論 文 の 内 容 の 要 旨

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論文題目　A landscape-scale approach for modeling Korean water deer habitat suitability in Chungnam province, Korea

（韓国チュンナム道におけるキバノロのハビタット適性モデリングのための景観スケールのアプローチ）

A wide variety of topographic and climatic conditions with marked seasonal change in rainfall and temperature have created extremely diverse habitat types, resulting in abundant wildlife species and ecological systems in Korea. However, due to the drastic increase of human population and urbanized area, natural areas have been fragmented or lost through the process of land transformation that accompanies the consequent increase in residential, commercial and industrial area. Many wildlife species were extinct such as large carnivores like Siberian tiger (*Panthera tigris altaica*) **,** leopard (*Panthera pardus*), wolf (*Canis lupus*), etc and are facing extinction and suitable wildlife habitats have not been efficiently protected from the pressure of development during the last four decades. To prevent deteriorating condition, the Korea government establishes wildlife protection measures, conducting nationwide extensive surveys, designating wildlife protected area, and monitoring wildlife species and habitat condition, etc. However, Few wildlife protected area had been designated for preserving these endangered species and their habitats in Korea. Appropriate actions to prevent habitat loss and fragmentation are needed for sustaining and restoring natural areas.

Geographic information systems (GIS) and abundant landscape-level data, often from remote sensing sources, provide new opportunities to model and evaluate wildlife habitat quality. The development of increasingly powerful GIS and the growing availability of digital landscape data in recent years have promoted the creation of large-scale habitat models for the identification of species-relevant sites (Mladenoff and Sickley, 1998; Kobler and Adamic, 2000; Graf et al., 2005). Most habitat models developed for defining priority conservation sites target areas currently exhibiting suitable habitat conditions. Habitat models also can be useful tools for monitoring the quantity, quality, and distribution of a species' habitat within the target area (Hartwell et al., 2006). Habitat requirements of wildlife species can be explored with the habitat model at the multiple scales, and the exploration is effectively used in wildlife management measures. For the efficient preservation of wildlife habitats, which is a core factor in conserving wildlife populations, these models are promoting systematic ecosystem preservation measures in wide regions. However, models of habitat quality have not been developed for some species, and many existing models could be improved by incorporating updated knowledge of wildlife–habitat relationships and landscape variables such as the spatial distribution of habitat components. Furthermore, landscape analyses and wildlife population priorities are common features of land management decision processes.

I developed GIS-based habitat suitability index (HSI) models proposed by U.S Fish and Wildlife Service (1981) for Korean water deer *(Hydropotes inermis argyropus)*. HSI models represent a range of potential conservation concerns and have diverse habitat requirements. Values of habitat variables are related to habitat quality on a suitability index (SI) scale from 0 = not habitat to 1 = habitat of maximum suitability.

Korean water deer is an endemic subspecies in Korea. The species can be found throughout the Korean peninsula and in southeast China. However, as many forest habitats have been lost to agriculture, forestry plantations and urban development, deer populations have declined dramatically. This species is now listed on the International Union for Conservation Nature (IUCN) red list as Vulnerable (VU) in 2008 (Harris and Duckworth, 2008). Moreover, for that reason, they are frequently observed near agricultural areas, especially during winter. Heavy feeding crop causes serious conflicts between local farmers and the deer. Therefore, it is needed to take measures to deal with these issues.

In order to suggest methods to conserve and manage Korean water deer habitat, I developed two kinds of habitat models using logistic regression analysis targeted at the Chungnam province, South Korea. One was based primarily on topographical factors, ecological factors, and human disturbance factors available in many GIS databases. Overall, habitat variables were compiled by reviewing the available literatures and classified into seven categories: Canopy cover, Distance to wetland, Distance to water area, Slope, Land use, Distance to roads and Distance to urbanized area.

The other habitat model was derived from landscape patterns factors of habitat cover types, as well as topographical factors, ecological factors, and human effects. To develop the habitat model, first I applied the procedure proposed by Lu et al. (2007) (i.e., Principal Components Analysis (PCA)-Maximum Likelihood Classification (MLC), Principal Components Analysis (PCA)-Extraction and Classification of Homogeneous Objects (ECHO), Decision Boundary Feature Extraction (DBFE)-Maximum Likelihood Classification (MLC) and Decision Boundary Feature Extraction (DBFE)-Extraction and Classification of Homogeneous Objects (ECHO)) to develop the land cover map using Multispec and ENVI software program. PCA-ECHO method out of four methods yielded the best classification accuracy (94.3 %, Kappa statistics: 0.923). And then I measured landscape configuration and composition within 25 ha (home range size for Korean water deer) and 100 ha (maximum potential home range) samples using the Patch Analyst Extension FRAGSTATS software in ArcView, which is a spatial pattern analysis program for categorical maps (Elkie et al., 1999). FRAGSTATS calculates a wide range of possible landscape metrics which are algorithms for quantifying specific spatial characteristics of landscape mosaics, classes of patches (McGarigal and Marks, 1995). These metrics fall into two general categories: those that quantify the composition of the map without reference to spatial attributes including the proportion of the landscape in each patch type, patch size, abundance, etc., and those that quantify the spatial configuration of the map, requiring spatial information for their calculation such as density, shape complexity, proximity, connectivity, etc.

