Chapter 36
Simulation–Based Approaches for Ecological Niche Modelling:
A Geospatial Reference

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ABSTRACT

Over recent years, many modelling approaches have been used to map and monitor both present and potential distribution of species in the context of ecological niche-based conservation, especially in the face of global environmental change. Using different statistical techniques in a built-in geographic information system (GIS), the development of predictive species distribution models has extensively increased. This chapter introduces a geospatial reference to simulation-based approaches of ecological niche models. The chapter discusses various environmental modeling tools and simulation models available in open source domain used by scientific communities. As an effort of this chapter, we focus on the potential of using such experimental models for large-scale ecosystem modelling studies, highlighting opportunities of research, for a variety of bio-geographical applications. It would serve as a basis for beginners in ecology exploring this field of research, who can further contribute and develop such models to better understand the complex field of ecosystem studies.

INTRODUCTION

The knowledge of spatial distribution of species is essential, especially to investigate the species' realized and fundamental niches. The understanding of this species-environment relationship is central for many current research programmes in ecology and conservation under global change (climatic and environmental) and it is of great scientific and societal relevance. This realization of the importance of predictive modelling of species is crucial in the field of both conventional as well as applied ecological research. Over past few years, species distribution models have seen an impressive growth in its mod-

elling approaches in studies of biogeography, conservation biology, ecology, palaeo-ecology, wildlife management, and more recently, studying the effects of climate change (Table 1). Such an experimental modeling approach allows us to estimate species' ecological requirements (Araújo and Guisan, 2006), generally based on various hypothesis (Guisan and Zimmermann, 2000). The idea is to quantify correlation between known occurrence of species and features of the ecological and environmental landscape (Miller, 2010). These models are often termed as *species distribution models*, *climatic envelope models*, or, most commonly known as, *ecological niche-based models*. The aim of such models is to reconstruct empirically derived 'environmental profile' which can be used to estimate the *ecological space* of species and/or predict the geographical distribution of species (Peterson, 2006). This sort of useful predictive modelling technique has had overwhelming success in the recent past (Austin, 2007, 2002; Elith et al., 2006, 2002; Guisan and Thuiller, 2005; Guisan and Zimmermann, 2000; Peterson, 2006; Sinclair et al., 2010). However, despite widespread use of these models, conceptual ambiguities and the biotic as well as abiotic limiting constraints need to be clearly addressed before any practical application of these modeling results are made available (Araújo and Guisan, 2006; Dormann, 2007).

The predictive modelling of species is one of the vital components of applied research (geography and ecology). With the advancement in geographic information system (GIS) and other related technologies, increased availability of satellite-based remotely sensed data and myriad number of open source tools that have developed; this enables scientists to employ powerful and sophisticated means of species' distribution modelling. As a result of simultaneous development of parallel applications with considerably different objectives, this process referred here as 'ecological niche-based modelling' has been previously described as 'predictive vegetation mapping' (Franklin, 1995; Miller et al., 2007), 'predictive habitat distribution modeling' (Guisan and Zimmermann, 2000), 'bioclimatic envelope modeling' (Heikkinen et al., 2006; Pearson and Dawson, 2003), 'habitat suitability index mapping' (Brown et al., 2000; Roloff and Kernohan, 1999), 'habitat suitability modeling' (Hirzel et al., 2006, 2002), and 'niche modeling'

Table 1. Some of the uses of ecological niche-based models

Quantifying the environmental niche of species	Austin et al., 1990; Vetaas, 2002
Testing biogeographical, ecological and evolutionary hypotheses	Anderson et al., 2002; Graham et al., 2004; Leathwick, 1998
Supporting appropriate management plans for species recovery and mapping suitable sites for species reintroduction	Pearce and Lindenmayer, 1998
Assessing species invasion and proliferation	Beerling et al., 1995; Peterson, 2003
Supporting conservation planning and reserve selection	Araújo et al., 2004; Ferrier, 2002
Suggesting unsurveyed sites of high potential of occurrence for rare species	Engler et al., 2004; Raxworthy et al., 2003
Modelling species assemblages (biodiversity, composition) from individual species predictions	Ferrier et al., 2002a; Guisan and Theurillat, 2000; Leathwick, 1998
Assessing the impact of climate, land use and other environmental changes on species distributions	Thomas et al., 2004; Thuiller, 2004
Building bio- or ecogeographic regions	No published example found
Improving calculation of ecological distance between patches in landscape meta-population dynamic and gene flow models	No published example found

Source: Guisan and Thuiller (2005).

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