Original Paper

Analysing Habitat Characteristics for Korean Water Deer (*Hydropotes inermis argyropus*) in Korea Using Remote Sensing and Landscape Metrics

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ABSTRACT

Korean water deer (*Hydropotes inermis argyropus*) is an endemic subspecies and one of the common species in Korea. However, deer have been threatened by human activities, which have resulted in the population decrease. To conserve and manage their populations, understanding Korean water deer's habitat characteristics, which depend on the structure of the landscape, and identifying the relationship between those would be a key component. Our main aim was first to make landcover maps from remote sensing imagery, and to determine some habitat metrics for Korean water deer at two different home range scales (25 ha and 100 ha), and finally to compare them between habitat and non-habitat of the Korean water deer.

This study analyzed spatial patterns at two scales in the Chungnam province environment by using the PCA-ECHO classification technique based on Landsat ETM+ remote sensing data (2001) and 19 habitat metrics. Study results show that habitat metrics for forest and open areas are more obviously distinguished within a 25 ha home range scales. Especially, more continuous and less fragmented forest patches and open area patches with a high edge density and connectivity were the main characteristics of Korean water deer's habitat. As a part of habitat management, these results could be used as a good proxy for assessing the habitat quality of Korean water deer.

Key words : GIS, Habitat, Korean water deer, Landscape metrics, Remote sensing

1. Introduction

Korean water deer (*Hydropotes inermis argyropus*) 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, recently crop loss and damage caused by deer has become more serious in farmlands and their surroundings. Therefore, effective habitat management plans for deer should be adopted.

Population dynamics are independently and interactively influenced by the spatial arrangement, size, type, and diversity of patches. That is, the distribution, abundance and diversity of animal species in an area are affected by the structural characteristics of a landscape such as habitat type, resource-patch size, edge length, configuration (Forman et al., 1976) and disturbance or manmade landscape structure (Fritz et al.,

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2003). Therefore, assessments based on simple measures of habitat quality, which do not take the effects of landscape pattern into account, are unlikely to provide accurate estimates of important aspects of landscape ecology such as population persistence, survival, and reproduction (Hansson et al., 1995).

This study was primarily addressed to detect the habitat spatial structure of Korean water deer using geographic information systems (GIS) and remote sensing. Various environment map layers derived from remote sensing are a cost-effective representation of the natural landscape and provide an appropriate source of spatial information. Landscape metrics are yielded through accurate landcover classes based on remote sensing data and might be used for management and conservation planning of wildlife habitats.

Previous studies on Korean water deer have mainly focused on their ecological or individual characteristic such as anatomical features, taxonomic classification, epidemiological investigation and genetic testing (Zhang, 2000; Kim et al., 2005; Park et al., 2009). Although Jung (2007) developed the Habitat Suitability Model for identifying habitat use information, the habitat model did not thoroughly consider spatial patterns and physical structure. Therefore, it is important to find out relationship between spatial patterns and the distribution of Korean water deer to preserve them effectively. Habitat characteristics that consider Chungnam province's environments as key indicators of habitat quality, will help the authorities to implement the program related to habitat monitoring and management.

By examining the Chungnam province landscape, this study aims to 1) make landcover maps derived from remote sensing imagery, 2) detect important habitat metrics for Korean water deer at two different home range scales (25 ha and 100 ha), and 3) compare them between habitat and non-habitat of the Korean water deer.

2. Methods

2.1 Study site and species

The study area, Chungnam province (about 862,900 ha) with an average altitude of 100 m, is located in the middle of South Korea (35°38'~ 37°71'N, 125°31'~127°38'E). This area has temperate monsoon climate with four distinctive seasons. The yearly average temperature is 12.8℃ and the annual average precipitation totals 1,577.5 mm. The mountains in Chungnam include the Charyeongsanmaek Mountain, the Gaya mountains, and the Gyeryong mountains which pass throughout the province. Forest area covers about 449,533 ha (52.1%). Forests are dominated by coniferous forest (197,839 ha), deciduous broad-leaved forest (115,813 ha), and mixed forest (107,291 ha). Other land uses are as follows: arable land (268,417 ha (31.1%)), water area (67,734 ha (7.8%)), commercial/industrial/residential area (38,616 ha (4.5%)), transportation area (25,958 ha (3%)), and the others (12,663 ha (1.5%)) (Chungnam Provincial Government, 2009).

Korean water deer are an evidently edge species, preferring habitat characterized by shrubs and small trees and wildly distributed in mountains and fields of the Korean Peninsula (Rhim and Lee, 2007). Although Korean water deer are reported to be moderately widespread in Korea, currently they are now decreasing due to poaching and habitat destruction (Harris and Duckworth, 2008). Commonly, 2~4 Korean water deer live together and appear unlikely to colonize areas > 20 km from a source population. They eat various kinds of herbaceous plants such as reeds, rough grasses and crops (Guo and Zhang, 2002).

