Heterogeneity

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A note from the authors: This version is static and as such has lost both formatting for viewing ease and important interactive elements like the ability to quiz oneself and click on key terms for hover-box definitions. We highly recommend using this module in it's interactive form by visiting the following link: https://passel2.unl.edu/view/lesson/ab491bda9f88

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Overview and Objectives

Overview - What Will You Learn In This Lesson?

This lesson discusses what heterogeneity is and how it relates to understanding and interpreting natural phenomena.

Objectives

This lesson covers the concept of heterogeneity. At the end of this module you should be able to:

1. Define heterogeneity in the context of environmental management
2. Explain the relationship between heterogeneity and ecological resilience
3. Differentiate between functional and measured heterogeneity in ecology
4. Understand the importance and usefulness of heterogeneity in resource management

Correct answers to all questions are highlighted

Introduction - What Is Heterogeneity?

Heterogeneity is variability within a system that accounts for scale. It is the quality of something to be made up of many different parts, elements, kinds, or individuals with these different components occurring at different scales at varying densities. The opposite of heterogeneity is homogeneity, or all parts or components of a place or system being identical or nearly identical. Heterogeneity is synonymous with the variability or complexity of landscapes at both the temporal and spatial scales. In other words, the heterogeneity of a landscape is impacted by the scale at which the heterogeneity is being measured or observed (Fuhlendorf et al. 2017). An example of heterogeneity might be a piece of a rainforest, with many different species of plants and animals and other abiotic components (like streams, patches of shrubs and grass, etc.), while an example of an equally sized homogenous plot of land could be a large lawn with only one species of grass present. However, as will be illustrated below, zooming in or out on these locations will determine whether or not they are viewed as heterogeneous or homogenous.

A visual representation of spatial heterogeneity and scale is given in Figure 1 below. Assume that each level (1, 2, 3, and 4) is a snapshot of the same landscape at a different spatial scale. The bottom level (4) encompasses the largest area and as you work up the levels, the area gets zoomed in and smaller in size. Level 1 (top) is homogenous, the opposite of heterogeneous, because there are no differences in cover as it is measured. At the second level (2) the observer has zoomed out and can now see that there are two distinct components to the landscape (blue and green). The blue and green components seem to occur evenly and without much variation. As the observer moves farther and farther out in view (3 and 4), they observe that there are more than just two components to the landscape and some components occur in greater density than others. There are many different parts (green, blue, orange, yellow) all occurring in varying quantities and in different places (i.e. spatial heterogeneity). As the observer increases their view, the scale at which they are working increases. The increase in scale also increases the heterogeneity and complexity of the landscape. These same principles can be applied to a landscape viewed through temporal scales of days, months, years, and beyond.

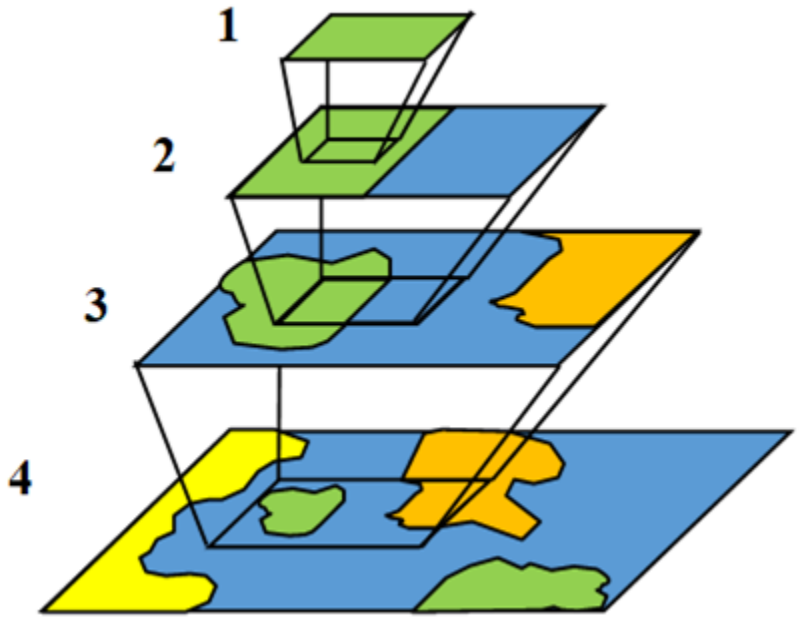

Figure 1. How scale impacts the perceived heterogeneity of the landscape. Conceptual figure provided by Jessica Johnson.

Measures of Heterogeneity

Functional Heterogeneity is variation at a scale that corresponds to the function of an ecological process or property (Li and Reynolds 1995, directly quoted from Fuhlendorf et al. 2017). The scale of measurement for functional heterogeneity is determined by the ecological entity of interest, rather than arbitrarily determined by an observer. For example, the ecosystem properties important to people are not the same as the ecosystem properties important to a beetle (Fuhlendorf et al. 2017).

