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Wetlands in the Pantanal, Brazil. Photo Credit: Shutterstock.

Explainer – Landscape and Spatial Ecology

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Overview:

This explainer article introduces the concept of spatial ecology. It will be helpful to read this article first before completing the accompanying three-part lesson series, as this article builds foundational understanding of the topic. The lessons in this series are available here:

- Lesson 1: Land Sparing versus Land Sharing
- Lesson 2: Landscape Design Contest
- Lesson 3: Integrating Resilience Theory to Understand Ecosystem Service Flows

Since the earliest days of ecology, scholars have recognized that space matters. But it was not until 1997 that the phrase spatial ecology was first coined (Tilman & Kareiva 1997). The distribution of ecological elements and processes across landscapes, in water bodies, and ocean floors influences the distribution of species, their interactions and access to resources. We know from years of ecological research that the amount of habitat and its diversity (habitat heterogeneity) are important ecologically —not only to biodiversity, but also to abundances, material flows, and the energy passed through food webs.

Additionally, Tilman, Kareiva, and others have shown, that it is not just the amount or type of tree cover or seagrass habitat that matters—it is how the pieces of nature are *clustered*. Their arrangement

can be highly fragmented into similar patches or a combination of different types of patches ("mosaics"). The distance between them may vary. Patches, such as pieces of land with different plant species, parcels of soil with different physical and chemical characteristics, and riffles vs. ponds within a stream may be contiguous (touching), could be randomly spaced, or even be over-dispersed on the land or water scape. These different patterns in spatial distributions influence what thrives where, foraging patterns of animals, the flow of propagules or water, and, of course, where humans have planted crops. The field of spatial ecology is closely related to many other branches or conceptual frameworks in ecology, including landscape ecology, island biogeography, meta-ecology, and movement ecology.

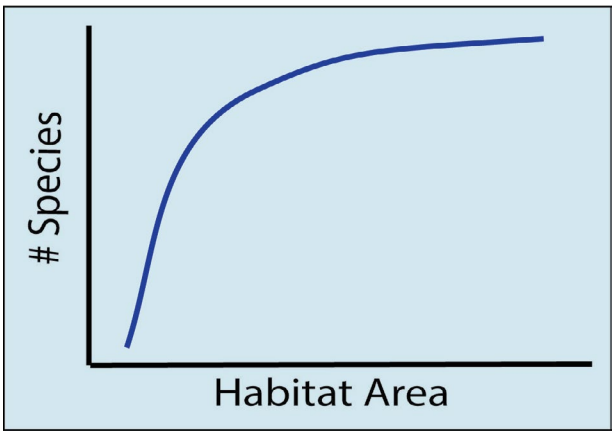
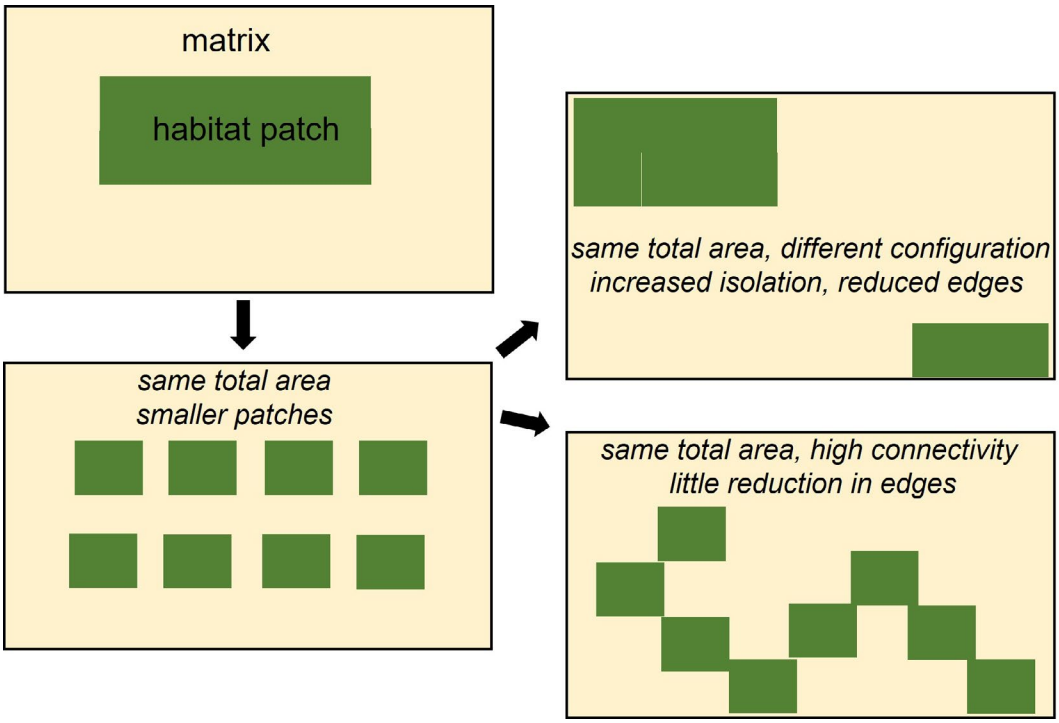


Illustration of the well-known relationship between area and species diversity. The increase in the number of species is often attributed, at least in part, to the fact that larger spatial scales are simply more likely to have different habitats (# patch types) and thus more niches for different types of organisms.



