

# Concept of Scale in Landscape Ecology



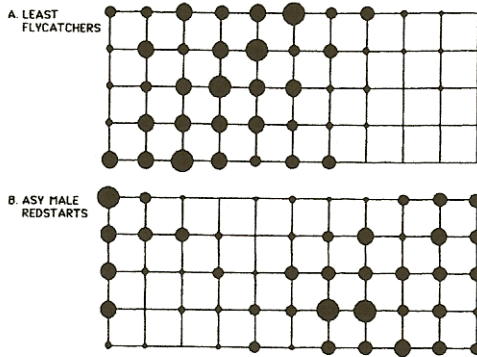
## Topics

- **Puzzling findings**
- **Scale defined**
- **Scale vs levels of organization**
- **Hierarchy theory**
- **Implications for management**

# Puzzling Findings

**Question: how important is competition between species in structuring communities?**

1975-80, LEAST FLYCATCHERS PRESENT



**American Redstart (Sherry and Holmes 1988)**

- Territory location negatively influenced by presence of least flycatcher territories.
- Across new England, these two species are found in the same places?



**American Redstart**  
*Setophaga ruticilla*



**Least Flycatcher**  
*Empidonax minimus*

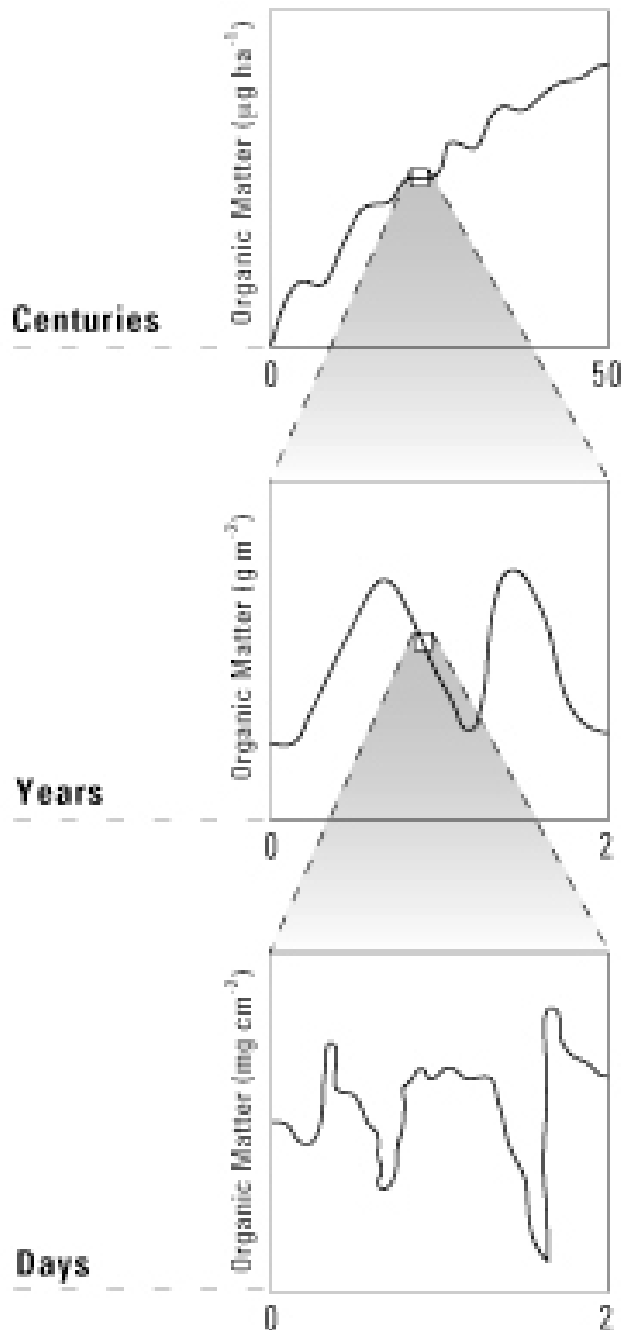


## Puzzling Findings

How does soil organic matter change over time?

Soil Organic Matter (Sollins et al. 1983)

- Dynamics differ across time periods.
- Why?



Text Fig 2.6



## Puzzling Findings

**Question: Are Northern Rockies landscapes disequilibrium or equilibrium systems?**

**Natural Disturbance – agent of death or balance?**

- Individual fires are highly destructive.
- Some landscapes undergo negative change (e.g. conifer encroachment) in the absence of disturbance
- Why?



# Puzzling Findings

**Answer:**

- Ecological properties may differ among scales.
- Thus your answer depends on the scale you work at.

# Scale Defined

**Scale - the spatial or temporal dimension of an object or a process.**

**It is measured in terms of:**

- **grain – the finest spatial unit of measurement (e.g., cell size)**
- **extent – size of the study area.**

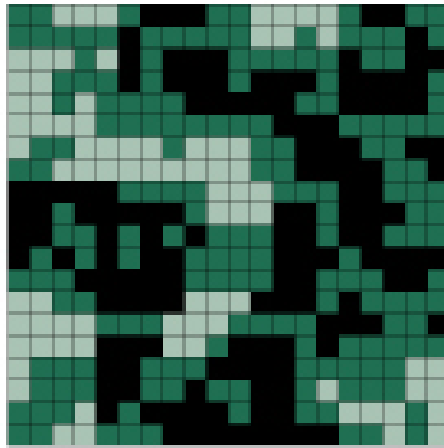
# Scale Defined

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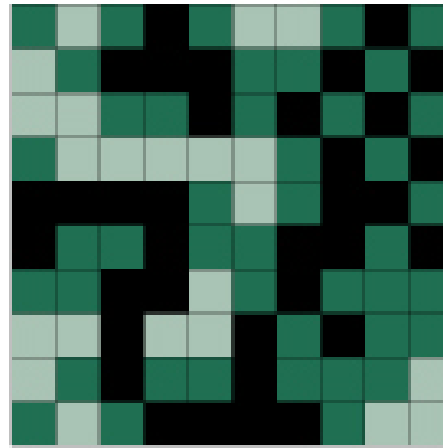
**It is measured in terms of:**

- grain – the finest spatial unit of measurement (e.g., cell size)**
- extent – size of the study area.**
- temporal resolution - frequency of sampling**
- duration – period over which sampling is done**