Measured Heterogeneity is a "measure of the variability of an ecological property or process without explicit relations to variability in animal behavior or ecological function" (Li and Reynolds 1995, directly quoted from Fuhlendorf et al. 2017). This is an important consideration for researchers, as measured heterogeneity is the act of taking measurements of heterogeneity without considering the ecological entity of interest (as in functional heterogeneity) but instead choosing measurements and sampling procedures based on what is easiest or most intuitive to the human doing the research (Fuhlendorf et al. 2017).

Spatial and Temporal Heterogeneity specifically refers to variability in an entity (e.g., a landscape) in space and time, respectively. Spatial and temporal heterogeneity are important because measures of heterogeneity will differ based on the spatial and temporal scales selected by an observer. For example, animal species are distributed differently across landscapes in space and time; their use of the landscape will vary due to spatial factors such as land cover and temporal factors such as season. Temporal heterogeneity can also be seen at a point in a crop field. The field may lack spatial heterogeneity but over time exhibits temporal heterogeneity. During the growing season, the field is mostly homogeneous, covered in one crop, but as time

passes the heterogeneity increases as the field transitions from crop covered, to bare and harvested and then back to vegetated again, possibly with a different crop.

Heterogeneity in Management - How Does This Concept Impact Real-World Management?

Historically, most natural resource management decisions have focused on reducing variability and increasing predictability in landscapes. Examples include dam construction to reduce interannual flooding variation and pest extermination to maximize agricultural output (Fuhlendorf et al. 2017). Heterogeneity in modern agricultural systems is extremely low. Most crop producers grow monocultures of crops and suppress all other plant growth (i.e. weeds or native plants). A goal of modern agriculture is to create a homogeneous field to maximize yields which can be seen in the picture on the right in Figure 2.

"Chalk grassland" by naturalengland is licensed under CC BY-NC-ND 2.0

"Grain field harvesting" by Oregon Department of Agriculture is licensed under CC BY-NC-ND 2.0

Figure 2. A nearly homogenous wheat field on the right and a heterogenous grassland/ meadow with many different grasses, flowers and trees on the left.

Systems tend to have low resilience when there is less heterogeneity present in space and time (Gunderson et al. 2010). While reducing heterogeneity creates easier harvesting and higher crop yields, monocultures are at greater risk of collapse from disturbance, such as disease. In this scenario, intensive management is needed to coerce the system into remaining homogenous. Incorporating heterogeneity into managed systems may reduce the necessity of intensive management and result in systems less vulnerable to disturbance or collapse.

Example - Heterogeneity of Zoning in Cities

Heterogeneity can also be seen in urban landscapes through the process of zoning. Zoning is the process of dividing land in a municipality into zones in which certain land uses are permitted or prohibited (Lamar, 2015). The standard categories of zoning in urban areas are residential, mixed residential-commercial, commercial, and industrial. If one considers the city and surrounding area, a few more zone categories could be included: agricultural, rural residential and national forest (see Figure 3 below).