Schematic illustrating how patch configuration can vary even when total habitat area within a broader matrix of unsuitable habitat is held constant. Depending on the type of ecosystem (e.g., prairie land, forest, agroecosystem, coastal lagoon) and species of interest (e.g., plant, fish, insect), the different configurations will have various effects on them.

Landscape Ecology:

The most well-known of these frameworks is the field of landscape ecology. While often focusing on large-scale topics like deforestation, landscape ecology is fundamentally the study of spatial heterogeneity and how that influences species and flows of materials such as propagules, water, and nutrients (Turner & Gardner 2015). Extensive research has focused on identifying spatial patterns and the underlying drivers—physically, biologically, or both. Today, this work has shown that the spatial

distribution of landscape features can impact gene flow, local adaptation, the flow of energy due to changes in food webs, and more (references within With 2019).

With the increase in availability of advanced technologies, including remote sensing imagery and data from spatially distributed environmental sensors, both above and below water, researchers are using spatial statistics to discover factors driving spatial patterns, as well as what the spatial patterns themselves may represent ecologically. For example, patterns of tree cover may reflect saltwater intrusion into groundwater as sea level rises (Ury et al. 2021); the patch configuration of coastal vegetation may explain patterns in the distribution of organic matter stored in coastal sediments ("blue carbon," Asplund et al. 2021); and remotely sensed images of the distribution of flowers may provide a path for assessing pollinator resources (Gonzales et al. 2022).

Island Biogeographic and Meta-Population/Meta-Community Theories:

The theory of island biogeography championed by Robert MacArthur and E.O. Wilson (1967) has helped explain the distribution and biodiversity of species in many settings. This theory predicts that larger and less-isolated islands will have more species than smaller, isolated islands. This is related to the relationship between the ability of organisms to reach an island (immigrate) balanced by their extinction or emigration rates. The dispersal abilities of organisms and the distance between islands (patches) exert a strong influence on this balance, but extinction or emigration rates are also highly influenced by resource availability on the island. This theory was widely adopted by conservationists who have argued that protected and restored areas should be large, and that fragmentation—even when it does not result in loss of total habitat—should be avoided at all costs. Today, we know that even small, isolated patches of habitat play critical roles and have inherent ecological value (Wintle et al. 2019).

Meta-population theory posits that if a species is part of a population that is spread out over a region into multiple subpopulations, then the population is more stable, i.e., less prone to loss from the region ("extirpation") or loss globally ("extinction"). More recently, this theory has been extended beyond single species. Meta-community theory is focused on multiple scales and how dispersal and spatial interactions from local to regional scales influence ecological process, distributions of whole communities, and their dynamics (Logue et al. 2011). Meta-ecology focuses on the important role that fluxes of all types—water, wind, sediment, organisms—play in ecosystem health and dynamics over time. And these fluxes themselves can regulate other fluxes (Little et al. 2022). For example, the movement of sediment in a riverbed can influence the rates of oxygen flow into the sediments, which impacts the microbial and invertebrate communities that call the river home.

Spatial and Social Dynamics: The Frontier:

Nature provides many benefits to people. These ecosystem services are experienced by people locally and therefore, the spatial distribution of ecosystem elements—the ecological components and processes that support ecosystem services—are critically important socially. At the same time, the spatial distribution of humans and their activities influence the status of ecosystem services and often in a way that degrades their provision—a topic that has received a great deal of attention (Metzger et al. 2021). But mapping the provision and flow of ecosystem services is not easy and represents a major area of research. The implications are vast. If we understand how human activities like mining influence the supply and flow of services across space, we can consider new laws that may hold groups accountable for the loss of services. If we understand what ecological features are critical to the provision of services, we may be able to design landscapes to enhance those services and reverse inequities in the winners and losers (Bagstad et al. 2014).

Spatial ecology provides analytical methods to approach landscape design with the best possible outcomes for humans and their natural environments in urban, suburban, and rural areas. Human health is positively affected by access to green spaces, with measurable physical and mental health benefits from so called "nature doses" that reduce the "extinction of experience" that results from lives lived indoors in the built environment without access to green space. It is crucial for learners to be able to understand and use spatial ecology to measure, design, and implement more healthful interfaces between human infrastructure and green space. In addition, students will learn how complementary benefits, such as greater physical and mental health, local food production, and wildlife habitat may coexist in well-planned spatial ecologies across urban, suburban, and rural habitats.

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