MACROECOLOGY

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Summary

The aim Ecology is to understand patterns of distribution and abundance of organisms on Earth, as well as the underlying mechanisms responsible for the origin and maintenance of these patterns. Macroecology is a field of ecology characterized by a statistical investigation of the relationship between the dynamics and interactions of species populations that have been studied on small scales by ecologists and processes of speciation, extinction and expansion and contraction of ranges that have been investigated on much larger scales by biogeographers, paleontologists and macroevolutionists. In this chapter we describe the main aspects of the modern macroecology research program, focusing on the main scientific problems evaluated by this research field. We also emphasize why tropical regions are challenging to macroecological studies and, although macroecology is still in its infancy, hopefully it will allow a deeper understanding of patterns and processes of biological diversity and provides the theoretical basis for developing efficient broad-scale conservation strategies.

1. Introduction

The main purpose of ecology is to understand patterns of distribution and abundance of organisms on Earth, and the underlying mechanisms responsible for these patterns. However, given the high complexity of ecological system, many different (but not mutually exclusive) approaches have been used to study these systems since early XX century, and one of the main dichotomies is related to geographical and evolutionary scales. Most of classical approaches in Ecology, derived from basic demographic and population dynamic equations (e.g., Lotka-Volterra equations), were developed at spatial and temporal local scales, and eventually projected to larger scales. On the other hand, it is possible to follow an opposite path and study the overall patterns at broad scales, without paying attention to details at local scales (e.g., equilibrium theory of island biogeography). These opposite approaches co-existed for a while in ecology, only in the second half of the XX century recently they started to be fused in the new context of macroecology.

The term "Macroecology" was proposed by James Brown and Brian Maurer in 1989, in a paper published in *Science*, and they define it as "*...a non-experimental, statistical investigation of the relationship between the dynamics and interactions of species populations that have been studied on small scales by ecologists and processes of speciation, extinction and expansion and contraction of ranges that have been investigated on much larger scales by biogeographers, paleontologists and macroevolutionists"*.

More recently, in the late 1990's decade, it has been argued that macroecology also can be understood as the analysis of a large number of "ecological particles", so that the research program should focus on the "…*statistical distribution of variables among large collections of equivalent, but not identical, units, such as individual organisms within species or species within communities or biogeographic regions*". Thus, because of the broad scale issues involved, macroecology can be viewed now as a unifying conceptual and methodological framework for understanding patterns of abundance and distribution, incorporating advances from a wide range of areas of scientific knowledge, including ecology, biogeography, evolutionary biology, population genetics, and physiology.

The number of studies in macroecology increased exponentially since the early 1990's (Figure 1), although it is in fact difficult to evaluate the growth of this integrative framework based on a simple scientometric search. Since macroecology develops upon a series of previous and now classical studies in community ecology from 1960's-1970's, it encompasses now different research lines. Indeed, although the definition formulated in 1989 for the field was a somewhat restrictive, the macroecology research program was later naturally expanded to incorporate many other classical research areas from community ecology and biogeography, including the species-area relationships, latitudinal diversity gradients, island biogeography and ecogeographical patterns, such as Bergmann`s rule. Thus, there is now a high heterogeneity in the research programs associated with the term macroecology.

The heterogeneity in the macroecology research program and the old history of investigation of some of the patterns, as well as the multiplicity of patterns and potential underlying ecological mechanisms behind them, led to the development of attempts to unify the field from first principles. Examples include J. H. Brown`s new metabolic theory of ecology, B. McGill and C. Collins` unified principles based on the relationship between abundance and distribution and Price`s fusion of macroecology and evolution. At the same time, it is important to be caution about linking patterns and processes, since neutral and null dynamics can also generate macroecological structures, as pointed out by G. Bell.

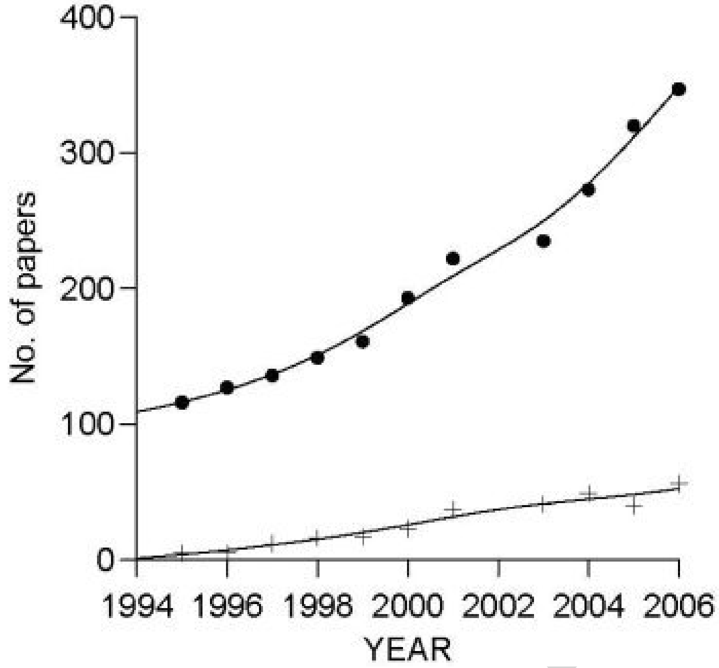

Figure 1. Increase in the number of published papers per year indexed in Thomson Instituto (Web of Science) between 1995 and 2006, using “macroecology” as a keyword (+) and using a more general definition, and using the terms "macroecology", "geographic range", "latitudinal gradients", “species-area relationship" "Bergmann's rule", as simultaneous keywords (●).

Although the current macroecology research program is clearly based on these early developments, it is important to stress the differences between the original studies and their “modern” counterparts. It is beyond the scope of this paper to review each detail of these studies, but it is possible to recognize general trends towards more processes-based approaches, under a more mechanistic basis (or at least a deeper attempt to achieve this mechanistic basis). These advances were possible both because of a clearer understanding of the theoretical basis ecological systems dynamics and due to advances in data analysis and acquisition at broad spatial and temporal scales. At the same time, it is important to consider that attempts to unify patterns and processes should take into account the multiple and hierarchical components due to variations in spatial and temporal scales (see the excellent papers by R. J. Whittaker and colleagues, T. Blackburn and K. Gaston, and C. Rahbek, on this subject). At the same time, biodiversity crisis forced ecologists to study systems at broader scales, in an attempt to solve conservation problems at regional, national and global spatial scales.

Besides providing significant information to ecology development as a whole, studying patterns in the individuals and species distributions across space have also contributed to decipher the forces that structure and maintain biodiversity. Such improvement in the theoretical framework shows important practical applications in management and conservation of biodiversity. We can highlight, for example, better predictions of species extinction rates or vulnerability levels under perturbations, at regional scales. On the other hand, it will also help to understand properly biological invasions under the perspectives of both invasive species and also invaded habitats. Moreover, this macroecological approach can also allow more effective land protection policies, the design of more efficient and accurate census strategies, and more effective estimates of species richness from sparse census data. Finally, it will likely to contribute to our predictions about how global climate changes will disturb current biodiversity patterns, as pointed out by M. B. Araújo and C. Rahbek in 2006, and by J. Kerr and colleagues in 2007.

Here we describe the main current aspects of the macroecology research program, mainly in terms of the main scientific problems evaluated by this research field. We also emphasize why tropical regions are challenging to macroecological studies. The macroecology research program it is still in its infancy, but hopefully it will allow a deeper understanding of patterns and processes of life or Earth and provides the theoretical basis for developing efficient broad-scale conservation strategies.

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Biographical Sketches

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