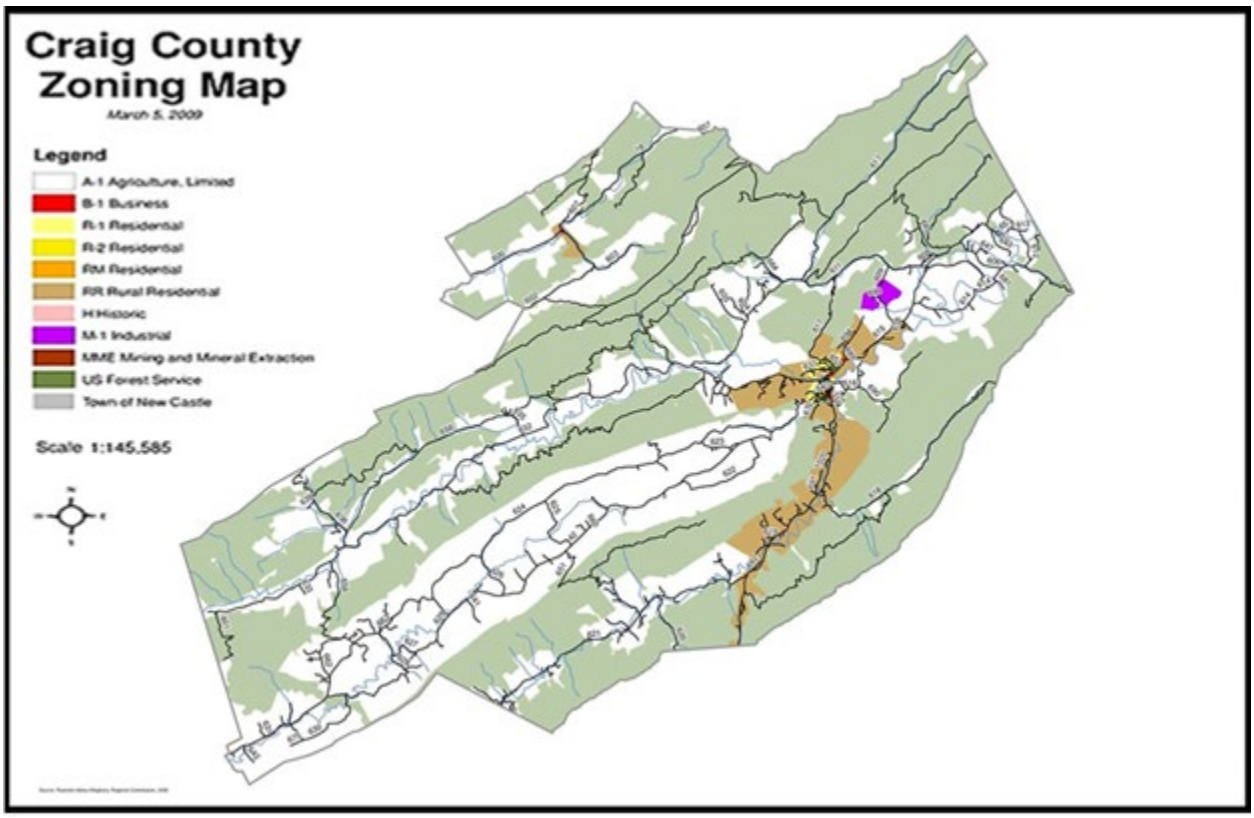

Figure 3. A county zoning map. Adapted from "Zoning Map" by jalbertbowdenii, licensed under CC BY 2.0.

While from a zoomed out perspective a city might look quite homogeneous, zoning of a city creates homogenous pockets of similar land use of the city that when combined creates a heterogeneous city-scape. At a finer scale, each zone category can have a degree of heterogeneity. In the commercial zone, there can be small retail, large retail, and office space. In the industrial zone there can be areas designated for different manufacturing types like heavy manufacturing, light assembly and warehouse uses. In the residential category, there can be areas designated for houses, houses and apartment buildings or the mix of the two. The mixed residential-commercial zone is inherently heterogeneous since it includes the mix of homes and retail. Moving to an even finer scale though and the heterogeneity can be lost. Take the mix of residential and commercial zone, if one zooms into too fine a scale, they could find that the area is only residential as the commercial areas are no longer in view at that scale.

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Summary - What Did We Learn?

Heterogeneity is a critical factor to consider in ecosystem management. The degree of heterogeneity in landscapes depends on the grain and extent (refer to scale module) used by the observer. The type of heterogeneity (i.e. functional versus measured heterogeneity) is dependent on whether an observer uses scales that reflect a functional relationships versus an observer's perspective. Heterogeneity is now recognized as an important system characteristic to consider during the management process in light of recent environmental change across scales, but historically system managers have focused on reducing the variability in landscapes to make environments more predictable. This paradigm of the past requires intensive management of the ecosystem to fight the inherent heterogeneity driven by natural processes (e.g., flooding, fire, drought, etc.), and creates a risks of collapsing the ecosystem into an alternative state due to lack of variability and diversity, as well as unforeseen complications from oversimplifying the system. Considering heterogeneity when managing systems may lead to more resilient ecosystems with long-term functionality.

Quiz Questions

Question

What word describes something made up of many different types of components, and is dependent on scale?

A. Homogeneity
B. Heterogeneity
C. Scale
D. Resilience

Question

If you were a researcher, would utilizing functional or measured heterogeneity ideas in your research produce work more relevant to answer your question of interest?

A. Functional heterogeneity
B. Measured heterogeneity

References and Further Reading

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Further Reading

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Glossary

Functional Heterogeneity

Variation at a scale that corresponds to the function of an ecological process or property (Li & Reynolds, 1995)

Heterogeneity

The quality or state of consisting of dissimilar elements, as with mixed habitats or cover types occurring on a landscape; opposite of homogeneity, in which elements are the same (Turner & Gardner, 2015)

Landscape

An area that is spatially heterogeneous in at least one factor of interest (Turner & Gardner, 2015)

Measured Heterogeneity

“A measure of the variability of an ecological property or process without explicit relations to variability in animal behavior or ecological function” (Li and Reynolds 1995, directly quoted from Fuhlendorf et al. 2017)

Scale

The spatial or temporal dimension of an object or process, characterized by both grain and extent (Turner & Gardner, 2015)