BDC334

Biogeography & Global Ecology

Topic 5

Unified Accounting: Understanding Patterns in Diversity over Space and Time

Patterns in space and time

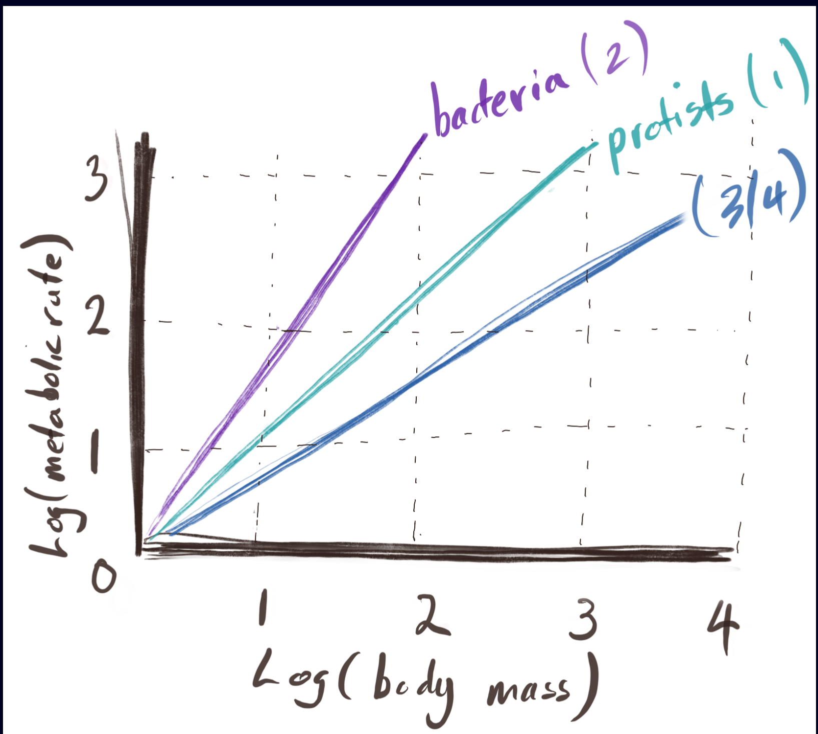
- studies across all scales of live (“mammoth, mule, marmot, or microbe” *sensu* Shade et al., 2018) revealed patterns (of communities) across landscapes
- species composition (richness), abundance per species
- these pattens vary in space …
- … and time

- you will have already seen the *distance decay* relationships in seaweeds, and you now know how to calculate it

Shade et al. (2018) Macroecology to unite all life, large and small. TREE.

Patterns in space and time

- ecological patterns of multicellular organisms
- since 2000s also in microbes
- do studies across these two scale show similar patterns?
- first evidence from metabolic scaling studies…



* "bacteria and archaea reveal scaling coefficient close to 2 (i.e., a quadratic increase of metabolic rate with body size"
* "metabolic rate is assumed to be limited by number of genes and proteins involved in metabolism (so that bigger bacteria have a disproportionately higher number of molecules participating in metabolic reactions)"

* "metabolic rate in protists scale proportionally to body size (i.e., the scaling coefficient is close to 1)"
* "supposedly limited by the number of mitochondria within the cell, leading to approximate proportionality between cell size and metabolic rate"

* "multicellular organisms indeed reveal 3/4 scaling"
* "limited by their ability to provide resources to all metabolically active cells, so that their metabolic rate is constrained by the structure of their transportation system, which leads to sublinear scaling, with coefficient close to ¾"

