

RESEARCH
PAPER

How are tree species distributed in climatic space? A simple and general pattern

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ABSTRACT

Aim Although many factors undoubtedly affect species geographic distributions, can a single, simple model nonetheless capture most of the spatial variation in the probability of presence/absence in a large set of species? For 482 North American tree species that occur east of the Rocky Mountains, we investigated the shape(s) of the relationship between the probability of occupancy of a given location and macroclimate, and its consistency among species and regions.

Location North America.

Methods Using Little's tree range maps, we tested four hypothetical shapes of response relating occupancy to climate: (1) high occupancy of all suitable climates; (2) threshold response (i.e. unsuitable climates exclude species, but within the thresholds, species presence is independent of climate); (3) occupancy is a bivariate normal function of annual temperature and precipitation; and (4) asymmetric limitation (i.e. abiotic factors set abrupt range limits in stressful climates only). Finally, we compared observed climatic niches with the occupancy of similar climates on off-shore islands as well as west of the Rockies.

Results (a) Species' distributions in climatic space do not have strong thresholds, nor are they systematically skewed towards less stressful climates. (b) Occupancy can generally be described by a bivariate normal function of temperature and precipitation, with little or no interaction between the two variables. This model, averaged over all species, accounts for 82% of the spatial variation in the probability of occupancy of a given area. (c) Occupied geographic ranges are typically ringed by unoccupied, but climatically suitable areas. (d) Observed climatic niche positions are largely conserved between regions.

Main conclusions We conclude that, despite the complexities of species histories and biologies, to a first approximation most of the variation in their geographic distributions relates to climate, in similar ways for nearly all species.

Keywords

Abiotic stress, ecological niche, Gaussian response curve, geographic range, habitat suitability, northern range limit, plants, potential range size, probability of occurrence, species distribution modelling.

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INTRODUCTION

Robert MacArthur (1972, p. 127), in his classic work *Geographical Ecology*, wrote, 'Patterns on islands (Chapter 5), of species diversity (Chapter 7), and of tropical communities (Chapter 8) are already clear and even moderately well understood, while patterns of single species' ranges still seems to be catalogues of special cases'. Textbook wisdom indicates that species distribu-

tions can be affected by factors including climate, soil, competition, predation, parasitism, mutualism, historical events, land use, phylogeny, dispersal limitation, physical barriers and more (MacArthur, 1972; Brown *et al.*, 1996; Gaston, 2003; Sexton *et al.*, 2009). Surprisingly few generalizations about how species are distributed in space are currently possible (Gaston, 2009).

Here we ask: can a single, general model, applied to a broad set of species (e.g. trees) account for the bulk of the variability

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