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Eurasian Otter (Lutra lutra) Habitat Suitability Modeling Using GIS; A case study on Soraksan National Park

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Abstract

Eurasian otter (Lutra lutra) is one of endangered wildlife species whose population size is declining in Korea. To manage and conserve habitat for Eurasian otter, it is crucial to understand which habitat components affect otter habitat qualities. The objectives of this study were to develop a habitat suitability model of Eurasian otter in Soraksan National Park, to validate the model in Odaesan National Park. The research methods of this study were as follows. First, trace data and characters of Eurasian otter habitat were collected with Geographic Information System (GIS) data and Global Positioning System (GPS) receivers between 2000 and 2002. Second, the habitat use factors were identified as habitat characteristics of Eurasian otter and classified with habitat use and availability analyses. Third, significant factors of habitat model were extracted by Chi-square test. The last, Eurasian Otter Habitat Suitability Model (EOHSM) was employed by logistic regression method. Otter habitat use was positively associated with the reeds and shrubs areas adjacent to streams, the size of boulders, and low human disturbance in Soraksan National Park by EOHSM. This model had a classification accuracy of 74.4% at cutoff value of 0.5. Model validation showed a classification accuracy of 86.6 % at cut off value of 0.5 for otter habitat in Odaesan National Park.

Keywords: Habitat Suitability Modeling, GIS, and Logistic Regression

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1. Introduction

Eurasian otters (*Lutra lutra*) are classified by the International Union for the Conservation of Nature (IUCN) in the Red Data Book as being especially 'vulnerable to extinctions', and one of the endangered wildlife species whose population size is recently declining in Korea. The habitat deterioration of Eurasian Otter is considered as the most significant threat to decrease its populations. To manage and conserve a habitat for Eurasian otter, it is necessary to understand how various habitat components affect Eurasian otter movements. The objectives of this study, therefore, were to analyze Eurasian otter habitat characteristics in Soraksan National Park, to develop the habitat suitability model of Eurasian otter in Soraksan National Park, and to validate the habitat suitability model in Odaesan National Park, a validation site, in order to evaluate an accuracy of the habitat suitability model.

Soraksan National Park (SNP) is located in Kangwon province, the northeastern part of South Korea. The elevation of the highest peak in Soraksan is 1,707m and SNP area is 373 Km2. It was selected as a conservation area, the only one in Korea, by UNESCO in 1982, because of its variety of plants and animals (Figure 1).

Soraksan National Park is dominated by red pine (Pinus densiflora), Mongolian oak (Quercus mongolica), Korean pine (Pinus koraiensis), needle fir (Abies holophylla), Cornus controversa and Carpinus laxiflora (SNP 2002). There are 39 species of wildlife, according to the research record in SNP. Since the Asian tiger, the Asian black bear, and the Asian wolf have not been found

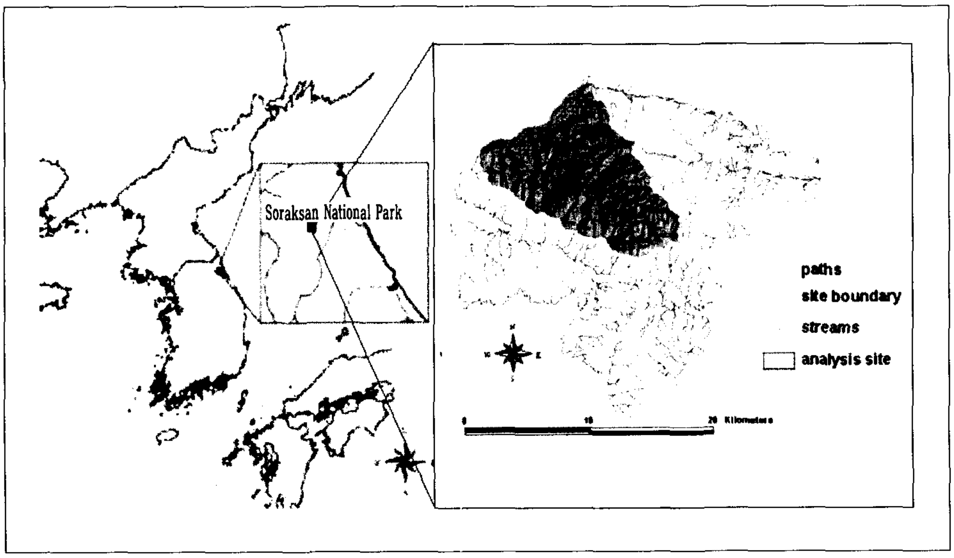

Figure 1. The map of the study site

recently, they are thought to be extinct species in SNP (SNP 2002). The climate of Soraksan National Park is characterized by warm, dry spring, and heavy rainy periods in summer, occasional rainy fall, and cold, dry winter. The average temperature in Inner-Sora k—SNP can be divided into three parts by the main ridges, Inner-Sorak is located in western SNP, Outer-Sorak encompasses eastern or coastal part of the mountain, and South-Sorak is located in southern part of SNP- ranges from -5.2℃ in January to 23.1℃ in July and August. Average annual precipitation in Inner-Sorak is 611.7mm (KMA 2002).

Figure 2 shows the procedure of this study to develop the habitat suitability model of Eurasian otter. First, location data of Eurasian otter trace were collected by several field surveys and characteristics of Eurasian otter habitat were recorded with digital maps. Second, habitat preferences of Eurasian otter were studied by both presence and absence data of Eurasian otter spraints in several field surveys and by literature studies. Third, the factors of habitat use were identified as habitat characteristics of Eurasian otters and classified with habitat use and availability analysis. Forth, environmental factors were extracted by a Chi-square goodness-of-fit test. Fifth, Eurasian Otter Habitat Suitability Model (EOHSM) was developed by using a logistic regression method and EOHSM map in the study site was produced. Finally, EOHSM was verified in other site similar to the study site.