Important concepts in paper

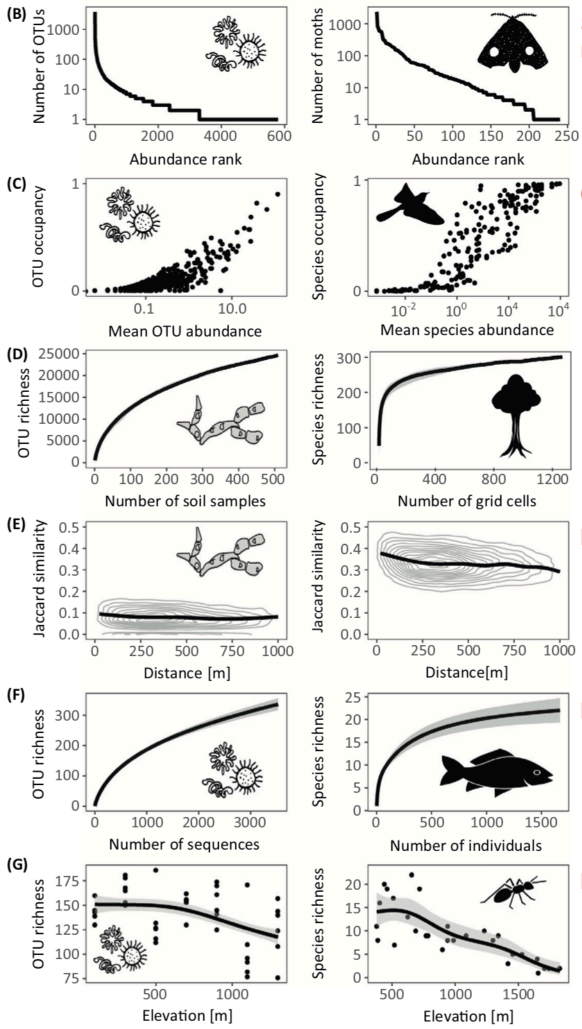
- Unified Currency: Individuals and Species
- Glossary (specifically highlighted items)
- Unified Accounting: Understanding Patterns in Diversity over Space and Time

The fundamental role of the site by species matrix

(A)

	Sample					
	A	B	C	D	E	F
Species 6	0	0	0	0	1	2
Species 5	0	1	0	0	0	0
Species 4	4	3	3	0	1	2
Species 3	25	11	23	8	25	10
Species 2	10	19	9	20	10	12
Species 1	0	0	0	0	5	6

	Species					
	1	2	3	4	5	6
Site A	0	10	25	4	0	0
Site B	0	19	11	3	1	0
Site C	0	9	23	3	0	0
Site D	0	20	8	0	0	0
Site E	5	10	25	1	0	1
Site F	6	12	10	2	0	2



Species-abundance distribution, or rank-abundance curves ✔

Occupancy-abundance curves ✔

Species-area curves ✔

Distance-decay curves ✔

Rarefaction curves

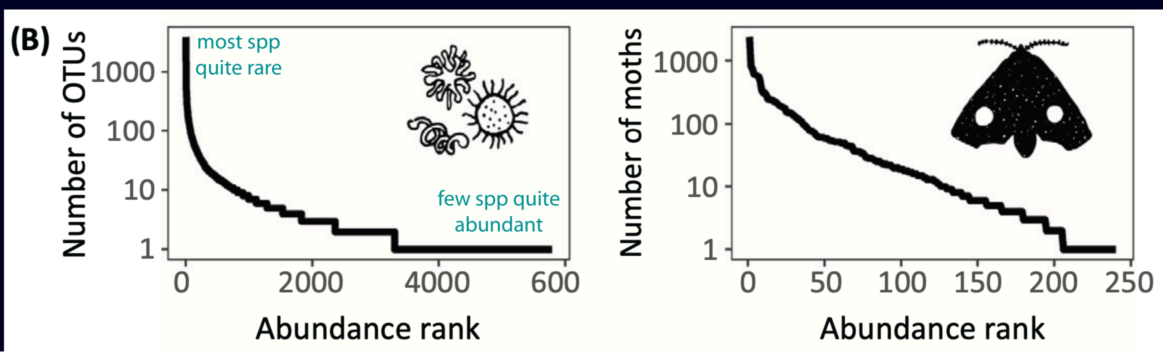
Elevation gradients ✔

Shade et al. (2018) Macroecology to unite all life, large and small. TREE.

