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Short communication

The sensitivity of species distribution modeling to scale differences

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ABSTRACT

Species distribution modeling is one of the most effective habitat analysis methods for wildlife conservation. We evaluated the sensitivity of species distribution modeling to different grain sizes and extent sizes from 30 m to 4950 m using maximum entropy (MaxEnt) modeling. The grain size represents a unit for analysis, whereas the extent size defines the scope of the analysis in a way that reflects the environmental data for the area in which the species of interest occurs. We compared the resulting suitability indexes and habitat areas based on two approaches. The first approach increases the extent size for a fixed grain size. The second approach increases the grain size and the extent size by equal amounts. The suitability index based on the first approach ($R^2 = 0.34$) was greater than the suitability index based on the second approach ($R^2 = 0.89$). The first approach was fitted to a logarithmic function with a critical point at approximately 0.5 km, converging to about 0.76. In contrast, the second approach showed a linear decrease to values less than 0.5. The distribution of habitat area found with the second method (R2 = 0.87) was broader than that found with the first method (R2 = 0.63). The relationship between the extent size and the landscape index of the first method can be displayed as a power-law graph with a critical point of 0.5 km. The method of expanding extent size has greater accuracy, although the time that it requires for data processing is long. The results of this study suggest that the maximum grain size should be approximately 1.5 km. If the grain size is greater than 1.5 km, the accuracy of the habitat suitability index decreases below 0.6, and the predicted habitat suitability increases dramatically.

1. Introduction

One of the central problems in ecology is the influence of pattern and scale on the observed distribution and abundance of organisms (Scott et al., 2002). Landscape ecology considers the patterning of ecosystems in space. Methods are needed to quantify aspects of spatial pattern that can be correlated with ecological processes (O'Neill et al., 1988). Parameters and processes important at one scale are frequently not important or predictive at another scale, and information is often lost as spatial data are considered at coarser scales of resolution (Henderson-Sellers et al., 1982; Turner et al., 1989b). Therefore, landscape ecologists address processes that occur at a variety of temporal and spatial scales (Turner et al., 1989a).

Recent decades have seen an explosion of interest in species distribution and habitat modeling (Franklin, 2009). This trend has resulted from a confluence of the growing need for information on the geographical distribution of biodiversity with new and improved techniques (Franklin, 2009). Maps of species distributions or habitat suitability are required for many aspects of environmental research, resource management and conservation planning. Habitat modeling methods can be applied to quantitative, categorical or binary (presence–absence) response variables, and these methods can be classified as statistical, machine learning and other models (Franklin, 2009). Statistical models include the generalized linear model (GLM), generalized additive model (GAM) and multivariate adaptive regression splines (MARS) (Scott et al., 2002). Recently, machine learning methods that include a decision tree (DT), artificial neural network (ANN), genetic algorithm (GA) and maximum entropy (MaxEnt) have been used in species distribution modeling and related ecological modeling applications (Franklin, 2009). Recent years have seen the development of a variety of methodologies. Current research highlights the analytical methods used to examine presence/absence or presence-only data and environmental information.

Many of the species inhabiting a heterogeneous landscape interact at a regional scale. Heterogeneous landscapes provide a particular challenge for modeling the population-level responses to habitat fragmentation because individuals may be utilizing multiple habitats to varying degrees across the landscape (With et al., 1997). Scale can be defined as the spatial, temporal and organizational dimensions at which patterns and processes are observed

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and characterized (Marceau, 1999). Ecological patterns depend on processes acting at different scales (Coreau and Martin, 2007). Due to the mobility of animal species, analytical ranges and scales are more important issues for animals than for other organisms. In a heterogeneous landscape, habitat selection by animals depends on the ways in which animals exploit the available resources on the spatial scale used for the analysis (Boyce, 2006; Morellet et al., 2011).

Recently, the assessment of habitat suitability has been discussed in terms of two concepts. The first concept, grain size, refers to the unit chosen for use in the analysis. The second concept, extent size, refers to the extent of the analysis. These concepts address different issues but yield similar conclusions: the appropriate grain sizes are determined according to the extent of the analysis. Generally, the ability to obtain an accurate representation of the details of surface distributions is reduced as the scale of the map decreases (Henderson-Sellers et al., 1982).

We evaluated methods for analyzing habitat suitability by changing the grain size and the extent size. We compared the suitability index and habitat area resulting from two different approaches. The first approach involved increases both in the grain size and the extent size, whereas the second approach involved increases in the extent size alone. By comparing these approaches, we evaluated methods for assessing habitat suitability that involved scale considerations in landscape ecology.

2. Methods

2.1. The study area and available data

The study was conducted in a 1668 km^2 heterogeneous agricultural and forest landscape (36°54′11″N–36°23′17″N and 127°12′48″E–126°35′50″E) in the *Sapgyocheon* watershed, *Chungcheongnamdo* Province (Fig. 1). The study area is located at a low elevation (approximately 1–680 m) in an area typical of the western Republic of Korea.

