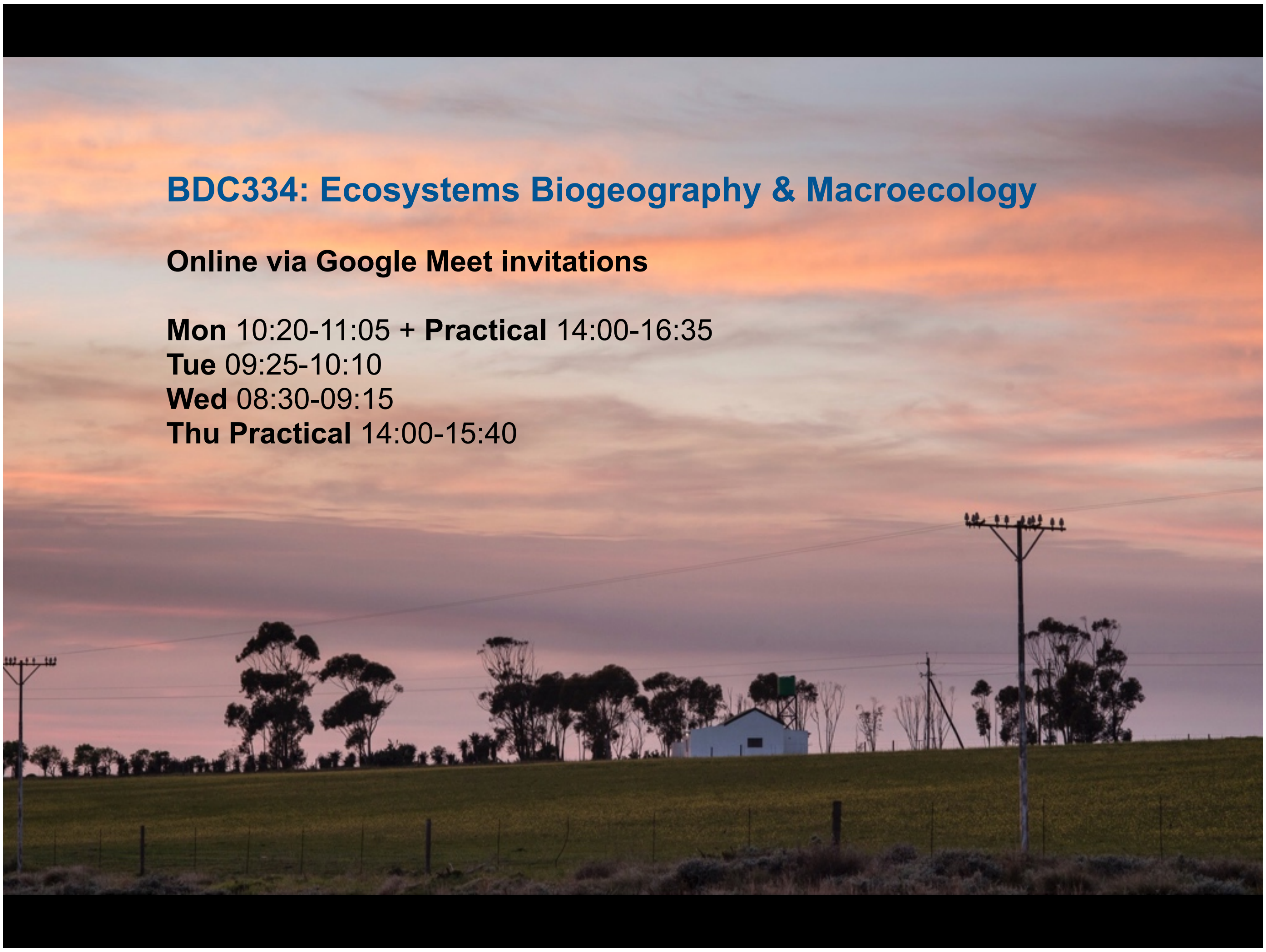

BDC334
Biogeography &
Global Ecology


BDC334: Ecosystems Biogeography & Macroecology
Online via Google Meet invitations
Mon 10:20-11:05 + Practical 14:00-16:35
Tue 09:25-10:10
Wed 08:30-09:15
Thu Practical 14:00-15:40