Species-abundance distribution (rank-abundance curves)

"the number of individuals (N) of each species in a sample, and is often expressed as a relationship between the logarithm of N plotted against species rank (from the most to the least abundant species)"

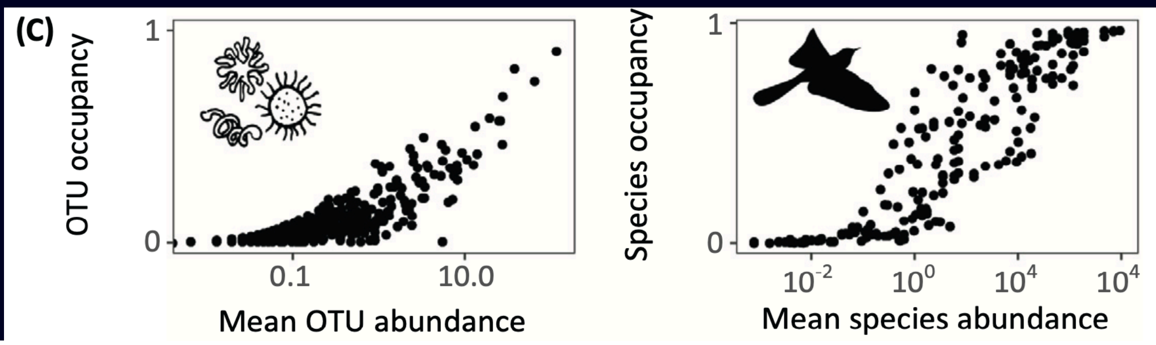
- it describes the *general tendency for communities to have a few highly abundant species and many species that are rare*
- it may be one of the true universal laws in ecology



Occupancy-abundance distribution

"*generally positive relationship between the mean abundance a species attains at individual sites, and the number or proportion of all sampled sites at which it is found*"

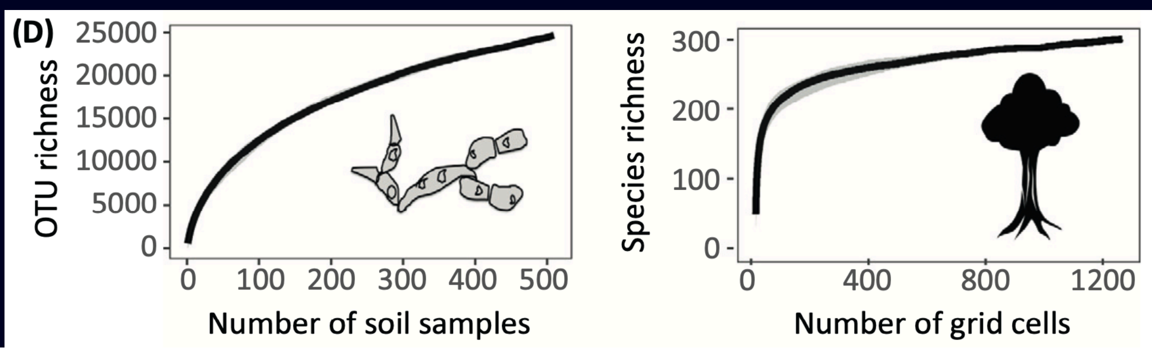
- occupancy: the number or proportion of sites in which a species is detected
  - *i.e.*, species that tend to have high abundance within one site also tend to occupy many sites, …
  - …while those that are rare at a particular site tend to not be detected in many sites
- deviations from a null hypothesis are suggestive of deterministic drivers of community structure



Species-area curves

generally an increase in the area covered by sampling (*e.g.* cumulative sum of representative quadrats representing the sampled contiguous 'unit') leads to an increase in species richness

- "can be used to predict and compare changes in diversity over increasing spatial extent"

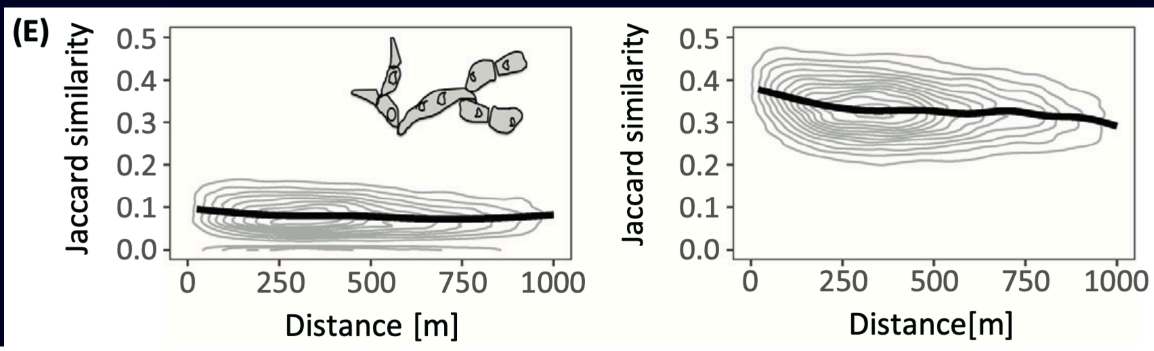


Distance-decay relationships

"assess how community similarity or beta diversity changes over space […] is used to address compositional turnover […] or shifts in relative abundance […] with distance from a reference community."