Some of landscape metrics which affect habitat quality were selected as a result of stepwise discriminant analysis (DA). And then, T-test was used to determine significant difference of landscape metrics selected by each DA. At last, Correlation analysis for selected landscape metrics in each home range size was performed to examine what is the relationship among forest, open area, water area and development area at landscape level. To compare the differences between habitat and non-habitat area, the Chungnam province was subdivided into two sub-regions by Kernel method, which are regions around each point location containing some likelihood of animal presence. I determined the 200 random points as a non-habitat area outside of the 95 % Kernel area. I assumed that non-habitat, outside of the Kernel area, is not suitable for Korean water deer.

Cohesion index (COHESION), Division index (DIVISION), Proximity index (PROX), and Similarity index (SIMI), in habitat were significantly (at 95 % confidence interval, P < .01) different from those in non-habitat in forest area within 25 ha home range. Shape index (SHAPE), Proximity index (PROX), and Radius of gyration index (GYRATE) had a meaningful difference within 100 ha home range.

In the case of open area in 25 ha habitat, the six landscape metrics (i.e., Total area index (CA), Percentage of landscape index (PLAND), Patch density index (PD), Perimeter-area ratio index (PARA), Proximity index (PROX), and Similarity index (SIMI)) based on DA showed a significant difference (P < .01) between habitat and non-habitat. In 100 ha habitat, the two habitat metrics, Percentage of landscape index (PLAND) and Similarity index (SIMI), were significantly different (P < .01) between habitat and non-habitat.

Within both 25 ha and 100 ha home range, Edge density index (ED) and the Proximity index (PROX) for development area were a significant difference (P < .01) between habitat and non-habitat. For water areas, Fractal dimension index (FRAC) and Similarity index (SIMI) showed a significant difference (P < .01) between habitat and non-habitat in 25 ha home range and there was difference in Landscape shape index (LSI) in 100 ha.

Among the selected landscape metrics, two landscape metrics with no correlation (PROX for forest patches and PROX for open area patches) were used to conduct a logistic regression habitat model. In habitat model, three variables, Slope, PROX for forest area, and PROX for open area had a large impact on the HSI logistic regression model, indicating its major contribution to the HSI values. The regression model updated with landscape metrics resulted in progressively better fits in terms of higher correct prediction (74 %) than model built with only environmental information data such as land cover, elevation, etc. (65.4 %). HSI model considering landscape metrics demonstrated that the province and randomly selected sites can be considered moderate quality habitat across the board (SI values = 0.33 and SI values = 0.23), but Korean water deer recorded sites belonged to fair quality habitat (SI values = 0.5) and were mainly distributed at the SI ranges of 0.4 and 0.8 (54 %). Habitat suitability map developed from model output was according to generally accepted species-habitat association of Korean water deer.

The importance of high proximity for forest and open area emphasizes that deer may be locally abundant over more concentrated patches in the province. It is widely accepted that edge effects induced by human activities are negative. Korean deer are edge species, meaning they thrive where forests meet fields. Newly created edges caused significant reduction in population should thus be minimized in landscape interventions, especially in forest area. Results indicate that landscape configuration and composition should be considered in creating deer management or when considering potential management problems associated with spatial variability in crop and property damage.

The model I have constructed did not sufficiently consider the weather factors (e.g., rainfall, temperature, snow, etc.) and food variables due to lack of data. Also there is a limitation of HSI model for identifying water deer habitat use pattern. Data applied to the habitat model were based on presence/absence of the water deer but it was not actual absence data. I determined some sites randomly outside of the Kernel area to compare with observation sites and presence data is not necessarily reflecting their preference of this area. This model was considering limited information regarding dispersal, competition, niche issues of single species, lack of interaction with other species. However, this model provides a tool for effective identification of potential Korean water deer populations and habitats in the Chungnam province, as well as contributing to the successful conservation and management of the species. I believe that the proposed method will allow a larger number of habitat assessments to be carried out in situation where sparse (but reliable) presence data is available from filed survey and provide a baseline for future detailed wildlife habitat assessments using current standards in habitat assessment methods. And lastly, in order to identify the habitat attributes more accurately, further research is needed to consider changes of deer’s behavior and habitat use, corresponding to the climate change (e.g., rainfall, temperature, etc.) and develop the model reflecting food variable such as shrub, preference plants.