**(a) Increasing Grain Size**



$n = 1$

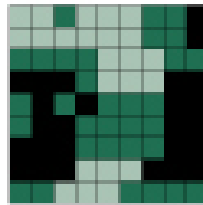


$n = 4$

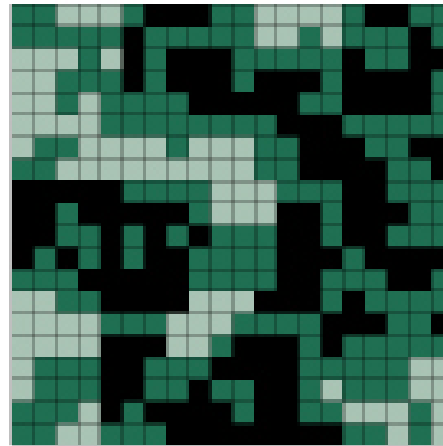
**(b) Increasing Extent**



$a = 16$



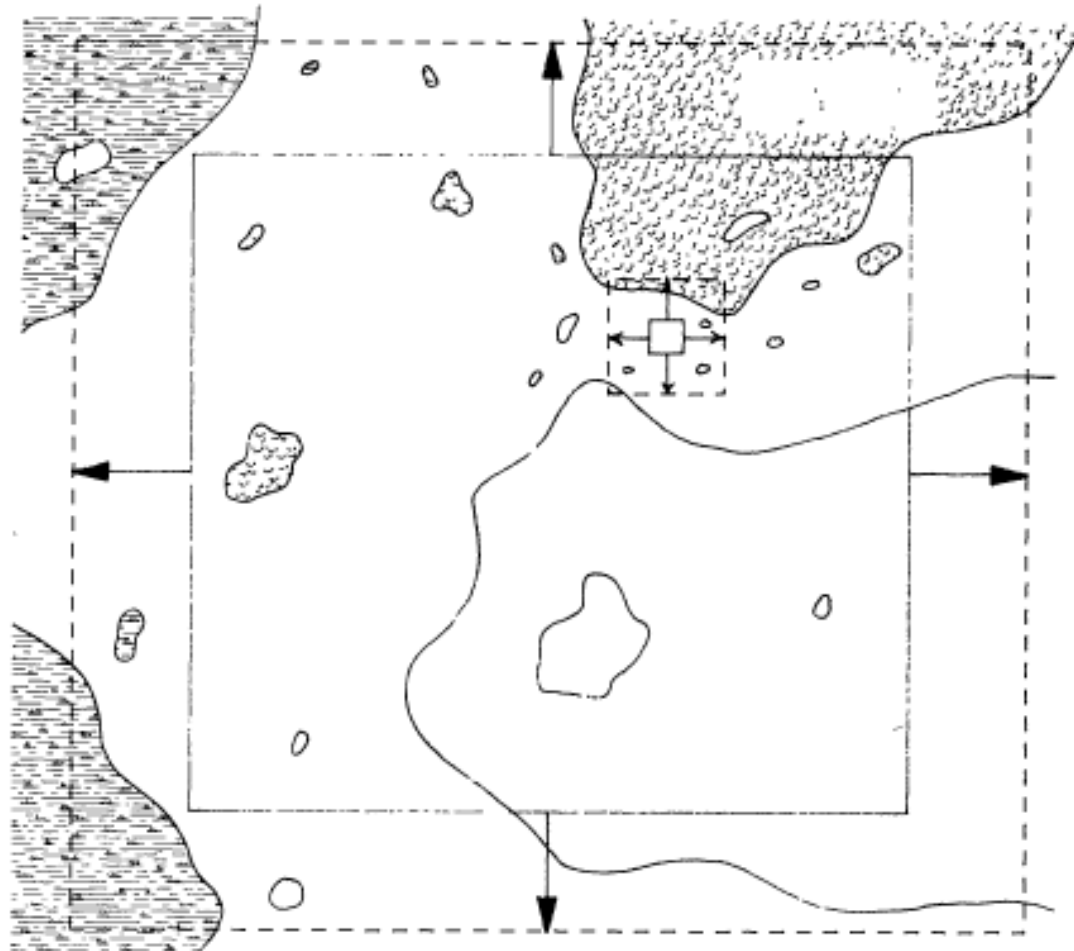
$a = 81$



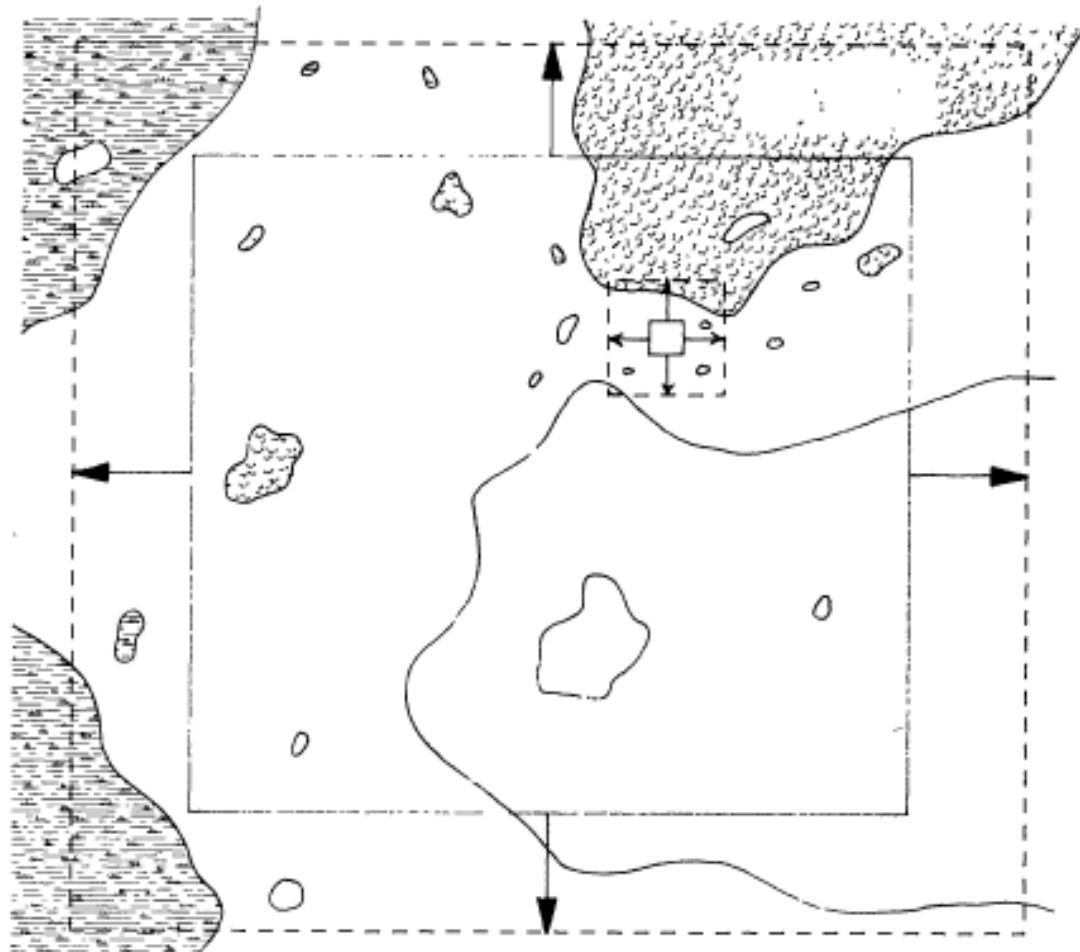
$a = 400$

**Why should properties of ecological systems differ depending on grain or extent of the study area?**

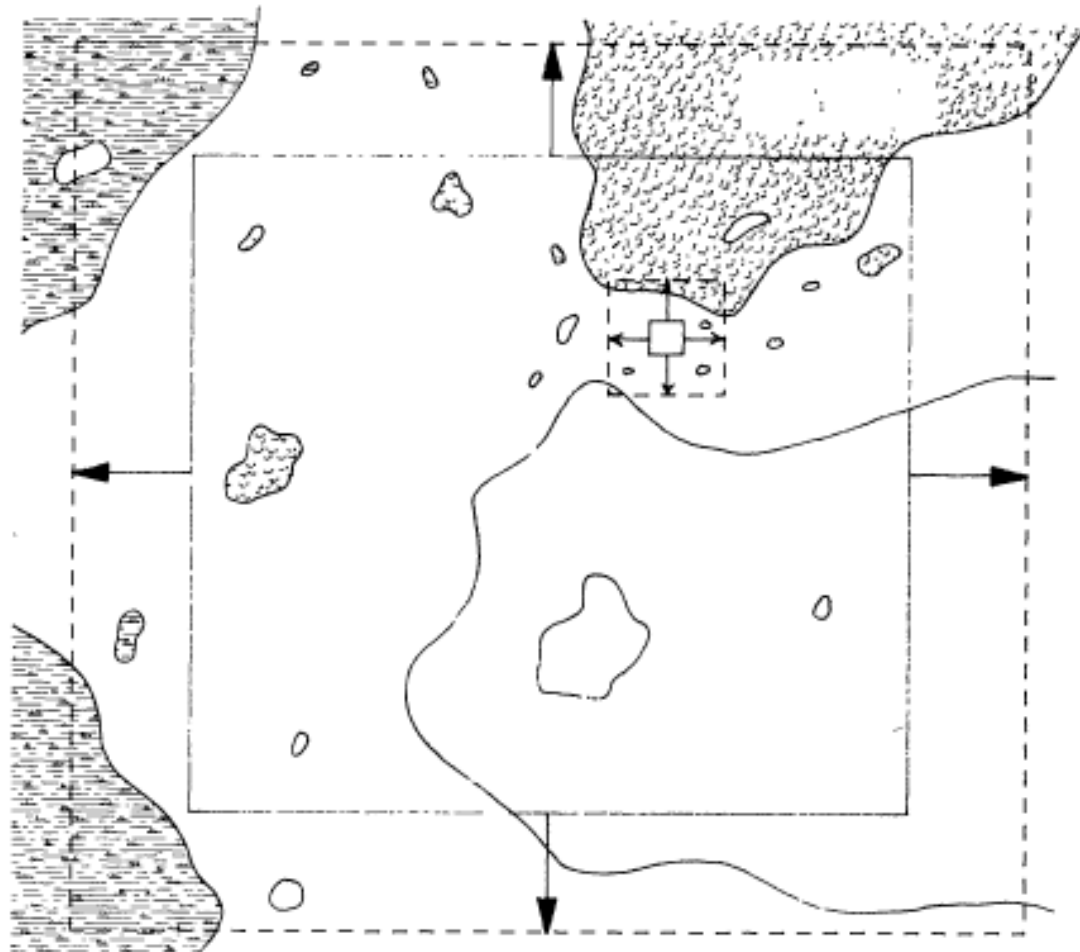




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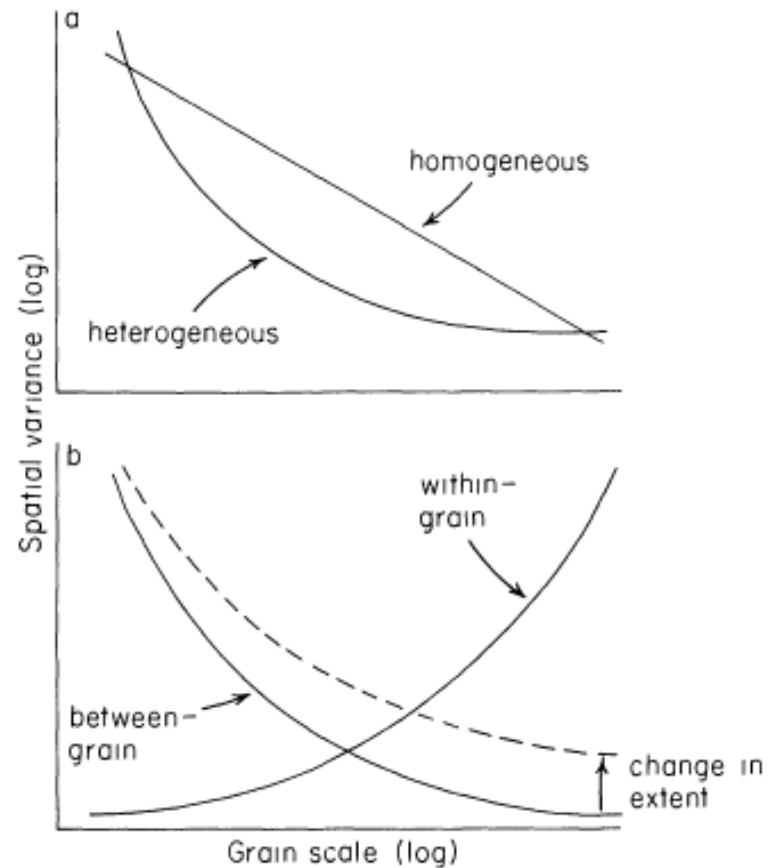


Increasing grain averages over the variation at finer grains.

Increasing the extent may add patterns or processes that differ from the original extent.

**Why should properties of ecological systems differ depending on grain or extent of the study area?**

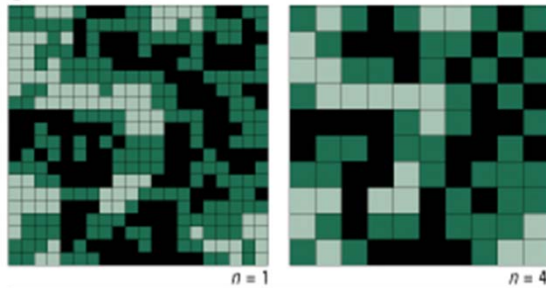
# Grain and Variance



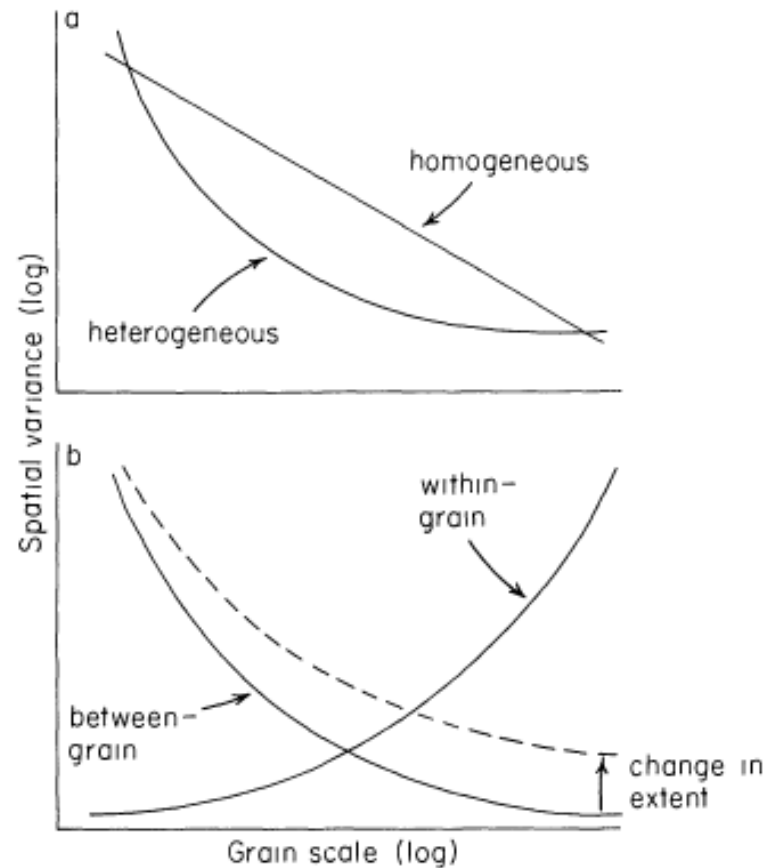
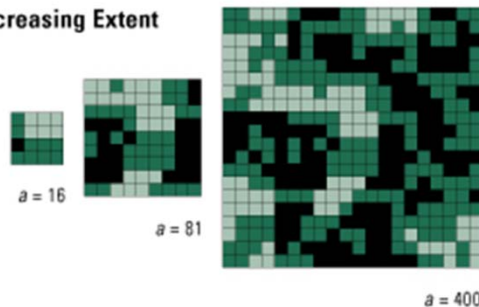
**Fig. 2.** (a) As the grain of samples becomes larger, spatial variance in the study system as a whole decreases, albeit differently for homogeneous and heterogeneous areas. This is related to the within- and between-grain (sample) components of variation. (b) With increasing grain scale, less of the variance is due to differences between samples and more of the overall variation is included within samples (and therefore averaged away). An increase in the extent of the investigation may increase the between-grain component of variance by adding new patch types to the landscape surveyed (Fig. 1), but within-grain variance is not noticeably affected.

# Grain and Variance

(a) Increasing Grain Size



(b) Increasing Extent



**Fig. 2.** (a) As the grain of samples becomes larger, spatial variance in the study system as a whole decreases, albeit differently for homogeneous and heterogeneous areas. This is related to the within- and between-grain (sample) components of variation. (b) With increasing grain scale, less of the variance is due to differences between samples and more of the overall variation is included within samples (and therefore averaged away). An increase in the extent of the investigation may increase the between-grain component of variance by adding new patch types to the landscape surveyed (Fig. 1), but within-grain variance is not noticeably affected.

