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Original Article

Mapping potential habitats for the management of exportable insects in South Korea

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ABSTRACT

Understanding the spatial distribution for the management of exportable insects is important for conserving and enhancing biodiversity. In this study, we predicted the spatial distributions of 24 species with statistical significance by means of Maxent species distribution modeling, using data of the 54 insect species. Based on simulation results using these 24 species, we analyzed the impacts of environmental variables on species distribution and identified topographic and climatic factors as determinants of their spatial distribution. Distance from shore line, aspect, and topographic position index were identified as the main topographic variables, and the winter minimum and summer maximum temperatures were found to be the main climatic variables. Among the land cover variables, the percent agricultural area was found to be most important. The findings of this study, which identify the spatial distributions of the insects and determine the impacts of environmental factors on these spatial distributions, are expected to provide useful data for survey site selection when establishing monitoring plans.

Q3 Introduction

In South Korea, the management of exportable species is officially designated and managed as part of efforts to conserve biodiversity. This measure significantly prohibits native biological resources from being brought abroad and prevents their indiscriminate capture and collection. In addition to being a well-functioning species management system, understanding the spatial distributions of insects and temporal variations is important for the efficient preservation and proliferation of such listed species. This is reflected in the recent increase in awareness of the importance of efforts to predict species habitat changes and to understand the impact of anthropogenic threats on species populations as an important process for species preservation and proliferation (Pereira et al 2013).

Large-scale field surveys on the habitats of various species are underway in many countries across the globe. Some representative examples include Countryside Survey (U.K.), National Ecological Observation Network (U.S.), Terrestrial Ecosystem Research Network (Australia), and Monitoring Sites 1000 (Japan). Moreover, monitoring surveys of some species are being conducted for protection purposes, with a focus on beetles and butterflies (Kindvall and Bergman 2004; Ranius and Hedin 2004). In South Korea, species distribution mapping projects are ongoing and include the National Ecosystem Survey, Baekdudaegan Survey, and DMZ Survey. However, such field surveys are limited in their ability to comprehensively map species distribution because they use methods based on point or line census due to the limited availability of budget, personnel, and/or time. To overcome such limitations, intensive surveys are being undertaken on the ecology and distribution of endangered species that require monitoring, albeit in a limited number of species (Bae et al 1999; Cho et al 2012; Kim et al 1999; Kim et al, 2008, 2011; Kim et al, 2012; Kim et al, 2014; Ko et al, 2004). Q4

Recently, spatial data and species distribution models have been used widely in studies to predict the geographic distribution of species and their potential habitats (Elith et al 2011; Merow et al

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2013). In addition, studies have also been conducted on insects using Maxent models (Barredo et al 2015; Khosravi et al 2016; Kumar et al 2014). The results of Maxent species distribution models are used in South Korea to determine the geographic distributions of alien species (Lee et al 2014) or certain target species (Kim et al 2012) and for establishing wildlife reserves (Kwon 2011). More recently, the Maxent has been used to select areas with a high potential for multi-species occupancy, permitting the efficient monitoring of changes in ecological systems that are related to changes in climate and land use (Carvalho et al 2015; Hashim et al 2017).

Given that export-restricted biological resources, which are important for conserving biodiversity, are often distributed over a large geographic area, it is more advantageous in terms of time and cost to use species distribution models for the prediction of spatial distributions of insects. Therefore, we performed species distribution modeling to predict the distributions of the insects, thereby identifying the environmental factors that influence their spatial distribution, to provide basic data for biodiversity conservation.

Materials and methods

Species distribution models

Two types of software programs are used widely as species distribution–modeling tools: generalized additive model (GAM) and maximum entropy model (Maxent), which are based on presence/absence data and presence-only data, respectively. Maxent is known to outperform generalized additive model when only presence data are used (Elith et al 2006; Franklin 2009; Seo et al 2008). Kim et al (2012) analyzed the potential habitats of several selected species using datasets from the National Ecosystem Survey and found no significant differences in the simulation performance between these two models. These authors suggested that Maxent is more advantageous in terms of user convenience because it does not involve pseudo random data-point generation for absent data. Therefore, we selected Maxent, version 3.3.3k (Elith et al 2011) as a potential habitat prediction model.