BDC334

Biogeography & Global Ecology

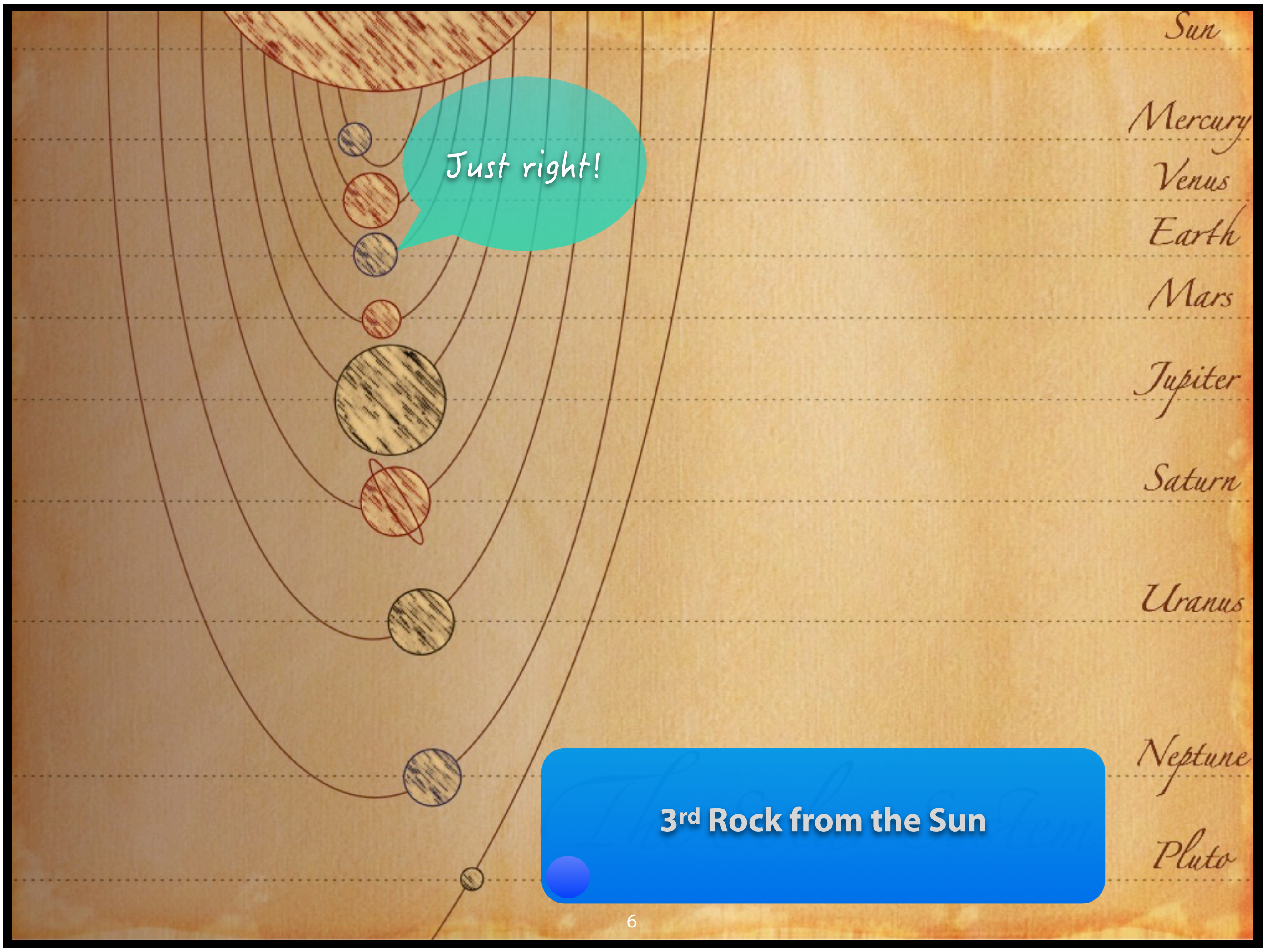
Topic 1

Prof AJ Smit

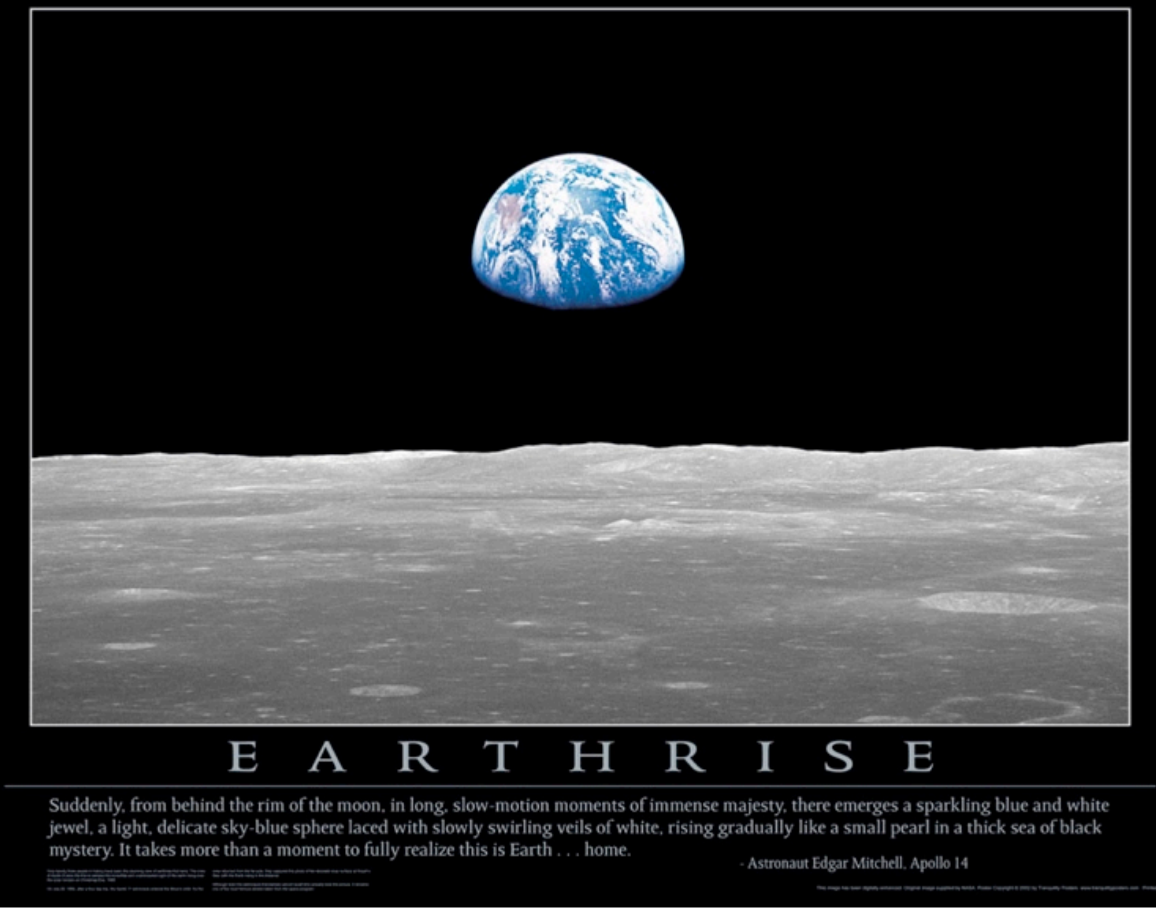
- Conceptual overview of **ecosystems and their characteristics** and drivers
- **Gradients** in diversity
- **Anthropogenic and natural impacts** on ecosystem integrity
- **Exploration** of selected marine and terrestrial ecosystems

Prof Stephen Boatwright

- Continental drift and glaciation
- Theories of biogeography and biogeographic reconstruction
- Phylogeography
- Interactions of body and population size on diversity and distribution
- Island biogeography theory and its applications for conservation



Macroecology



Macroecology—topics

- what is macroecology…
  - …in contrast to more 'traditional' ecology (*i.e.* population and community ecology)?
- concepts of diversity
- properties of species and environmental datasets
- (dis-)similarity matrices; interpreting (dis-)similarity matrices
- theories of macroecology: unified theory, niche-, neutral-, metabolic-, *etc*.
- macroecology: unification of marine and terrestrial ecology?
- what use is biodiversity?
- ecological goods and services
- global change and sustainability
- macroecology: infectious diseases

biology letters
Community ecology

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Meeting report

What is macroecology?