# Three scale problems

- **Scale coverage** – Many desired study areas (e.g., the biosphere) are too large to study at fine resolutions.
- **Scale linkage** – given that detailed field work is restricted to relatively small areas, how do we relate fine-scale data to broader spatial scales?
- **Scale standardization** – research and data are often collected at different scales. How can we standardize data from different scales to a reference scale?

# **Levels of Organization**

(a place in a biotic hierarchy)

**organ**

**individual**

**population**

**community**

**ecosystem**

**biome**

**biosphere**

# What is the Scale of Each Level of Organization?

## Levels of Organization

## Scale

organ

Fine

individual

population

community

ecosystem

biome

biosphere

Broad



# Landscape is Which?

## Levels of Organization

## Scale

organ

Fine

individual

population

community

← Landscape ? →

ecosystem

biome

biosphere

Broad

# Different Views on Landscape

**landscape - a heterogeneous land area (kilometers in extent) composed of a cluster of interacting ecosystems that are repeated in similar form throughout. Forman and Godron (1986)**

**landscape - focus on interactions among neighboring entities at any scale and on interactions with higher and lower levels in a hierarchy. Tim Allen (1992)**

**landscape – an area that is spatially heterogeneous in at least one factor. Text.**

# Landscape is Which?

## Levels of Organization

## Scale

organ

Fine

individual

population

community

Ecosystem

Landscape

biome

Broad

biosphere

**Delcourt and Delcourt. 1983. Dynamic plant ecology: the spectrum of vegetational change in space and time. Quaternary Sci. Rev. 1:153-175.**