Maxent is based on the principle of maximum entropy as an approach to model species' ecological niche. This model creates a model of a given species range using input data consisting of a set of georeferenced occurrence locations and a set of layers or environmental variables (elevation, precipitation, etc.). We applied a 10-fold cross-validation to the Maxent simulation runs, and model performance was assessed on the final results of the average simulation outputs. Ten-fold cross-validation is a method of evaluating simulation accuracy in 10 runs, whereby 90% of the full data are used for training and 10% are used for testing in each fold test. The area under the curve (AUC) was used to evaluate the model's simulation performance. AUC is obtained from the receiver operating characteristic curve, a type of diagnostic test interpretation; it is an objective function used to evaluate a model's simulation performance (Hanley and McNeil 1982). In general, simulation performance is considered good when the AUC value is 0.7 or higher (Swets 1988). We calculated the AUC for each training and testing data set and judged the distribution prediction result to be valid at AUC $\geq$ 0.7.

Environmental variables

We used 14 environmental variables grouped into four categories for the Maxent model (Table 1). Topographic variables included distance from shore line, aspect, and topographic position index. The maximum and minimum temperatures in the hottest and coldest months (August and January, respectively) and precipitation in the low-flow and high-flow periods (November–May and June–October, respectively) were used as climatic variables. Percentages of urbanized arid area, forestland, agricultural area, wetland, water body, and road area were included as land cover variables. Lastly, the vegetation map was used for the vegetation variable.

Table 1. Environmental variables for the Maxent.

Type	Variable	Abbr.	Raw data
Topology	Distance from shore line	DSL	GDEM (gdem.ersdac.jspacesystems.or.jp)
	Aspect	ASP	
	Topographic position index	TPI	
Land cover (%)	Water body	PWB	Land cover map (ME, 2010)
	Forest	PFO	
	Urban area	PUA	
	Wetlands	PWL	
	Agricultural area	PAA	
	Road area	PRA	
Vegetation	Actual vegetation	AVE	Actual vegetation map (ME, 2013)
Climate	Minimum temperature in Jan.	MNT	Gridded climate data (www.climate.go.kr)
	Maximum temperature in Aug.	MXT	
	Precipitation in dry season (Nov. to Apr.)	PDS	
	Precipitation in wet season (Oct. to Mar.)	PWS	

All environmental variables were constructed as raster datasets with a spatial resolution of 1 km^2. The input data for ground elevation, aspect, and distance from shore line were obtained by performing GIS analysis of advanced spaceborne thermal emission and reflection radiometer global digital elevation model (ASTER GDEM), Version 2 (released in October 2011) mapped at 30 m spatial resolution. Temperature and precipitation data were extracted from 2000–2010 climate data (spatial resolution: 1 $\times$ 1 km) retrieved at the climate data portal www.climate.go.kr. Input data for land-cover variables were obtained by analyzing the low-level land-cover map constructed at the end of the 2000s by the Ministry of Environment. The actual vegetation map was extracted from the 3rd National Ecosystem Survey data (Ministry of Environment, 2013).

Scope of study and data collection

The geographical area covered in this study was the South Korean territory, including islands (Jejudo, Ulleungdo, Baekryongdo, Daecheongdo, etc.). For the target species, 54 species in 29 families having at least 30 samples were selected from a total of 257 insect species in 78 families whose adult individuals were confirmed in the 3rd National Ecosystem Survey. Overall, 5902 samples were collected from the sampling locations marked in Figure 1. The numbers of samples per species are listed in Appendix 1.

Results

The AUC values of the target species ranged between 0.5 and 0.8, with 24 species scoring 0.7 or 0.8 (Table 2). Species with AUC $\geq$ 0.7 were confirmed to be evenly distributed in six orders, with the exception of Dictyoptera and Neuroptera. Potential habitats of 24 of 54 target species could be predicted with statistical significance.

The potential habitat distribution of each species (Figure 2) shows that *Asiopodabrus fragiliformis, Lucanus maculifemoratus dybowskyi, Prismognathus dauricus, Problepsis diazoma,*

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