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ORIGINAL PAPER

What is the shape of the fundamental Grinnellian niche?

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Abstract
Since it was defined by Hutchinson, in 1957, the fundamental niche has been assumed, implicitly or explicitly, to have some convex shape. This assumption requires some critical analysis. In this work, we examine the special case of Grinnellian niches (those composed by sets of points of non-interactive variables in multidimensional spaces). We show that annual species in seasonal environments are likely to have very non-convex shapes, and be composed not of sets of points, but of sets of trajectories. We also examine under what circumstances trajectories may be approximated using sets of points. It appears to be the case that the breadth of requirements at each stage in the life history is a key parameter. We conclude by comparing the situation with perennial species.

Keywords Fundamental niche · Existing niche · Realized niche · Life history · Seasonal environments

Introduction

In the last 20 years, correlative estimation of species' environmental requirements (an activity known as ecological niche modeling, or "ENM") has increased dramatically, with now hundreds of papers published yearly in this area (Jiménez-Valverde et al. 2008; Guisan et al. 2013). ENM is often a step en route to estimating the geographic distribution of a species (termed species distribution modeling, or "SDM"). However, the non-geographic objects estimated by ENM methods are interesting in themselves, since they can be interpreted as approximations to classic multivariate ecological niches; getting these approximations "right" is also crucial to any transfer to other regions or to future or past conditions (Peterson et al. 2011).

The explosive growth of ENM and SDM coincided—probably causally—with a point in time at which a number of organizations began making massive amounts of data documenting presences of species available online (Soberón et al. 1996; Graham et al. 2004; Chapman 2005b), and when global data characterizing environments (e.g., climate, topography) also became available in mass quantities (Hijmans et al. 2005). By extracting values of environmental variables from the localities where a species is recorded as present, reconstruction of some aspects of the "niche" becomes possible (Araújo and Guisan 2006). Many interpretations exist for the term "niche" (Chase and Leibold 2003; McInerny and Etienne 2012), with a regrettable proliferation of poorly defined variations. In ENM and in this contribution, we use what has been termed a Grinnellian interpretation (Jackson and Overpeck 2000) that focuses on conditions necessary for existence (rather than on responses of species), and variables that are non-interactive with the presence of the species in question (e.g., climate, as opposed to interactive variables like resource abundance). Restricting niche variables to non-interactive dimensions allows the use of simple sets as niche representations (Peterson et al. 2011), rather than the more complex phase-space isoclines that are needed when variables interact with one another (Chase and Leibold 2003). Of course, the fitness of a population cannot possibly be a function only of conditions: without resources, a population will be extirpated. We are assuming that interactive resources are available in sufficient quantities to the population,