**Paul**



**Hazel**

# Delcourt and Delcourt. 1983

**Perturbation**

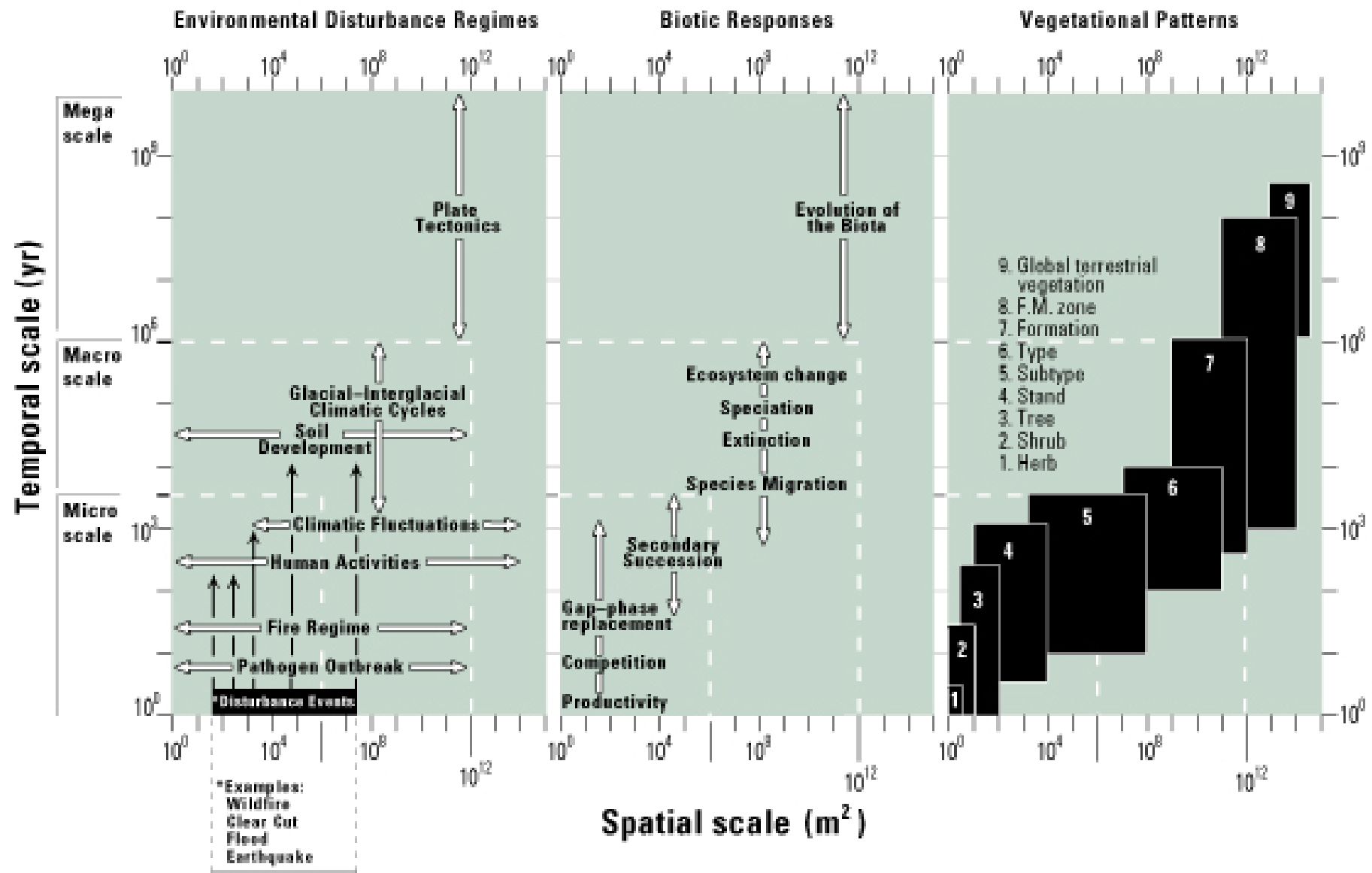


**Biotic Response**



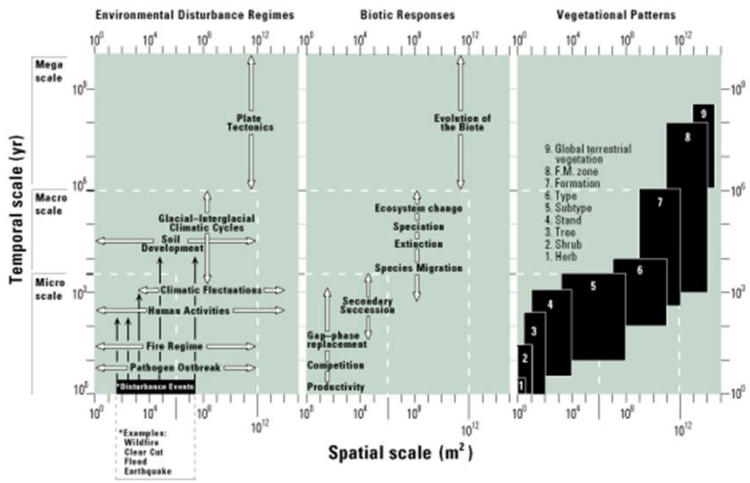
**Biotic Pattern**

# Delcourt and Delcourt. 1983

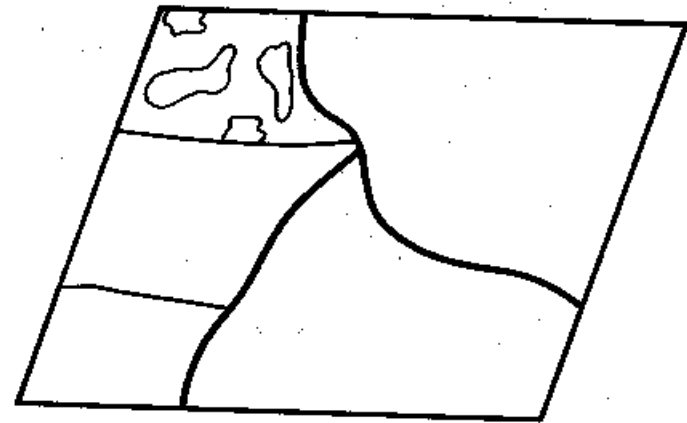
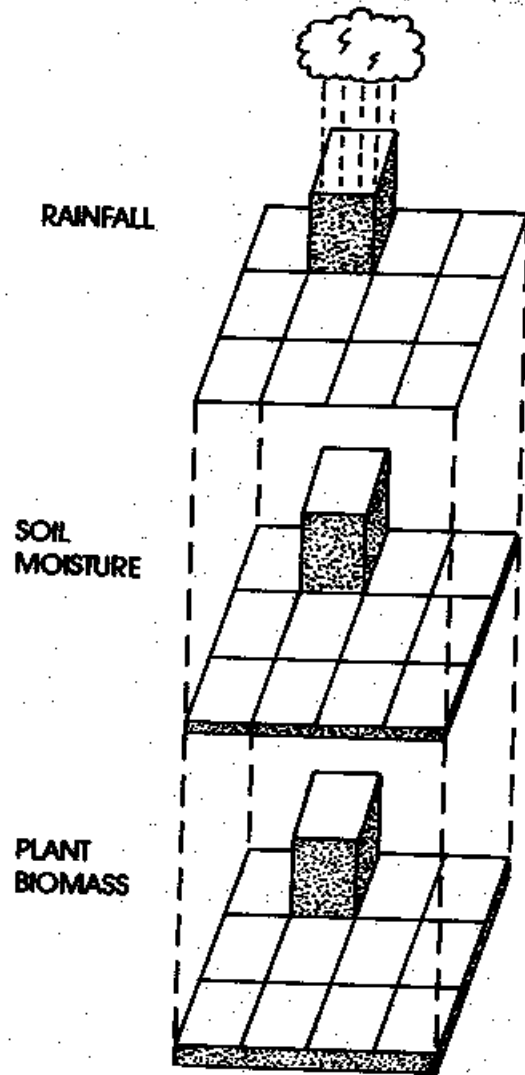


# Delcourt and Delcourt. 1983

- Each event occurs at a characteristic scale and elicits response at this scale.
- In some cases, ecological system behavior varies with scale. What you observe varies with the scale you are looking at.
- In other cases, drivers and patterns at very different scales are not necessarily very different phenomena. We can understand those dynamics by controlling for scale.
- Different tools are used at different scales but they can be used to address similar questions.
- Scientists working at different organizational scales may be addressing similar questions and integration among disciplines and scales is often needed to solve a problem.



## Concept of Landscape

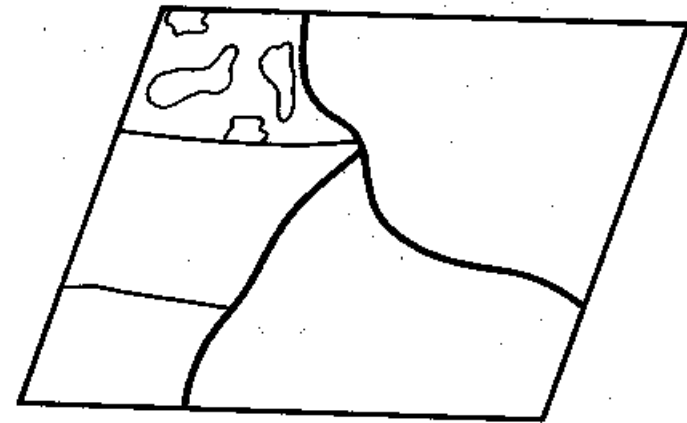
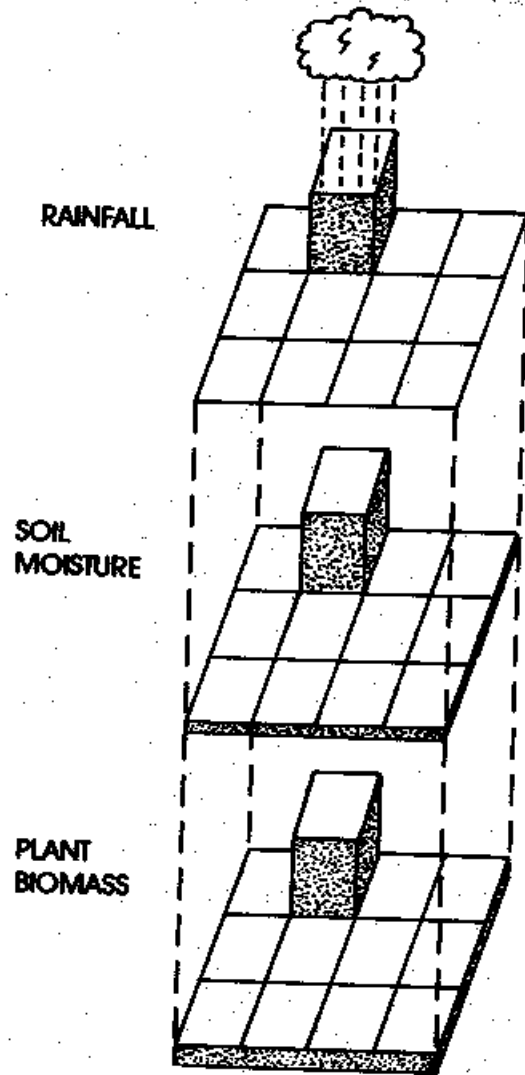


Hansen and Walker 1986

A landscape has perturbation, biotic response, biotic pattern happening at many scales, hence it is a mosaic of patches of differing scale that overlay one another.



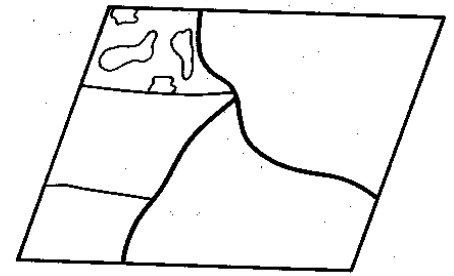
## Concept of Landscape



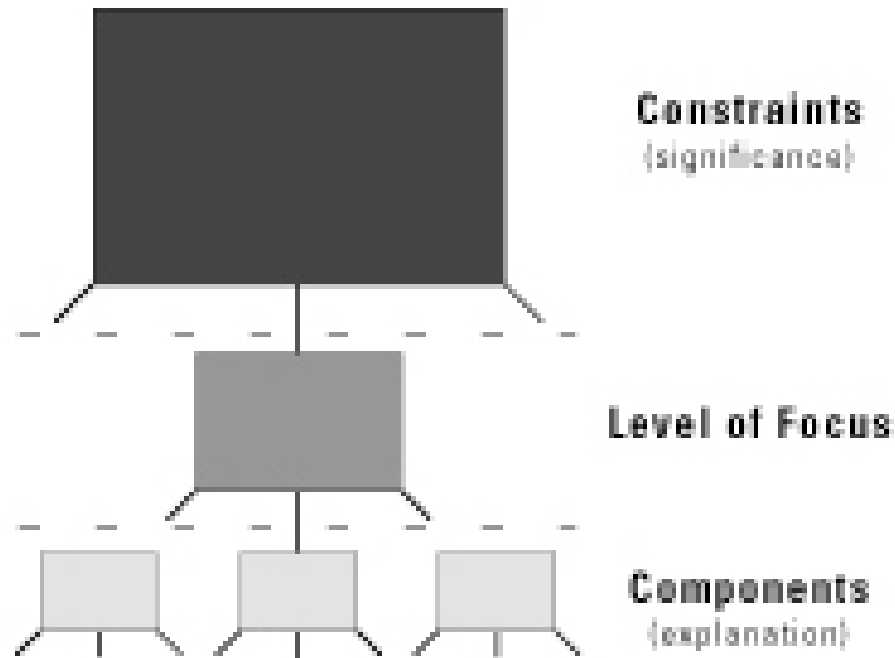
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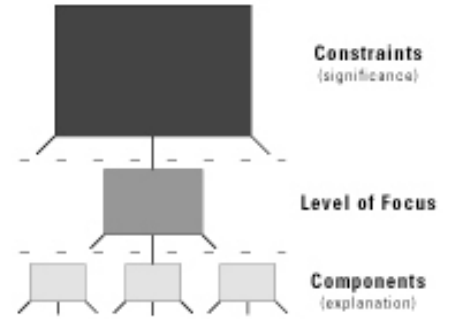
# Hierarchy Theory



- A hierarchy is defined as a system of interconnections wherein the higher levels constrain the lower levels to various degrees, depending on the time constraints of the behavior.
- Upper levels constrain the focal level and provide significance. Lower levels provide details required to explain response of focal levels.

