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GIS-based application of resource selection functions to the prediction of snow petrel distribution and abundance in East Antarctica: Comparing models at multiple scales

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Abstract

Snow petrel numbers must be of the order of several millions. However, accurate population estimates are sparse although such information is necessary to monitor potential changes in the Antarctic ecosystem. A census of snow petrel nests was conducted at Casey (East Antarctica) during summer 2002–2003. Twenty percent of the ice-free areas (available nesting habitat for snow petrels) was surveyed using a "random block design". During this survey, approximately 5000 nests were located. Generalized additive and linear modelling techniques and classification trees (GAM, GLM and CT) were used to fit resource selection functions, which modelled snow petrel abundance or presence–absence in relation to a set of environmental predictors (elevation, slope, aspect, curvature and substrate types estimated in percentage cover). The effect of spatial scale on the processes that influence habitat selection was investigated using GIS as a tool to create and test models at a hierarchical range of scales—from 200 m grid-sites level to 20 m quadrats. The strong predictive value of aspect, slope and percent cover in boulder and SCREE were identified at all scales. However, the significance of environmental predictors varied with scale, indicating that spatial scale matters in detecting habitat selection processes. In general, models were improved with the addition of spatial dependence terms representing the effect of conspecific attraction (coloniality), but these models were less applicable for predictive purposes. By predicting abundance from environmental characteristics (acquired for example, using aerial photography), resource selection functions may be a useful tool to refine population estimates of several petrel species in Antarctica without requiring intensive ground surveys.

Keywords: Habitat selection; Generalized additive model; Generalized linear model; Classification tree; Model comparison; Scale; Conspecific attraction; Population estimate

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1. Introduction

Resource selection functions (RSF) are defined as any function that is proportional to the probability of use of a resource or area by an organism (Manly et al., 1993, 2002; Boyce et al., 2002; Austin, 2002). RSF-based models are used to study habitat selection, and have applications across a remarkably diverse range of species, from exploring stream site selection by the brown trout (Belaud et al., 1989) to the distribution of goats (Gross et al., 2002) or the factors affecting the recruitment of intertidal clams (Schoeman and Ridchardson, 2002). In conjunction with the use of modern statistics, such models are very powerful tools to address relationships between species and their environment in terms of habitat use and have become increasingly common in ecology. They particularly gained importance as a research tool on conservation issues, especially for assessing the effect of accelerated land use and climate change (Peterson, 2002; Lischke et al., 1998; Kienast et al., 1996) on the distribution of organisms. Meanwhile, recent advances in geographic information systems (GIS) provide alternatives to the traditional ground surveys for the production of species distribution maps (Corsi et al., 2000; Manly et al., 2002). The extension of RSF to density models (Boyce and McDonald, 1999) now permits the spatial prediction of species abundance. In conjunction with habitat selection modelling, the GIS approach contributes to the understanding of ecological phenomena that experiments cannot address due to the large scale at which the processes occur (Ormerod et al., 1999). A variety of software is now being developed in order to directly implement models into GIS interfaces such as the extension GRASP (Lehmann et al., 2002), which maps the output of generalized additive models (GAMs) (Suarez-Seoane et al., 2002) and Biomapper, which applies ecological niche factor analysis to produce predictive distribution maps (Hirzel et al., 2002).

Careful review of recent advances in habitat selection modelling led us to consider a number of methodological points in applying RSF to our specific needs. Three types of habitat selection models are tested and compared in this study. In modelling species–environment relationships, non-parametric generalized additive models have become a popular approach (Suarez-Seoane et al., 2002; Guisan et al., 2002) as it has been shown that the generalized linear model (GLM) approach may be more restrictive, therefore biologically unrealistic (Heegaard, 2002). However, there are instances where the habitat–organism response curves are still simple enough to be modelled robustly with GLMs. Thus, both techniques were evaluated here and incorporated in the model building methodology. Classification tree models (CT) were applied to the data as an alternative to generalized linear modelling as they offer a classification approach to the determination of habitat selection (De'ath and Fabricius, 2000).

Scale is a critical component of both patterns and processes in ecological studies, including habitat selection studies (Wiens, 1989). The concept of spatial scale can be applied to three different categories in ecology (Dungan et al., 2002): the phenomenon studied, the sampling units and the analysis of the data. Throughout this study, we make all efforts to use the word "scale" unambiguously as the synonym for the area that is observed and/or analysed. The scale at which habitat selection processes occur is a priori unknown to the observer conducting the study. Changing scale of observation or analysis can make substantial differences to the inferences about the underlying phenomena (Dungan et al., 2002). A number of studies may have been limited by analysing habitat selection at an arbitrarily selected scale without investigating a range of scales at which variables may influence the selection process. In relating an animal to its environment, ecological studies may be more meaningful when taking the perspective of the organism studied. Indeed, in homogeneous environments, spatial and temporal variability will be a function of the size of the window used to view the world (Levin, 1992). Thus, multi-scale studies are preferable to identify the scale(s) at which habitat selection processes happen (Johnson et al., 2004; Luck, 2002), often inferred from the distribution pattern. With small organisms over a restricted spatial extent (e.g. marine invertebrates, Bishop et al., 2002) a near-continuum of scales may be used to identify the scale at which the processes happen, but over large spatial extents (regions), it is necessary to investigate habitat selection at a limited number of scales based on relevant ecological traits of the species (Orians and Wittenberger, 1991; Morris, 1987). When dealing with landscapes, GIS is a valuable tool to assimilate data at the desired scale and compile the spatial information necessary to