"The slope of the distance–decay relationship is interpreted as a rate of change over space, and there are macroecological studies as well as microbial-focused studies that have compared these rates."

E.g. see study by Smit et al. (2017)—next slide, and paper on iKamva… this leads directly onto environmental gradients



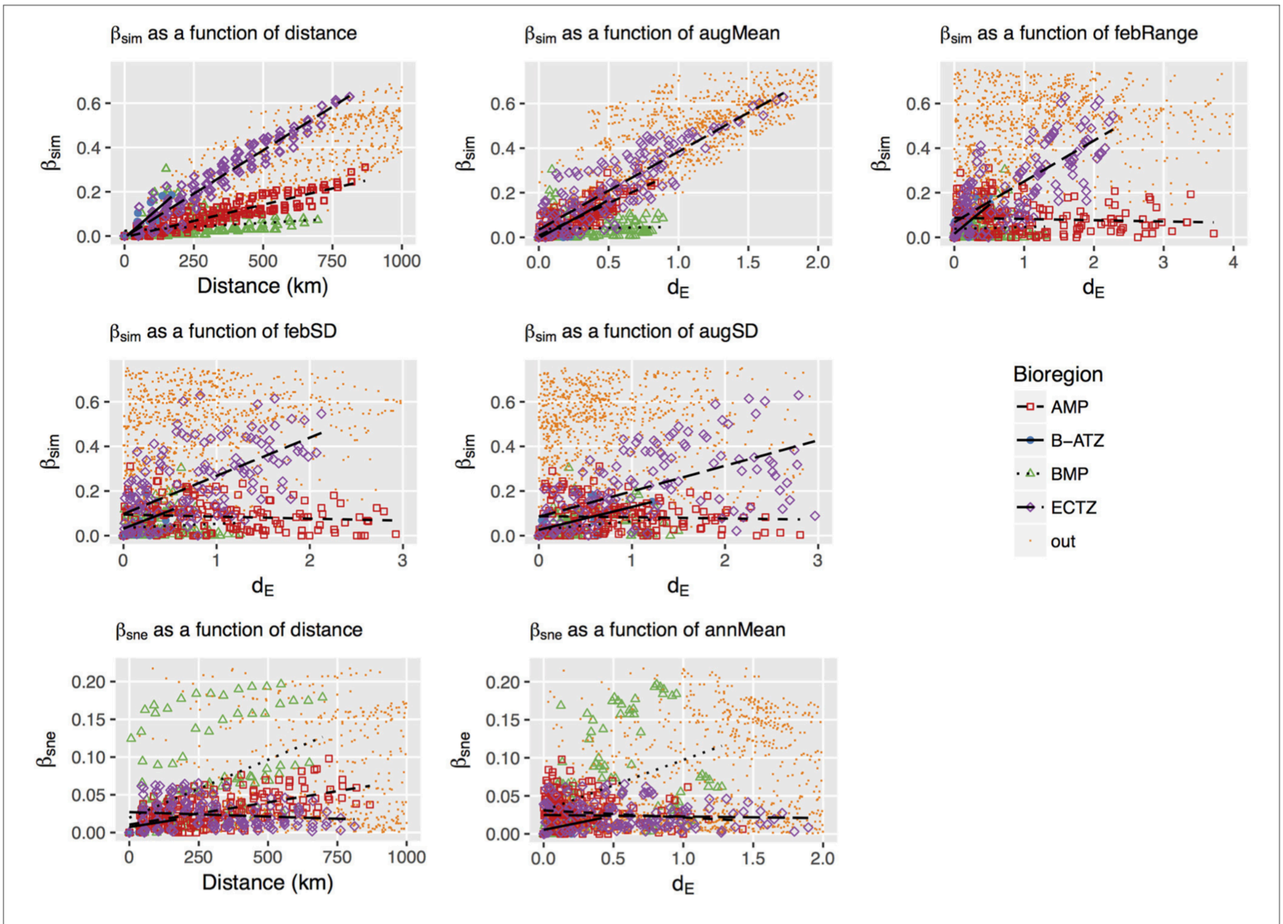


FIGURE 5 | Plots of the turnover (β_{sim}) and nestedness-resultant (β_{sne}) forms of β-diversity as a function of geographical or thermal distance between the coastal sections. The influential d_E variables (*augMean*, *febRange*, *febSD* and *augSD* for β_{sim}, and *annMean* for β_{sne}) were determined in the db-RDA procedure. β_{sim}, β_{sne}, d_E and geographical distance were calculated as differences between coastal section pairs, and data points representing section pairs falling between bioregions