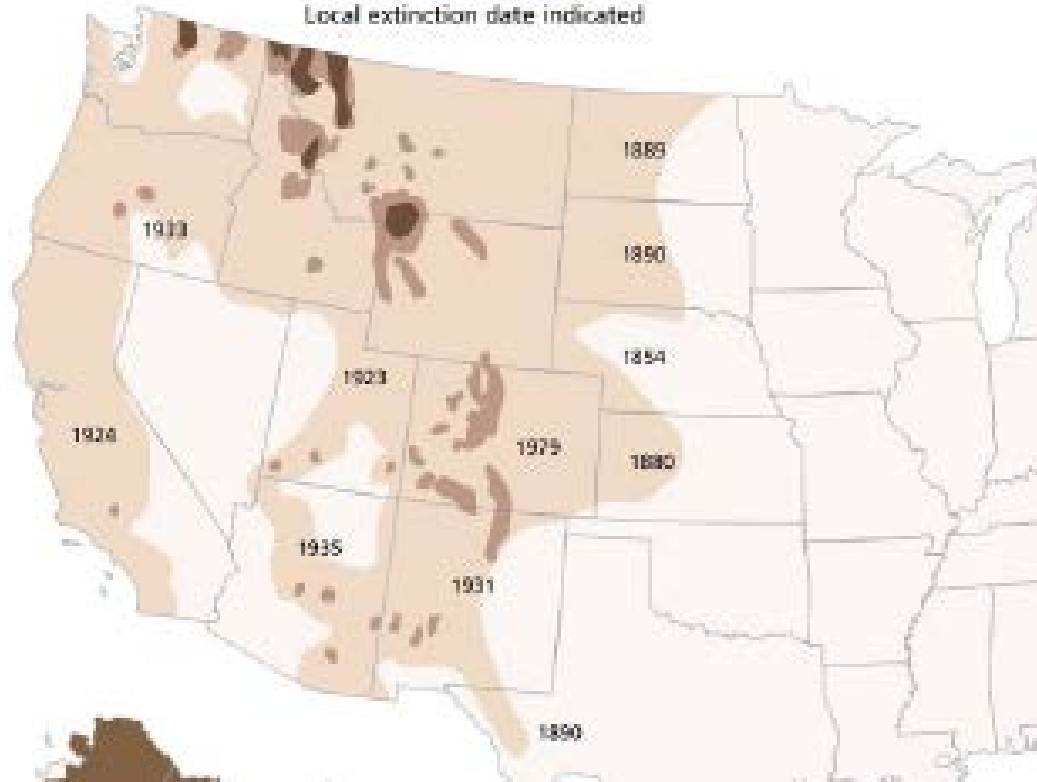


# Hierarchy Theory



## Historic and Current Range

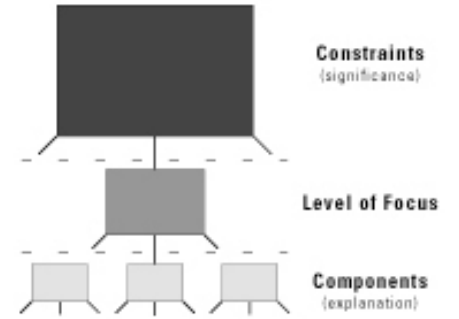
1850
  1922
  Present  
 Local extinction date indicated