Sally A. Keith[1], Tom J. Webb[3], Katrin Böhning-Gaese[4], Sean R. Connolly[1,2], Nicholas K. Dulvy[5], Felix Eigenbrod[6], Kate E. Jones[7], Trevor Price[8], David W. Redding[7], Ian P. F. Owens[9] and Nick J. B. Isaac[10,*]

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The symposium 'What is Macroecology?' was held in London on 20 June 2012. The event was the inaugural meeting of the Macroecology Special Interest Group of the British Ecological Society and was attended by nearly 100 scientists from 11 countries. The meeting reviewed the recent development of the macroecological agenda. The key themes that emerged were a shift towards more explicit modelling of ecological processes, a growing synthesis across systems and scales, and new opportunities to apply macroecological concepts in other research fields.

Keywords: macroecology; spatial scale; process-based model; theory; ecosystem; disease

1. INTRODUCTION

The idea of macroecology as a distinct field of research has been around for more than two decades [1] and was conceived as a response to the realization that small-scale local processes alone were not able to fully explain the abundance and distribution of species. This led to a broader perspective that searched for generalized patterns at large spatial and temporal scales [2], characterized by the search for statistical relationships to explain the distribution of biodiversity from a historical and geographical perspective [2,3]. Ten years ago, a symposium of the British Ecological Society (BES) was convened with the aim of reconciling divergent perspectives on large-scale ecological patterns. This 'Causes and Consequences' symposium set the tone for a decade of research in macroecology [4].

Recently, a macroecology special interest group of the BES was formed. The inaugural meeting brought together a diverse group of researchers to review the evolution of macroecology as a research discipline, highlight recent notable developments and explore new applications. Nick Isaac described the aims of the BES macroecology group, which include providing a forum to share ideas and concepts, promoting data access and standards, showcasing methodological advances and setting the agenda for future research. This was followed by a keynote address from Ian Owens, who presented a personal perspective on the development of macroecology throughout the past decade. Owens argued that macroecology has been revolutionized by a combination of the availability of large molecular phylogenies, high-resolution datasets on geographical distribution, extensive computational power and new analytical approaches. As a result, rapid advances have been made towards answering many of the questions that originally occupied macroecologists, such as variation in body size, geographical range dynamics, and the role of neutral processes. These advances have brought with them a new set of opportunities and challenges [5], many of which were recurrent themes during the day. These themes are summarized below.

2. FROM PATTERN TO PROCESS

The strongest theme that percolated all of the talks was the increased emphasis on the processes that drive biodiversity patterns (see also [5]). This theme was introduced by Owens, who outlined a shift from describing patterns to a search for mechanistic understanding. In other words, the way we address key research questions has changed, notably by the increased use of process-based conceptual models of biodiversity [6]. This theme was further developed by Sean Connolly, who identified a mismatch between the biological reasoning that underpins hypotheses about the drivers of macroecological patterns and the statistical models that are actually fitted to data. Connolly illustrated how this has hindered progress in our understanding of large-scale species-richness gradients, and demonstrated how models based on biological processes can be used to derive testable hypotheses [7]. Although macroecology is relatively advanced in its use of statistical methods, the theoretical basis of the predictions involved is sometimes poorly developed. Connolly argued that the explicit formulation of theoretical models, and the robust derivation of statistical expectations from those models, is one of macroecology's most significant challenges.

