent are correlated: As the study area increases, we generally lose resolution; high resolution usually requires a smaller study area.
- The smaller the grain, generally the more information or data collected.

* The upper limit of data resolution is set by the extent
* The lower limit by the grain.
* We cannot detect patterns finer than the grain or coarser than the extent.



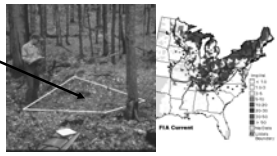

## Ecological scaling: notes and rules

***To an Organism:***

- Grain is the smallest component of the environment that is relevant to the organism.
- Extent is the maximum distance at which an organism interacts with an external object.

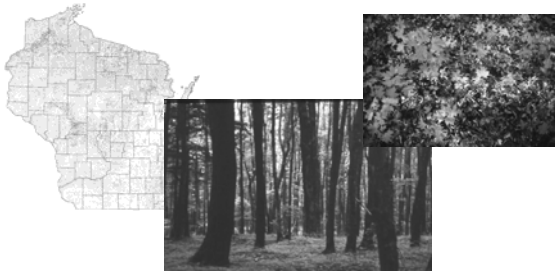
***To Humans:***

- Grain might be the finest unit of management or study.
- Extent is the total area under investigation or management.
- May be determined by the scale of the data or other technological limitations.



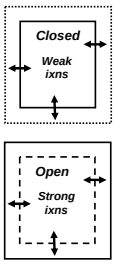
## Effects of scale: Abiotic/biotic relationships

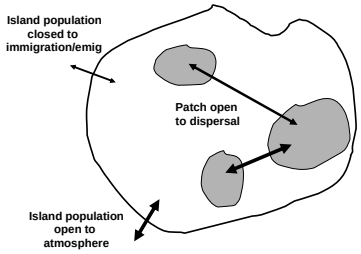
- Biological interactions may separate or reduce the relationships between the abiotic template and landscape pattern.
- Biota may introduce indirect effects, feedbacks, and spatial or temporal lags that are not observable at larger scales.



## Effects of scale: Openness

- Openness is defined by the strength of the interactions between scales.
- When systems are open, processes at broader scales will affect those at the scale of observation.



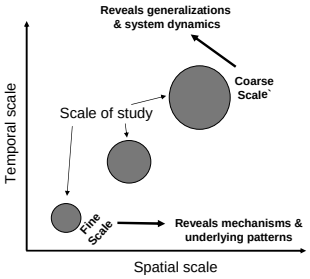




## Effects of scale: Detail and Mechanism

A. Fine-scale studies may reveal more detail about the underlying mechanisms of a pattern

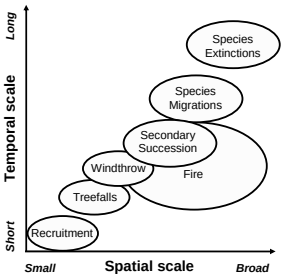
B. Mechanisms will be generalized at broader scales.

C. The scale(s) of the mechanism determines the patterns that can be detected.

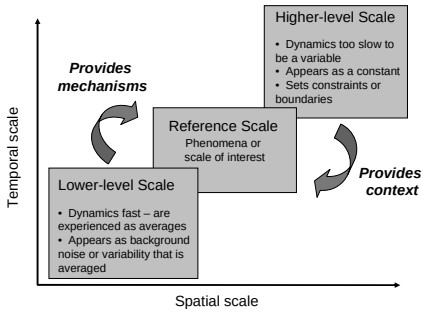


## Theories of Scale: Characteristic scale

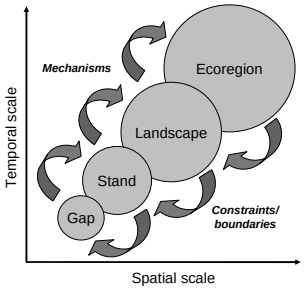
- Ecological phenomena have characteristic spatial and temporal scales, or spatiotemporal domains, and should be addressed at their characteristic scales.
- As the spatial or temporal scale changes, the phenomena of interest change.
- Short-term changes often affect small areas while long-term changes affect larger areas.




## Theories of Scale: Hierarchy theory



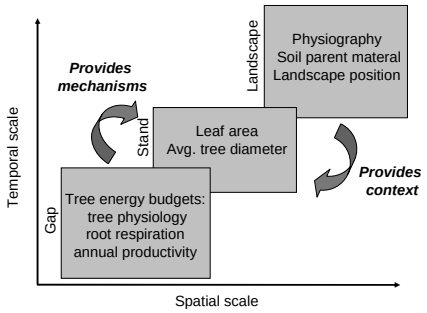

## Hierarchy theory: examples




- Ecoregion: defined by climate and geology; 100,000s ha; 1,000s-10,000 yrs.
- Landscape: defined by physiographic province, changes in land use, disturbance regimes: 10,000s ha, 100-1,000 yrs.
- Stand: defined by topographic position, disturbance patches: 1-10s ha, 10-100s yrs.
- Gap: defined by the influence of a single large tree: 0.01-0.1 ha, 1-10s yrs.

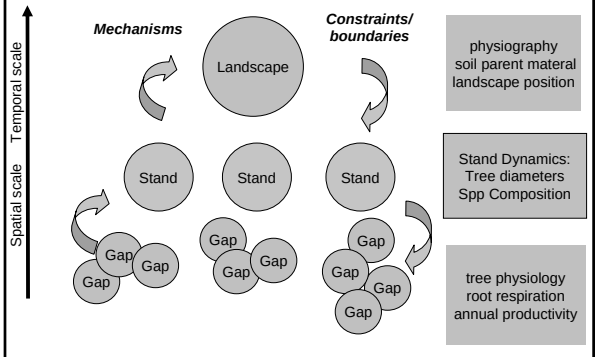
## Hierarchy Theory: Examples

Objective: predict the increase in biomass of a forest stand over 100 years

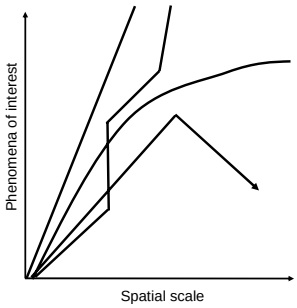



## Hierarchy theory: examples

Objective: predict forest stand dynamics over 100 years




## Dealing with ecological scale: Scaling up




- "Scaling up" involves extrapolating data to scales of higher levels; values are inferred for higher scales often beyond the range of the data collected for estimation.
- Not all data may be scaled up, since it assumes constant processes across scales, linearities, and a lack of thresholds.

## Theories of Scale: Hierarchy theory

Summary

- Ecosystems can be divided into smaller components that operate at finer-scales than the phenomena of interest.
- Ecosystems are nested within increasingly larger ecosystems that influence processes occurring in the systems.
- Lower level generate behaviors for levels above; higher levels constrain levels below.

## Ecological scale: Summary

1. The scale of an observation has very strong influence over what you observe, which is important because scales of study are often arbitrary and based on human perception.

2. Conclusions, as well as data, documented at one scale may not be applicable or transferable to another scale.

3. Finding the appropriate scale is sometimes difficult, and there are few shortcuts in doing so; one must consider the hierarchy and processes for the object in question.