**Focal Level:**  
 ) Subpopulations

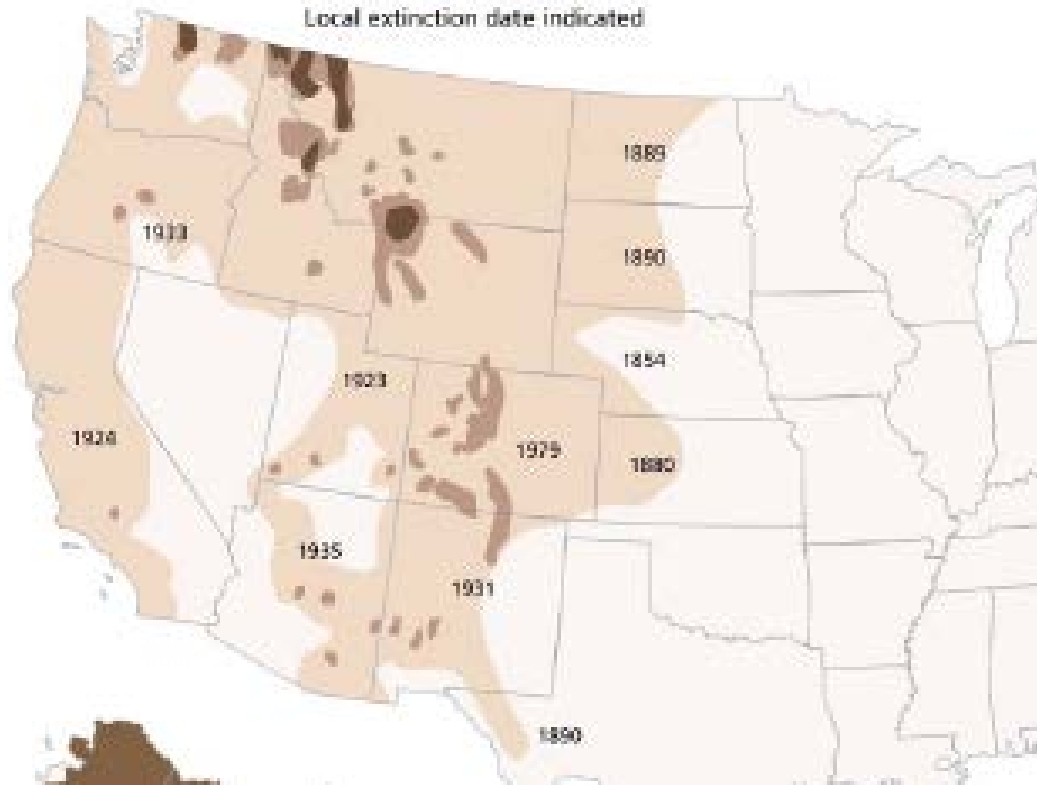


# Hierarchy Theory



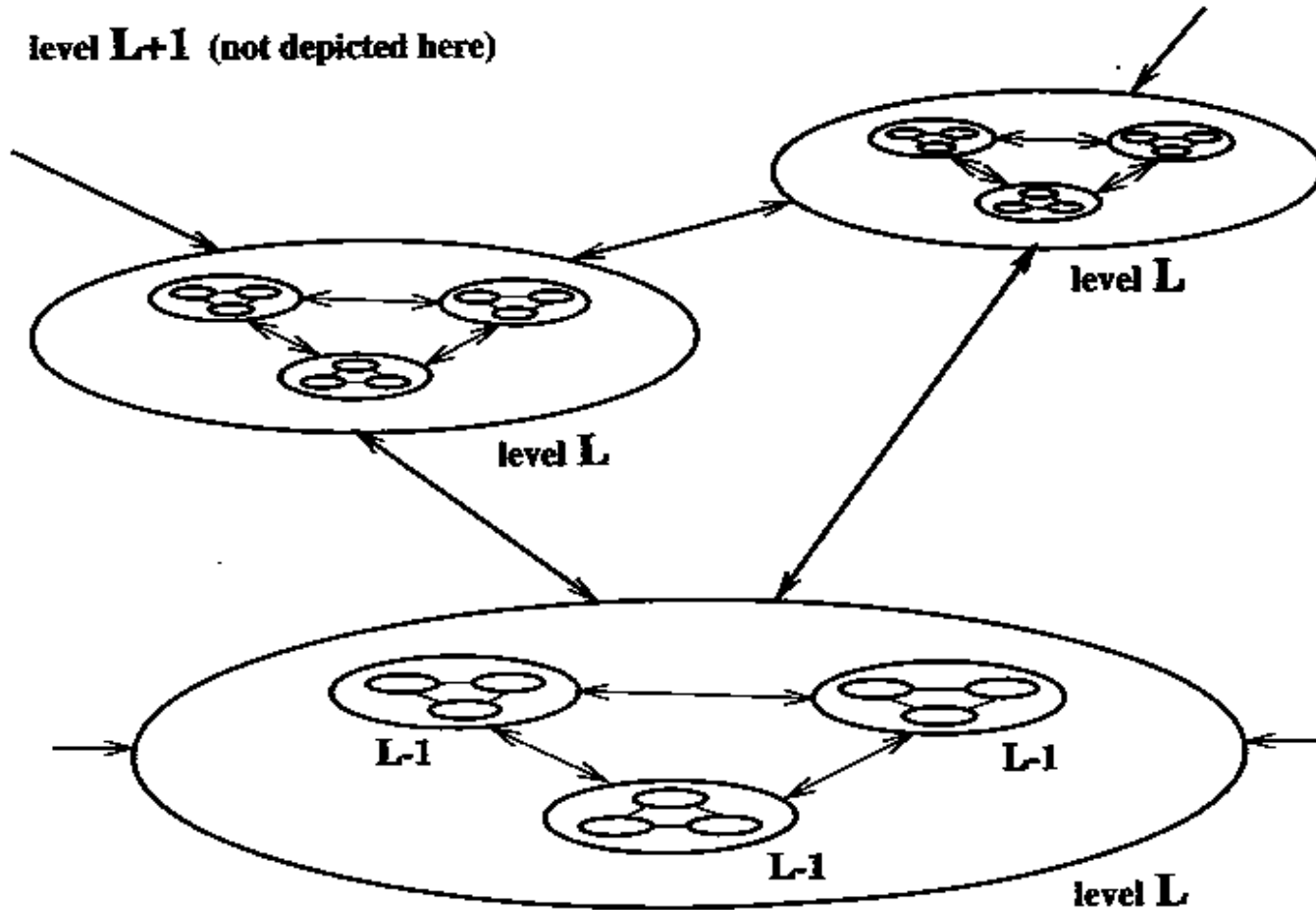
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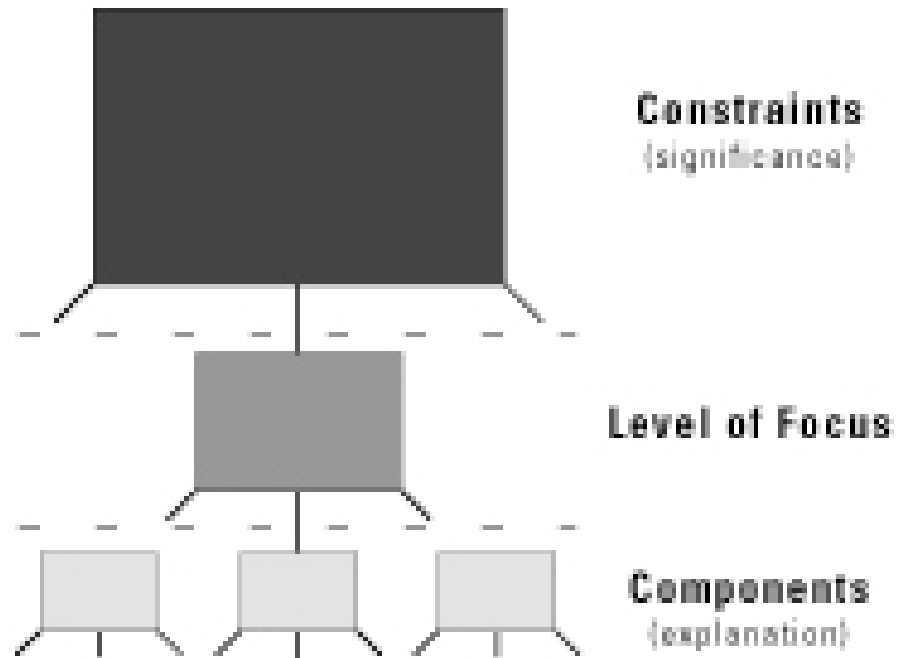
**Focal Level:**  
 ) Subpopulations  
 ) Individual bear

# Nested Hierarchy



A nested hierarchy is a "system of subsystems". Systems at one scale are subsystems of systems of the level above.

# Hierarchy Theory



It is often useful in ecology to consider at least three hierarchical levels in a study.

- The focal level, as derived from the question or objective.
- The level above, because it constrains and controls the focal level.
- And the level below, which provides the mechanisms or details that explain the focal level.

# Hierarchical concept of landscapes helps:

- in classification.
- determine what to study to answer a particular question and appropriate scales for study.
- identify the sampling frequency and area right for the problem.
- focuses thinking on what are the mechanisms, what are the constraints.
- understand incorporation - dynamics of subsystems are merged or averaged at the level above.



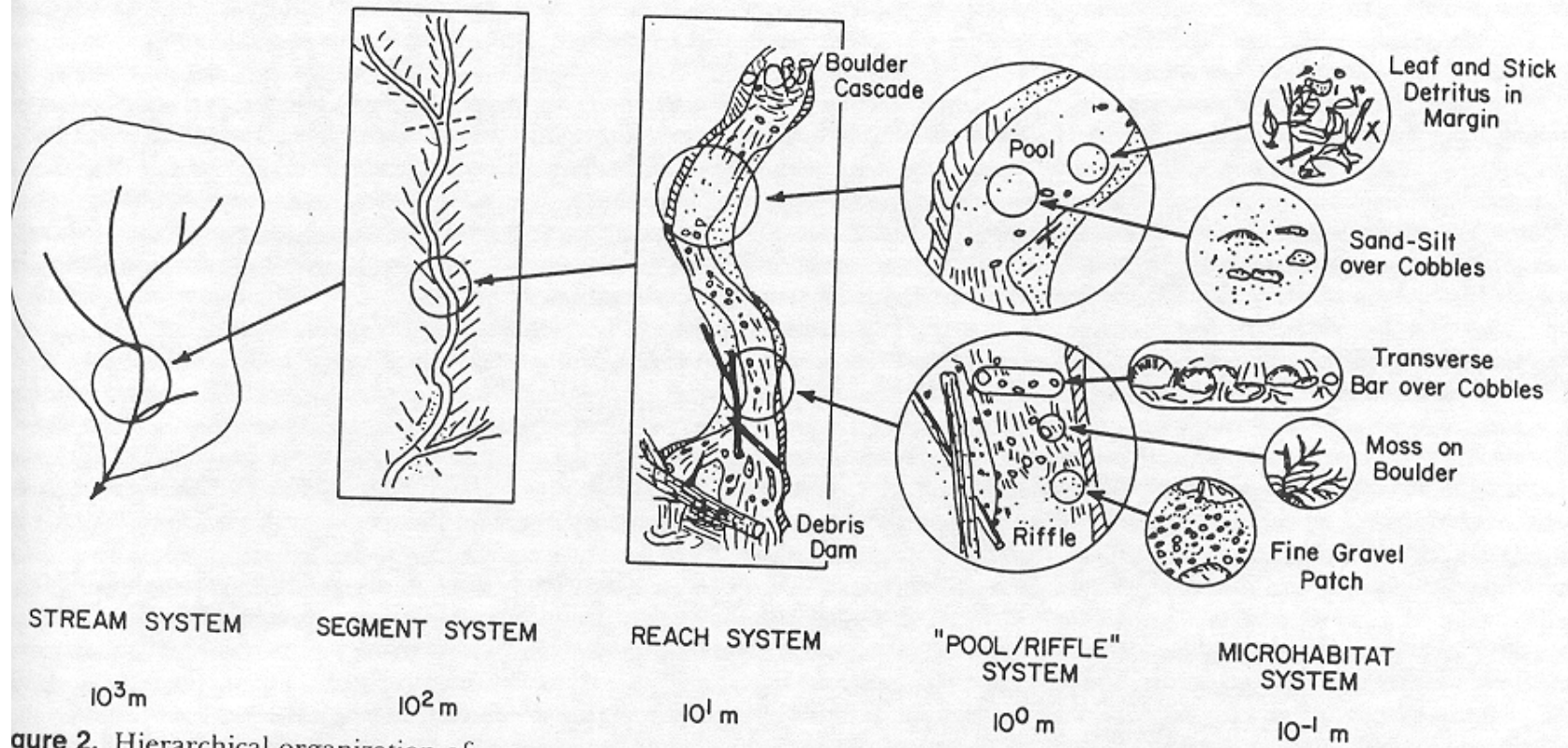


Figure 2. Hierarchical organization of a stream system and its habitat subsystems. Approximate linear spatial scale, appropriate to second- or third-order mountain stream, is indicated.