2.2 Landcover map production

Chungnam province landcover map with 30 x 30 m resolution was created using Landsat ETM+ remote sensing data (by providing Maryland Uni. 2001/09/23) to update the landcover map produced by the Ministry of Environment of Korea (1997–1999). We applied the PCA-ECHO method proposed by Lu et al. (2007) to develop the landcover map using Multispec software program. Areas covered by cloud/shadow are excluded from the analysis. We should stress that the area of cloud cover affecting the image was fairly small (about 8.4%) and was largely limited to the southeastern areas of the Chungnam province.

We used a feature extraction method, Principal Components Analysis (PCA), to reduce the data dimensionality and computational cost. PCA is often used to compress the information content of original image bands into a fewer number of transformed components that recover as much variability in the data as possible (Gonzalez and Woods, 1993). Then, Extraction and Classification of Homogeneous Objects (ECHO) was applied to the extracted images. ECHO procedure is based on the groups rather than individual pixels, which use the spectral information from neighbor pixels to allocate it to a probable class, and subsequently subdivide the landscape into an arbitrary mosaic inadequately related to the actual

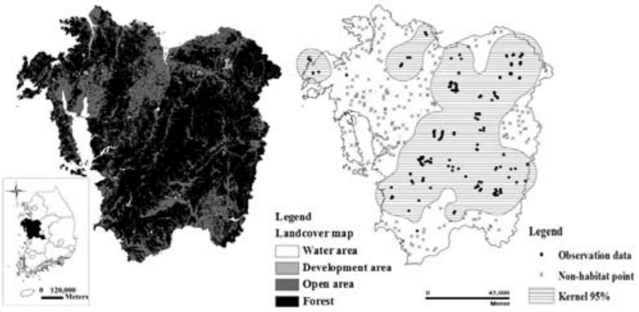

Fig. 1 Landcover map and result of Kernel estimation of study area, Chungnam province.

landcover pattern (Campbell, 1996). After mapping through the classification method, the kappa statistic was used to confirm classification accuracy. Across different ecoregions, the core components of deer habitat are consistent; water, food, and cover. We considered that forest is suitable for sleeping and hiding cover and open area is an integrative place which can provide many functions such as resting, reproductive, and feeding covers. Thus, we reclassified cover types into four habitat categories, i.e. forest, open area (grass land, wetland and farm land), water area, and development area (Fig. 1).

2.3 Kernel home range estimation

Home ranges were estimated based on probability 'Kernel', which are regions around each point location containing some likelihood of animal presence. It is considered the most robust of the probabilistic techniques (Hooge et al., 1999). The two probabilities (95% and 50%) are most commonly used in the literature. The 95% area is considered the area of active use and 50% area, on the other hand, is considered the core area of activity. Therefore, 95% kernel is more suitable for separating habitat area within Chungnam province. It was estimated by using the Animal Movement Extension of ArcView (Rodgers and Carr, 1998).

For this study, we used deer observation data for seven years (2000-2006), which were derived from the 2nd and 3rd National survey on the Natural Environment Report (Ministry of Environment of Korea). A total of 183 stations were located within the site and regarded as habitats because there were no big environmental changes for seven years. To avoid over counting due to deer's reappearance, we excluded overlapping samples in the buffer zone (< 100 m). To compare the differences between habitat and non-habitat area, the Chungnam province was subdivided into two sub-regions. We determined the 200 random points as a non-habitat area outside of the 95% Kernel area (Fig. 1 right).

2.4 Landscape pattern metrics

In order to compute landscape pattern metrics, 25 ha and 100 ha scaled samples were applied. Because Korean water deer's home range is known for approximately 25 ha (Cook and Ferrell, 1983) and an extended area of 100 ha is considered as a potential home range deer can commonly traverse in a 24 h period.

We measured landscape configuration and composition within 25 ha and 100 ha samples using the Patch Analyst Extension FRAGSTATS software in ArcView (Elkie et al., 1999). Calculated landscape pattern indices are regarded as habitat metrics. Each metric is integrated over all the patches of a given landcover type (i.e., forest, open area, water area, and development area) and represents the amount and spatial distribution of a single landcover type. 19 habitat metrics which are divided into 5 groups were computed for each landcover type (Table 1) and equations and definitions for the metrics can be found in the Fragstats Spatial Pattern Software user guide (McGarigal and Marks, 1995).