Katrin Böhning-Gaese provided a clear demonstration of how incorporating local processes can influence large-scale patterns of species distributions. For example, projections of the impact of climate change on bird species richness yielded very different results when biotic interactions with tree species were taken into account [8]. Similarly, Trevor Price emphasized that both biotic and abiotic factors can explain large-scale diversity gradients. He showed how niche conservatism is not enough to explain diversity gradients of Himalayan birds, unless competitive interactions are incorporated. Kate Jones and David Redding showed how the spread of a zoonotic disease (Lassa fever) can only be understood with

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Macroecology — definition

"*Macroecology is the study of the mechanisms underlying general patterns of ecology across scales*" — Shade, A., Dunn, R.R., Blowes, S.A., Keil, P., Bohannan, B.J., Herrmann, M., Küsel, K., Lennon, J.T., Sanders, N.J., Storch, D. and Chase, J., 2018. Macroecology to unite all life, large and small. Trends in ecology & evolution.

Review concepts of ecology and macroecology

Review concepts of ecology and macroecology

- ‘traditional’ ecology—focus on the ‘local’ scale… concepts to recap and understand
- biodiversity … se IUCN definition
- populations and communities
- ecology
- population ecology and community ecology
- properties of communities (see concepts of diversity and diversity indices in later topics on the matters…)

eventual realisation that small scale processes are inadequate at fully describing the distribution and abundance of species

IUCN definition of biodiversity

The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity).

Macroecology—regional to global scales

- achieved by leveraging advances in **molecular phylogenetics**, **high-resolution datasets** of abiotic and biotic variables, enormous **computational power**, and new **numerical approaches**
- **sharing of ideas** and **access to open data**
- questions around variations in **body size**, **diversity**, **abundance**, **geographical range dynamics**, the role of **neutral processes**, *etc.*
- the development of unified theories of macroecology came to the fore in the past two decades
  - …from which flowed the development of an appropriate statistical framework

Macroecology—patterns to processes

- ‘traditional’ ecology focussed on patterns, and in macroecology there has been a shift towards finding mechanistic explanations for the processes that result in the patterns in biodiversity
- necessitated a reconciliation of the biological reasons that form the basis of hypotheses about patterns and processes with statistical models that are able to explain them
- local species interactions explain broad-scale patterns in species distributions
- this lead to attempts to develop unified theories (*i.e.* predictive) of ecology

Macroecology—applications

- "the influence of macroecology has been unusually broad and deep at the interface of science and policy, especially around land-use, climate change and biodiversity loss"
- "*macroecological ideas are gaining traction in mapping ecosystem services (MES) and epidemiology*"
  - epidemiology, *e.g.* biodiversity may regulate the emergence of diseases, thus benefitting human health

TREE 2422 No. of Pages 14 ARTICLE IN PRESS

Trends in Ecology & Evolution

CellPress REVIEWS

Opinion

Macroecology to Unite All Life, Large and Small

Ashley Shade,[1,*] Robert R. Dunn,[2,3,4] Shane A. Blowes,[4] Petr Keil,[4] Brendan J.M. Bohannan,[5] Martina Herrmann,[4,6] Kirsten Küsel,[4,6] Jay T. Lennon,[7] Nathan J. Sanders,[3,8] David Storch,[9,10] and Jonathan Chase[4,11]

Macroecology is the study of the mechanisms underlying general patterns of ecology across scales. Research in microbial ecology and macroecology have long been detached. Here, we argue that it is time to bridge the gap, as they share a common currency of species and individuals, and a common goal of understanding the causes and consequences of changes in biodiversity. Microbial ecology and macroecology will mutually benefit from a unified research agenda and shared datasets that span the entirety of the biodiversity of life and the geographic expanse of the Earth.

It Is Time to Unite

Every individual, be it a mammoth, mule, marmot, or microbe, occupies a particular space and exists at a particular time. The number of marmots varies from place to place, as does the number of any particular microbial taxon. Identifying and counting individuals, regardless of where they reside in the tree of life, is at the crux of understanding **biodiversity** (see Glossary) and the natural world [1]. Decades of research have revealed that variation in the number of individuals of different species in space and time can give rise to a number of patterns, such as **species abundance distributions** and **species–area relationships**. These variables form the foundations of research in **macroecology**, biogeography, and community ecology. From the biodiversity patterns that emerge from counting individuals and species, many of the most general rules of ecology and evolution emerge [2–4].