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# Relevance to Concept of landscape:

The landscape is a hierarchical mosaic of patches.

This hierarchy can be decomposed to cut through complexity and study levels of interest.

Dynamics at one level can be "incorporated" into the next higher level. E.g., disequilibrium behavior at one scale becomes shifting steady-state equilibrium at higher scale.

# Implications for management:

- Pattern is generated by env constraints, disturbance, biotic response. Need manage all three to get desired pattern.
- To manage a landscape, we consider both mechanisms and broader context. e.g., YNP as part of larger system.
- One, we need disturbance to keep some systems as they are. Two, nature reserves have to be big enough to incorporate their disturbances if quasi equilibrium is to be maintained.

# Implications for management:

- **Helps to understand human activities-**

**rescale disturbance,**

**rescale landscapes by altering boundaries,**

**novel disturbances**

**We must manipulate these to accomplish objectives.**

**Some systems need disturbance to stay as they are,**

**Nature reserves have to be big enough to incorporate their disturbances if quasi equilibrium is to be maintained.**

**We may have to manipulate disturbance type and scale and landscape boundaries in altered systems.**

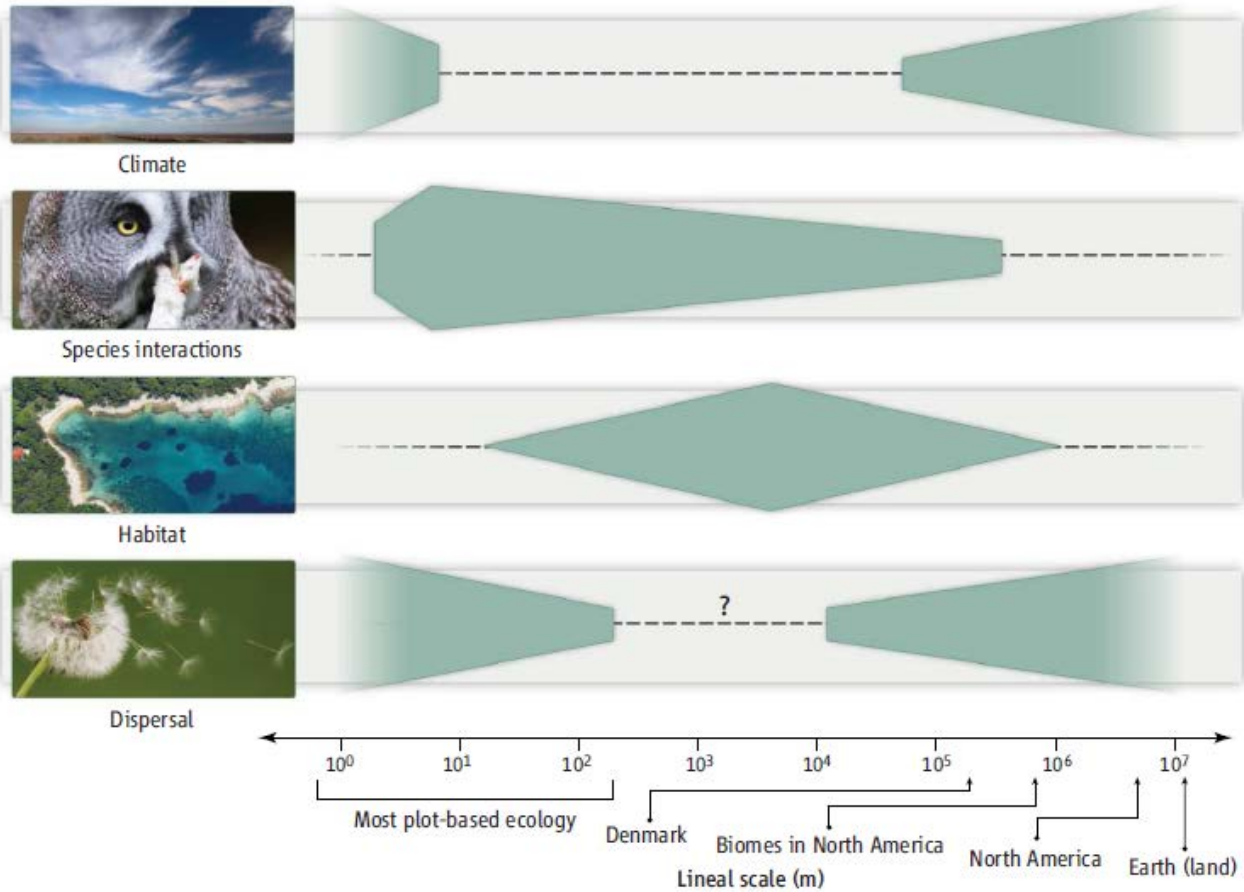
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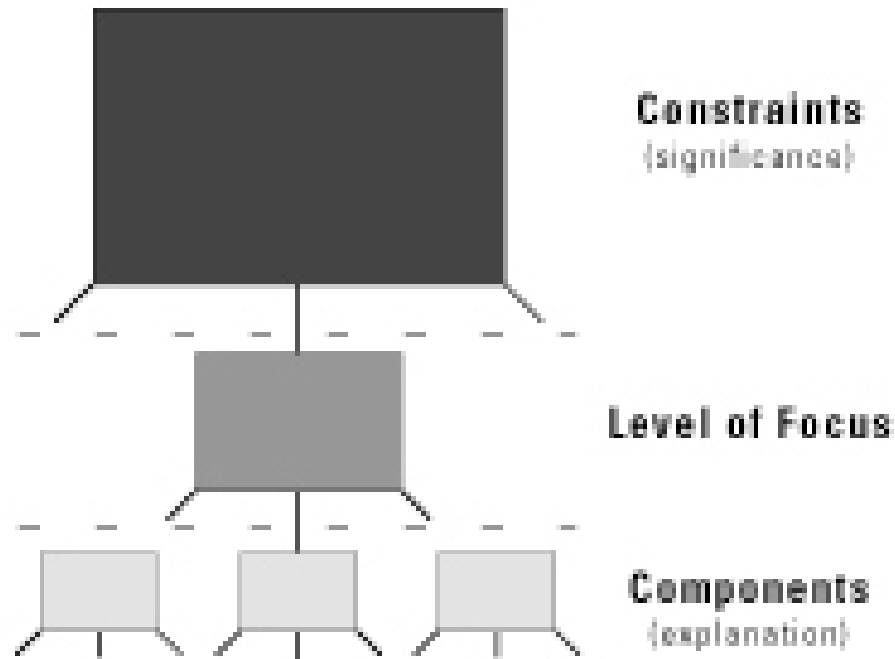
## Topics

- **Puzzling findings**
- **Scale defined**
- **Scale vs levels of organization**
- **Hierarchy theory**
- **Implications for management**

# What controls the distribution of species?



# Hierarchy Theory



- Holon – entities within a system that are both parts of a larger entity and also a whole that fits within its environment (both wholes and parts).

- Levels are distinguished by differences in rates or frequencies of their characteristic properties. Hence holons tend to interact most with other holons at the same level.