2.5 Data analysis

Stepwise discriminant analysis (DA) was used to quantify the statistical significance of the identified habitat metrics across two sub-regions, habitat and non-habitat area, because DA function maximizes the distance between the means of the extracted metrics. The function score is given by

$$Z = \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n + C$$

where the α's are discriminant coefficients, the X's are habitat metrics and C is a constant. In executing the stepwise procedure, we determined Wilk's Lamda as the criterion and used the probability of F-value with $P_{in} = 0.05$ and $P_{out} = 0.10$. And then, we conducted T-test to compare significant difference of habitat metrics selected by each DA. The results show habitat information about the present habitat conditions and habitat metrics which can be used to assess habitat quality as indicators.

3. Results and Discussion

PCA-ECHO classification method yielded an overall accuracy of 94.30% (Kappa, 0.923). The result was a pair of quite believable classification maps whose patterns seem to closely

Table 1 Habitat metrics used in this study and their brief definitions (McGarigal and Marks, 1995)

Metric (unit)	Description
Area/Density/Edge	
CA (m^2): Total class area	Sum of the areas of all patches
PLAND (%) : Percentage of Landscape	Percentage the landscape comprised of the patch type
PD (n/100ha) : Patch density	Number of patches of the patch type divided by total area
TE (m): Total Edge	An absolute measure of total edge length of a patch type
ED (m/ha): Edge Density	Sum of the lengths of all edges divided by the total area
GYRATE# (m) : Radius of gyration	Mean distance between each cell in the patch and the centroid
LSI (none) : Landscape Shape Index	Measure of class aggregation. LSI ≥1, LSI = 1 when the landscape consists of a single compact patch
Shape	
SHAPE# (none) : Shape index	Patch perimeter divided by the minimum perimeter possible for a maximally compact patch
FRAC# (none) : Fractal Dimension Index	Mean patch fractal dimension with the addition of individual patch area weighting applied to each patch
PARA# (none) : Perimeter-Area Ratio	Ratio of the patch perimeter to area
Connectivity	
COHESION(none) : Patch Cohesion Index	Measure of physical connectedness. COHESION approaches 0 as the proportion of the landscape comprised of the focal class decreases.
Contagion/Interspersion	
DIVISION (%) : Landscape Division Index	Probability that two randomly chosen pixels in the landscape are not situated in the same patch
Isolation/Proximity	
PROX# (none) : Proximity Index	Sum of patch area divided by the nearest edge-to-edge distance squared between the patch and the focal patch.
SIMI# (none) : Similarity Index	Sum of all neighboring patches with similarity coefficient between the focal patch and neighboring patch, divided by the nearest edge-to-edge distance squared

: Area-weighted mean of each habitat metric.

Table 2 Prediction accuracy of discriminant analysis for land cover

Landcover type	Habitat scale	
	25 ha	100 ha
Forest	98.0%**	78.7%**
Open area	94.3%**	79.5%**
Development area	86.7%**	70.5%**
Water area	90.3%**	63.5%**

depict reality. This method would be applied to provide information about landcover change.

Classification results were a simple summary of the number and percentage of subjects classified correctly or incorrectly, and used to assess how well the discriminant function works. Total percentage correctly classified into 'habitat' or 'non-habitat' groups ranged from 86.7% to 98.0%. On the other hand, in the case of 100 ha home range scale, prediction accuracy fell dramatically by 63.5% in water areas (Table 2).

The results of the T-test for the habitat metrics showed that there were distinct differences between the habitat and non-habitat in Chungnam province (Table 3).

Except SHAPE metric, COHESION, DIVISION, PROX, and SIMI in the habitat were significantly different from those in non-habitat in forested areas within a 25 ha home range. SHAPE, PROX, and GYRATE had a meaningful difference within the 100 ha home range ($P < .01$). In this study, the appearance of Korean water deer relied on a larger and more complicated shaped forest patch area and a high proximity in distribution. Especially, high connectivity or less fragmented patches for the 25 ha home range were important. This result can be interpreted that the probability of occurrence of deer in suitable patches increases with proximity and connectivity. That is, more connected forest patches likely provide easier movement for deer because forests provide cover and resting places from inclement weather and disturbance by humans or predators. The DA results showed that if the 25 ha samples were suitable for habitat, the discriminant function scores ($Z = 0.687$ SHAPE − 0.015 COHESON + 3.199 DIVISION + 0.061 PROX − 0.027 SIMI − 2.211) would be over 1.07 for forest patches.

