Mapping species distributions: spatial inference and prediction

Maps of species distributions or habitat suitability are required for many aspects of environmental research, resource management, and conservation planning. These include biodiversity assessment, reserve design, habitat management, and restoration, species and habitat conservation plans and predicting the effects of environmental change on species and ecosystems. The proliferation of methods and uncertainty regarding their effectiveness can be daunting to researchers, resource managers, and conservation planners alike. Franklin summarizes the methods used in species distribution modeling (also called niche modeling) and presents a framework for spatial prediction of species distributions based on the attributes (space, time, scale) of the data and questions being asked. The framework links theoretical ecological models of species distributions to spatial data on species and environment, and statistical models used for spatial prediction. Provides practical guidelines to students, researchers, and practitioners in a broad range of environmental sciences including ecology, geography, conservation biology, and natural resources management.

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The world's biological diversity faces unprecedented threats. The urgent challenge facing the concerned biologist is to understand ecological processes well enough to maintain their functioning in the face of the pressures resulting from human population growth. Those concerned with the conservation of biodiversity and with restoration also need to be acquainted with the political, social, historical, economic, and legal frameworks within which ecological and conservation practice must be developed. The new *Ecology, Biodiversity, and Conservation* series will present balanced, comprehensive, up-to-date, and critical reviews of selected topics within the sciences of ecology and conservation biology, both botanical and zoological, and both "pure" and "applied." It is aimed at advanced final-year undergraduates, graduate students, researchers, and university teachers, as well as ecologists and conservationists in industry, government and the voluntary sectors. The series encompasses a wide range of approaches and scales (spatial, temporal, and taxonomic), including quantitative, theoretical, population, community, ecosystem, landscape, historical, experimental, behavioural, and evolutionary studies. The emphasis is on science related to the real world of plants and animals rather than on purely theoretical abstractions and mathematical models. Books in this series will, wherever possible, consider issues from a broad perspective. Some books will challenge existing paradigms and present new ecological concepts, empirical or theoretical models, and testable hypotheses. Other books will explore new approaches and present syntheses on topics of ecological importance.

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Mapping species distributions

Spatial inference and prediction

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To Serge, Savannah, and Connor

Contents

Preface

Maps of actual or potential species distributions or habitat suitability are required for many aspects of environmental research, resource management, and conservation planning. These applications include biodiversity assessment, biological reserve design, habitat management and restoration, species and habitat conservation plans, population viability analysis, environmental risk assessment, invasive species management, community and ecosystem modeling, and predicting the effects of global environmental change on species and ecosystems. In recent years a burgeoning number of statistical and related methods have been used with mapped biological and environmental data in order to model, or, in some way, spatially interpolate species distributions, and other biospatial variables of interest, over large spatial extents. This practice is known as species distribution modeling (SDM). It has also been referred to as environmental, bioclimatic, or species niche modeling, and habitat suitability modeling, but, in this book, the term SDM will be preferred.

The proliferation of modeling methods applied to SDM, and conflicting results regarding their efficacy and relative merits, is daunting to researchers and resource analysts alike. The lack of integration of modeling and Geographic Information System (GIS) tools can impede the effective implementation of SDM. This book summarizes the key components of, and various approaches to, this problem that have been applied worldwide. This comprehensive summary provides guidance to novice species distribution modelers and also a review of current practices for more advanced practitioners. The book is organized according to a framework for modeling species distributions that has three parts: the ecological, data, and statistical models. The ecological model includes ecological theory used to link environmental predictors to species distributions according to a response function. The data model includes the decisions made regarding how data for modeling are collected and measured. The statistical model includes the choice of modeling methods and decisions required during model fitting and evaluation.

The elements of SDM are: a conceptual model of the abiotic and biotic factors controlling species distributions in space and time; data on species occurrences in geographical space; digital maps of environmental variables representing those factors thought to control species distributions; a quantitative or rule-base model linking species occurrence to the environmental predictors; a geographic information system (GIS) for applying the model rules to the environmental variable maps in order to produce a map of predicted species occurrence; and, data and methods for evaluating the error or uncertainty in the predictions.

This book discusses each of these elements. It then concludes with a framework for mapping species distributions from biological survey data, statistical models and digital maps of the environment. That framework is based on the attributes (space, time, scale) of the data and questions being asked. The framework links ecological theories of species distributions to the spatial data and statistical models used in empirical studies. This provides practical guidelines for model formulation, calibration, evaluation, and application.

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I invited Jennifer Miller to coauthor Chapter 6, contributing the material on spatial autocorrelation and statistical species distribution models. I appreciate the breadth and depth she has added to this topic and I believe that the readers will benefit from her expertise.

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