Until recently, the field of macroecology almost exclusively involved the study of large, multicellular organisms (also known as macroorganisms or macrobes), especially plants, vertebrates, and a few charismatic invertebrate groups like butterflies. However, in the early 2000s, the advent of new (and increasingly less-expensive) molecular tools inspired some ecologists to ask the simple question: do microscopic forms of life play by the same rules as plants and animals? Initially, discussion centered around whether microbes exhibited macroecological patterns that were common in macrobes [5]. For example: do microbes exhibit distance–decay relationships [6,7]? Are there elevational gradients in microbial diversity [8,9]? Do places with high macrobial diversity also have high microbial diversity [10,11]? An especially robust debate commenced around the ideas of dispersal limitation and whether microbial taxa where found everywhere [12] and then selected by the environment, which initiated new research on microbial biogeography (e.g., [13–15]). Despite these initial lines of inquiry, microbial ecology has evolved largely independently from macroecology and the two fields are not yet well integrated. Their continued separation seems to arise for historical and cultural reasons rather than inherent differences.

There is a need to unify microbes and macrobes to ask overarching questions and to test general theories about the rules and mechanisms underpinning patterns in ecology across

Highlights

Macroecology is the study of the mechanisms underlying general patterns of ecology across scales. A major focus of research within macroecology is understanding biodiversity patterns and their underlying processes. The field of macroecology has been biased towards charismatic macroorganisms (also known as macrobes), and has largely ignored insights and breadth that can be gained by considering microorganisms.

We argue that microbial ecology and macroecology are united by common currencies (individuals and species), as well as by comparable challenges of documenting their distributions and abundances.

Future directions that would lead to a unified macroecology include: expansion of spatial and temporal scales to encompass the diversity of microbes; synthesis-driven, systematic comparisons of macrobial and microbial macroecological patterns and processes; and support of interdisciplinary approaches in training, publishing, and funding to equitably value macrobial and microbial insights into understanding the rules and exceptions of life.

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Macroecology—the ‘large’ scale

- **generalise patterns** to large high-level taxonomic groupings, large spatial scales, and/or long temporal scales
  - “*this implies that macroecology embraces and overlaps with macroevolution and palaeoecology, […]*”
- strong emphasis on the processes that drive macroecology
  - move away from description of patterns towards mechanistic explanations

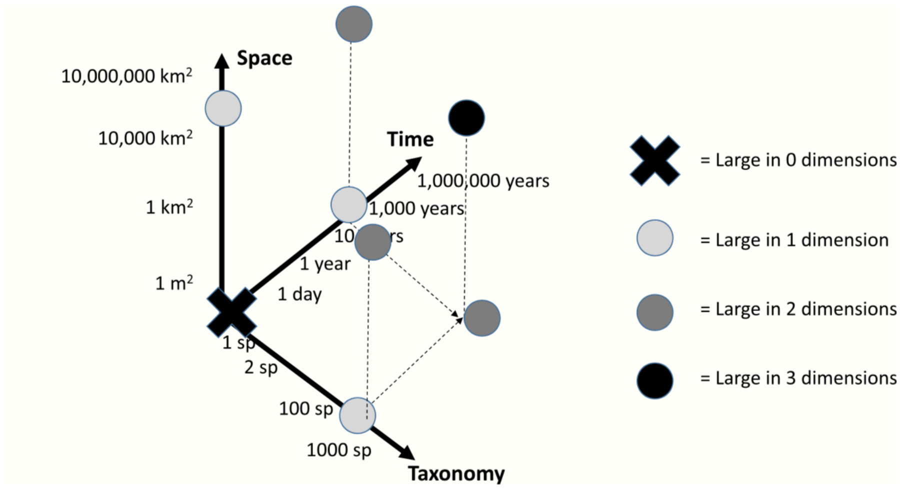

FIGURE 1 How many dimensions does it take to be large scale? Space, time and taxonomy are three dimensions of every ecological (biological?) system. A system can be relatively large or small in each of these dimensions. To qualify as large scale, how many dimensions must be large? [Colour figure can be viewed at wileyonlinelibrary.com]