In the case of open area in the 25 ha habitat, the six habitat metrics (i.e., CA, PLAND, SIMI, PARA, PROX, and PD) showed a significant difference between habitat and non-habitat. In the 100 ha habitat, the two habitat metrics, PLAND and SIMI, were significantly different ($P < .01$). The selection of different vegetation communities by herbivores should reflect foraging and refuge-seeking strategies (Andersen et al., 1998). If an increase in the amount of edge is related to an increase in the availability of resources, also, if greater resource availability is offered by habitat edges, then more time would also be spent near these edges, which is consistent with the fact that edges are good browsing habitats for water deer. As a feeding place, spatial patterns for open area would be proper to meet the discriminant function score ($Z = -0.621$ CA + 0.249 PLAND + 0.012 PD + 0.002 PARA − 0.036 PROX + 0.029 SIMI − 6.03) below 1.98. And degree of similarity had a tendency to increase in the extension area (25 ha: ΔSIMI = 61.022, 100 ha: ΔSIMI = 320.371).

In the development area in both the 25 ha and 100 ha home

Table 3 Canonical discriminant function derived from habitat metrics and mean of habitat metrics between habitat and non-habitat for 25 ha and 100 ha home range

Landcover type	Habitat scale	Metric	Canonical discriminant function coefficients (α) / Standardized ones	Habitat type	
				Non-habitat	Habitat
Forest	25 ha	PROX#**	.061 / 1.343	1.451	49.192
		SIMI#**	-.027 /-1.085	103.800	2.554
		DIVISION**	3.199 / .991	.824	.507
		SHAPE#	.687 / .361	1.655	1.750
		COHESION**	-.015 / -.310	74.790	95.441
		(Constant)	-2.211 / -		
	100 ha	GYRATE#**	.012 / 1.132	157.685	311.480
		SHAPE#**	-.463 / -.390	2.214	2.550
		PROX#**	.027 /.340	6.529	10.389
		(Constant)	-1.818 / -		
Open area	25 ha	PLAND**	.249 / 5.799	54.431	24.442
		CA**	-.621 / -3.777	14.087	6.357
		SIMI#**	.029 / 1.443	64.696	3.674
		PARA#**	.002 /.627	419.662	678.093
		PROX#*	-.036 / -.234	3.111	4.789
		PD**	.012 /.143	16.620	20.629
		(Constant)	-6.030 / -		
	100 ha	SIMI#**	.003 /.522	240.711	561.142
		PLAND**	-.026 / -.514	53.405	22.643
		(Constant)	.033 / -		
Development area	25 ha	PROX#**	.862 / 1.612	2.422	0.062
		SIMI#**	-.650 / -1.515	2.422	1.602
		ED**	0.11 /.556	104.715	71.244
		(Constant)	-.762 / -		
	100 ha	ED**	.028 / 1.241	107.821	66.731
		PROX#**	-.067 / -.385	6.936	4.112
		(Constant)	-2.138 / -		
Water area	25 ha	SIMI#**	.017 /.739	111.670	.006
		FRAC#**	17.359 /.450	1.069	1.018
		(Constant)	-19.640 / -		
	100 ha	LSI**	1.844 / 1.000	1.766	1.284
		(Constant)	-2.897 / -		

This table includes only metrics selected by the stepwise procedures.
** At the 0.01 significant level (2-tailed)
* At the 0.05 significant level (2-tailed)
# : Area-weighted mean of each habitat metric

range, edge density (ED) and the degree of proximity (PROX) were significantly different (P < .01). Edge density in a non-habitat was larger than that in a habitat. Development area patches were closer and more contiguous in the non-habitat area than habitat ones regardless of home range size. Overall, non-habitat areas were more strongly influenced by anthropogenic factors.

For water areas, FRAC and SIMI metrics showed a significant difference (P < .01) in the 25 ha home range and there was difference in LSI metric of shape index in 100 ha. Cook and Ferrell (1983) reported that water deer prefer water areas and areas nearby. However, the water area has experienced developmental pressure for many years, resulting in interference with the deer's approach to the water area. Therefore, habitat metrics for the water area could not be utilized as habitat indicators in the environment which have been strongly affected by anthropogenic factors.

Overall, high connectivity and proximity of forest patches, high edge density of open area, and low edge density of development area were important factors for the 25 ha habitat area. However, results for the 100 ha range as a potential home range couldn't show distinct habitat characteristics (Table 2). It suggests that there were significant limitations associated with home range scales to analyze habitat characteristics.

In this study, habitat metrics were basically computed on the basis of species distribution data (presence/absence data). An absence data (lack of observation) may have three causes: 1) The species was present but was not detected. 2) The habitat is suitable, but the species is not yet in that habitat or no longer present. 3) The habitat is actually not suitable. Continuous monitoring of its appearance or not will help assess habitat quality more explicitly. The results will provide suggestions for allowable developments and habitat management.

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