are colored yellow and labeled "out." The strengths and gradients of the regression lines indicated in the panels are presented in **Table 3**.

Smit et al. (2017)

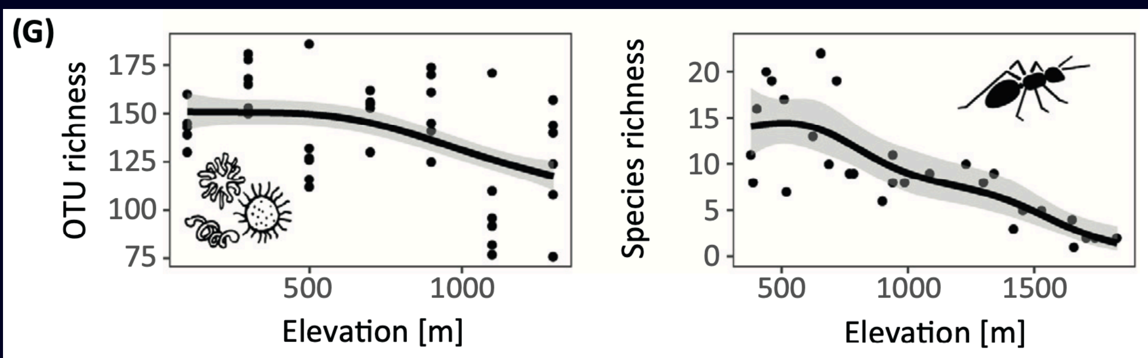
Environmental gradients

"The first four features of diversity matrices we have described above are intrinsic to the matrices. Each of these features can, as we have shown, be calculated just as readily for microbes as for macrobes. Once these aspects of diversity are estimated, they can be compared along geographic (e.g., *latitude and elevation) and [other] environmental* (e.g., *energy and disturbance) gradients ([to show] diversity gradients)."*

Diversity gradients (*e.g.* with elevation)

these aspects of diversity are estimated, they can be compared along geographic (e.g., latitude and elevation) and environmental (e.g., energy and disturbance) gradients