The target species for this study was the Korean water deer (*Hydropotes inermis argyropus*). This small deer is widely distributed throughout Asia and is classified into 2 subspecies with different habitats and characteristics. The distribution of the species in the Republic of Korea includes areas located at the bases of mountains but does not include *Jeju* and *Ulleung* Islands. The species is well adapted to the ecosystems of the Republic of Korea, and many field surveys have studied its habitat characteristics. Therefore, this species is appropriate for analysis with habitat suitability modeling. Since 2006, field experts from the National Institute of Environmental Research, universities, and research institutes have conducted surveys to acquire data on species occurrences and spatial distributions for wildlife via direct observation, surveys of local people, and field signs such as tracks, feces, and footprints. These studies constitute the 3rd national environment survey in South Korea. The Korean water deer was found at 193 points in the study area.

The selection of environmental variables to define the habitat characteristics for the analysis was based on literature reviews. The Korean water deer (*H. inermis argyropus*) and another subspecies, the Chinese water deer (*H. inermis inermis*), usually inhabit low forest hills or wetlands near lakes, reeds, or sedge areas (Zhang, 2000). The species prefers grasslands to forested areas and inhabits reeds and meadows adjacent to forested areas (Zhang, 2000). The Korean water deer especially prefers grasslands near water and low, hilly forested areas near agricultural areas, but the species avoids steep rocky mountains (Choi and Choi, 2007). In addition, the Korean water deer prefers coniferous forests, grasslands, reeds, south-facing slopes greater than 20°, areas near water, and areas far from roads. According to the kernel density estimation method, the home range of the Korean water deer is 0.2–0.6 km^2 (Cooke and Farrell, 1998; Kim, 2011). The habitat preferences of the Korean water deer show a strong relationship to the geography, land cover, forest vegetation, water system, and distances to roads. Therefore, this study selected 10 environmental variables for analysis: DEM (elevation, slope, aspect, landform, and wetness), land cover (grassland, distance to forest, and distance to grassland), water system

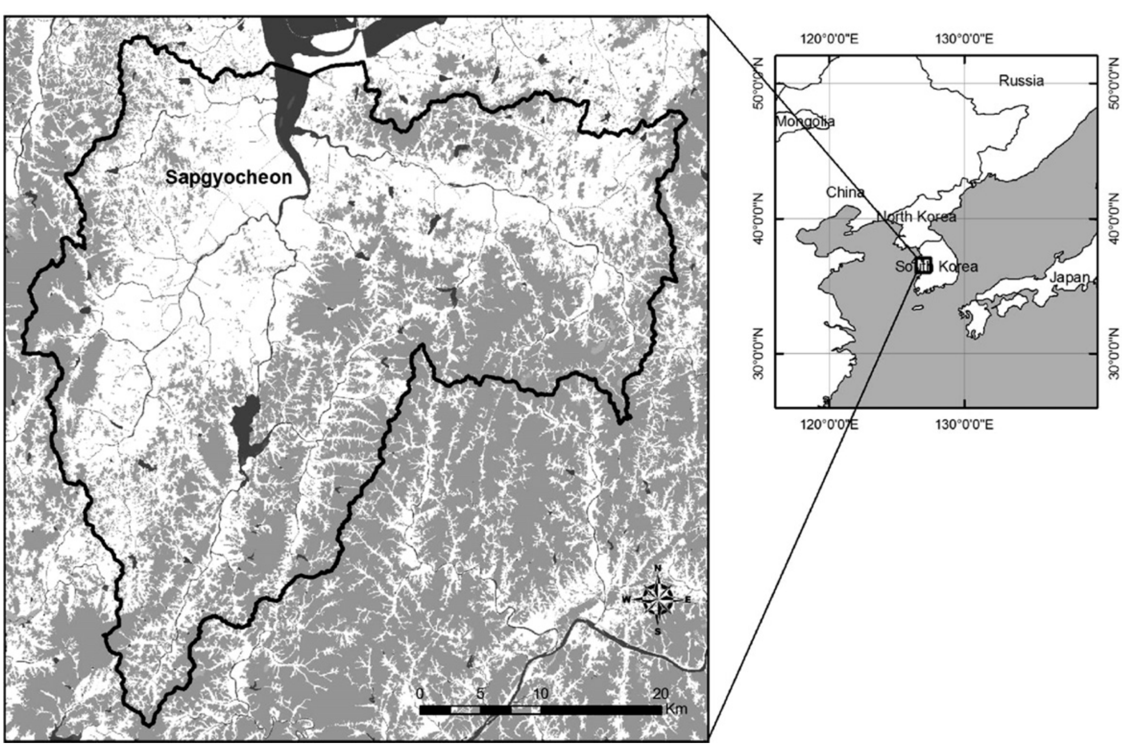

Fig. 1. Study area. The black line indicates the watershed boundary. The dark gray areas indicate the *Sapgyocheon* river and other streams. The light gray areas are forest patches.