e.g. see study by Smit et al. (2017)—next slide, and paper on iKamva



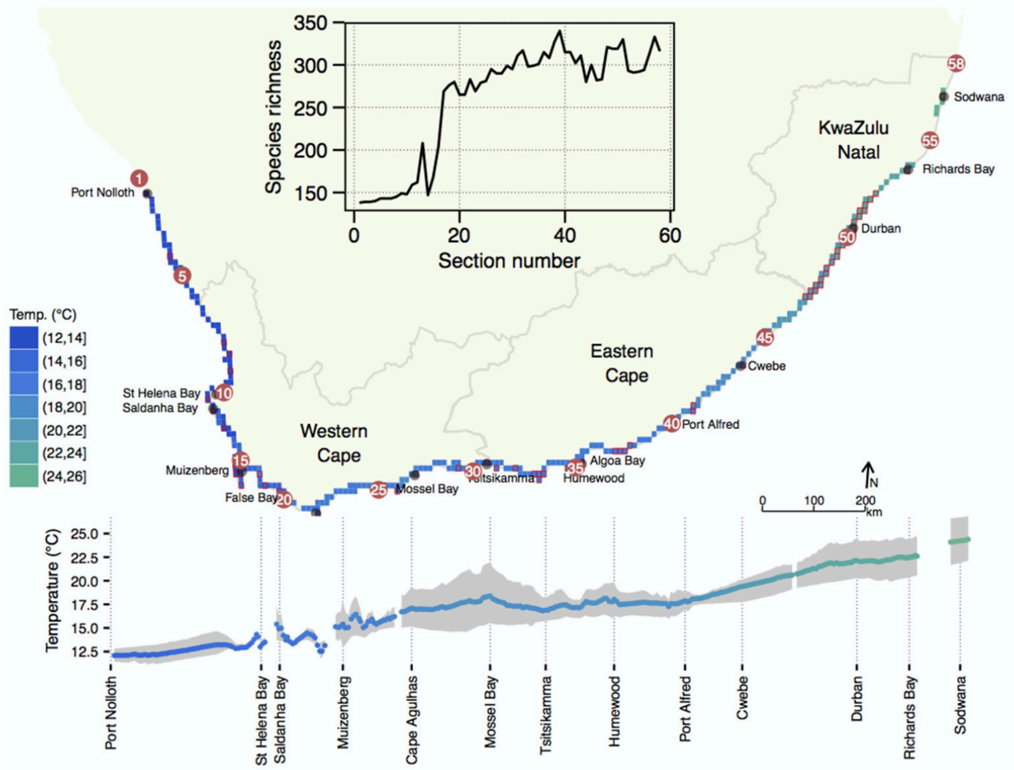


FIGURE 1 | Profile of mean annual temperature along the coast of South Africa. Profiles are indicated as a function of geographical position on a coastal map (**top**) and as a function of distance away from section **1** (**bottom**). The latter visualization also indicates the long-term minimum (mean August) and maximum (mean February) temperatures as a gray shaded area around the annual mean temperature. The inset shows the species richness of macroalgae along the coast. Note that although a detailed temperature profile is displayed here, further analyses in this paper proceed with temperature data interpolated to the 58 sections for which seaweed diversity data are available.

Smit et al. (2017)

frontiers in Marine Science

ORIGINAL RESEARCH
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Check for updates

Seaweeds in Two Oceans: Beta-Diversity

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Several species assembly mechanisms have been proposed to structure ecological communities. We assess the biogeography of seaweeds along 2,900 km of South Africa's coastline in relation to a thermal gradient produced by the Agulhas Current, and contrast this with the environmental structure created by the Benguela Current. We subdivided the coastline into "bioregions" to examine the regional patterning. To investigate the assembly mechanisms, we decomposed Sørensen's β-diversity into "turnover" (β_{sim}) and "nestedness-resultant" (β_{sne}) dissimilarities, and used distance-based redundancy analysis (db-RDA) to relate them to the Euclidean thermal difference, d_E, and geographical distance. Moran's eigenvector maps (MEM) were used as an additional set of spatial constraints. Variation partitioning was then used to find the relative strengths of thermal and spatially-structured thermal drivers. Spatial and environmental predictors explained 97.9% of the total variation in β_{sim} and the thermal gradient accounted for 84.2% of this combined pool. β_{sim} was the major component of overall β-diversity in the Agulhas Current region, suggesting niche influences (environmental sorting) as dominant assembly process there. The much weaker thermal gradient in the Benguela Current-influenced region resulted in a high amount of β_{sne} that could indicate neutral assembly processes. The intensification of upwelling during the mid-Pliocene 4.6–3.2 Ma (i.e., historical factors) were likely responsible for setting up the strong disjunction between the species-poor west coast and species-rich south and east coast floras, and this separation continues to maintain two systems of community structuring mechanisms in the Atlantic and Indian Ocean influenced sides of South Africa.

Keywords: beta-diversity, species assembly, seaweed, turnover, nestedness-resultant, Benguela Current, Agulhas Current

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1. INTRODUCTION

The assembly processes that structure biodiversity across a range of scales form the theme of macroecology (Chave, 2013). This paper deals with the composition of seaweed assemblages along the ~2,900 km South African coastline, including the identification, description and explanation for the spatially-structured patterns at scales from 100s to 1,000s of kilometers. Inshore conditions along this coastline range from cool through warm temperate to fringe tropical (Bolton and Anderson, 2004; Bolton et al., 2004), and are influenced by two major ocean currents in two oceans that set up a strong thermal gradient along the shore (Smit et al., 2013). We investigate how a gradient in seaweed community composition may have arisen in response to this temperature gradient (e.g., Qian and Ricklefs, 2007),

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The distance decay of similarity in biogeography and ecology

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Abstract

Aim Our aim was to understand how similarity changes with distance in biological communities, to use the distance decay perspective as quantitative technique to describe biogeographic pattern, and to explore whether growth form, dispersal type, rarity, or support affected the rate of distance decay in similarity.

Location North American spruce-fir forests, Appalachian montane spruce-fir forests.

Methods We estimated rates of distance decay through regression of log-transformed compositional similarity against distance for pairwise comparisons of thirty-four white spruce plots and twenty-six black spruce plots distributed from eastern Canada to Alaska, six regional floras along the crest of the Appalachians, and six regional floras along the east–west extent of the boreal forest.

Results Similarity decreased significantly with distance, with the most linear models relating the log of similarity to untransformed distance. The rate of similarity decay was 1.5–1.9 times higher for vascular plants than for bryophytes. The rate of distance decay was highest for berry-fruited and nut-bearing species (1.7 times higher than plumose-seeded species and 1.9 times higher than microseeded/spore species) and 2.1 times higher for herbs than woody plants. There was no distance decay for rare species, while species of intermediate frequency had 2.0 times higher distance decay rates than common species. The rate of distance decay was 2.7 times higher for floras from the fragmented Appalachians than for floras from the contiguous boreal forest.

Main conclusions The distance decay of similarity can be caused by either a decrease in environmental similarity with distance (e.g. climatic gradients) or by limits to dispersal and niche width differences among taxa. Regardless of cause, the distance decay of similarity provides a simple descriptor of how biological diversity is distributed and therefore has consequences for conservation strategy.

Keywords
Similarity, spatial dependence, distance decay, biological diversity, boreal forest.

INTRODUCTION

The similarity between two observations often decreases or decays as the distance between them increases, a pattern long recognized in the geographical literature and once called 'the first law of geography' (Tobler, 1970). That early interest in the distance decay of similarity led subsequently to formal analyses of spatial autocorrelation and eventually to the field of geostatistics, a field that has grown tremendously in the last decade (Cressie, 1993).

While ecologists and biogeographers have rarely referred to distance decay *per se*, a negative relationship between distance and similarity is implicit in several ecological and evolutionary phenomena. For example, species turnover along spatial environmental gradients produces a decrease of similarity with distance (e.g. Whittaker, 1975; Cody, 1985). Mass effect (Shmida & Ellner, 1984), source-sink dynamics in metapopulations (Hanski & Gilpin, 1991), and supply side ecology (Roughgarden, Gaines & Pacala, 1987) have stressed the importance of dispersal and therefore distance in explanations

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Important concepts

Knowledge:

- recap *α*-, *β*-, and *γ*-diversity
- focus on *β*-diversity
- influences of *β*-diversity, *i.e.*
  - number of species remain constant, but species change (species turnover, β_{sim})
  - same species (pool A and pool B), but pool B a reduced subset i.t.o. number of species of pool A (nestedness-resultant, β_{sne})
- environmental gradients
- first mention of neutral processes

Application:

- in-depth understanding of how species and environment tables are made into (dis-)similarity matrices, of how *α*-, *β*-, and *γ*-diversity are calculated from the tables and matrices, how to interpret the (dis-)similarity matrices, and how the presence of gradients can be determined

Important concepts

Knowledge:

- recap distance decay and gradients; how to determine these from matrices
- distance decay resulting from i) niche difference model along environmental gradients; ii) the model of temporal and spatial constraint
- ask questions about how species with different dispersal types/growth forms influence rates of compositional change (*i.e.* β-diversity)
- scale dependence, *i.e.* grain and extent
- models for distance decay:
  - environmental distance
  - the spatial template
  - niche breadth and overlap (ref. unimodal species distribution models and coenoclines)
  - dispersal ability

Important concepts

Application:

- extend your understanding of environment and species tables and the derived distance matrices
- apply your understanding to the kinds of knowledge that environmental and species dissimilarity matrices can provide
- derive a mechanistic understanding of the assembly process behind community structure across landscapes

"*Knowledge is not a resource we simply stumble upon. It's not something that we pluck out of the air. Knowledge is created. It is coaxed into existence by thoughtful, creative people. It is not a free good. It comes only to the prepared mind*".

—Frank H. T. Rhodes, Speed Bumps on the Road Ahead, Trusteeship, May/June 1999