In the study, a digital map of 1/25,000 scale and Digital Elevation Model (resolution 30×30m) was used for analyzing and mapping habitat suitability. To collect trace data of the Eurasian Otter, 2 GPS receivers (Explorer 2 and E-trex made by Trimble, Inc. and Garmin, Inc., respectively) were used in field surveys.

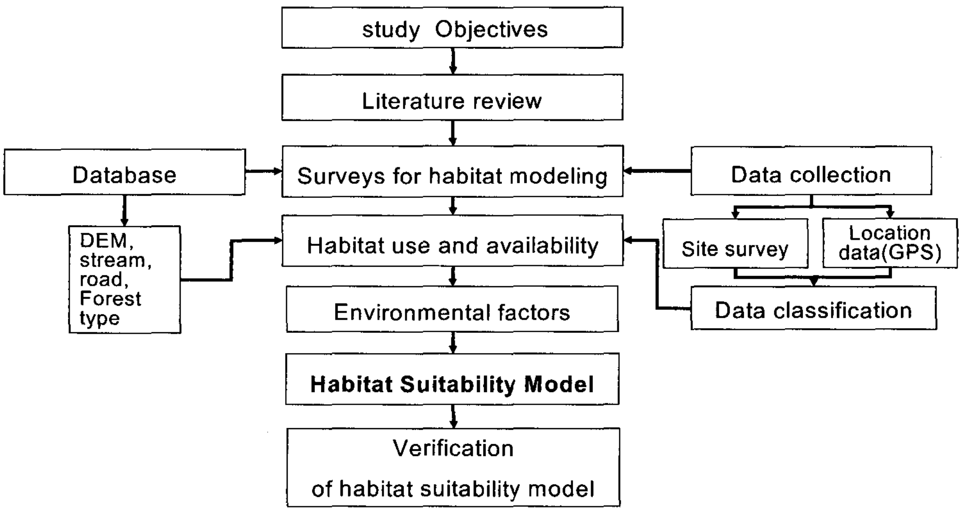

Figure 2. The process of the study

The tools for analysis of GIS data and mapping of habitat assessment are Arc/Info ver 8.0.1 , Arcview 3.2 and spatial analyst 2.0. SAS ver 8.1 was used for statistic analysis such as a Chi-square test and Logistic Regression.

2 Background

2.1 Habitat requirements of Eurasian otter

Eurasian or European otter (*Lutra lutra*) was once a top piscivorous predator in coastal and riparian habitats throughout much of Britain, continental Europe, the former USSR, Asia and Japan (NRA 1993). The range of otters in Korea can be grouped into two: coastal and head water. Coastal otters are mainly distributed on the southern coast of Korea, including Koje Island. The fresh water otters can be found at remote and clean head waters in Kangwon province, northern Kyungbuk province, and Chiri Mountain (Han 1997).

Eurasian otters may be solitary, or live in group territories in the sea or fresh water (Kruuk 1995). Eurasian otters live along rivers and also use marshes, small streams, ditches and lakes. The size of the home range depends on the quality of habitat, food supply, and social interaction with neighboring otters. A typical home range will include a river, side streams, ponds and adjacent woodlands and wetlands. Home ranges may extend from as little as 1.1km on coasts with a rich food supply to 40km along rivers (NRA 1993). According to Kruuk's (1995) study, female otters in Shetland were living in group range of 5-14km of coast, with little overlap between ranges. Males had larger ranges, overlapping with several female group areas, and individual males overlapped widely with each other, although they were aggressively territorial. Sprainting (scent marking) probably enables otters to avoid the others who are living in the same range in order to exploit the fish and other resources without interference. Holts or dens take a variety of forms including cavities on the roots of bank side trees, piles of logs or flood debris, drains and caves in rock falls (NRA 1993).

Eurasian otters are carnivorous with a varied diet. On average an adult otter eats about 1kg of food per day. Otters will also eat amphibians, birds, mollusks, crustaceans and small mammals. Hunting is usually by sight, but in murky water the whiskers play an important role, sensing the vibration caused by fish movements (NRA 1993). In Korea, food sources of the Eurasian otter were also studied in four localities by analyzing scats collected from the banks of the Ungok River during October-November 1998 and October 1999. Cray fish (98.7%, 37.6%) were the main food source in the two localities, whereas frogs (71.3%, 90.5%) were the main food source in other two localities. Other preys were fishes, insects, reptiles and mammals (Han 1999).

2.2 Habitat Modeling

Studies of Eurasian otter have focused on the its ecologic behaviors and characteristics using radio-telemetry (Kruuk 1995), analysis of prey (Carss et al. 1997), individual identification by DNA fingerprinting of spraints (Hansen and Jacobsen 1999), and analysis of home range and sprainting behaviour (Sauer et al. 1999, Kranz 1996). However, recently, studies and researches to characterize otter habitat and to develop a predictive model for otter' s habitat use have been suggested, as well mapping of distribution has become an important tool for the management of Eurasian otter and its habitats (Reuther et al. 2000).

To predict a wildlife habitat use and to develop a single-species habitat model for evaluating the habitat quality of different areas, several studies and researches have been approached. Multivariate statistical analysis, for instance, have been used to develop inductive and empirical models such as DFA (Discriminant Function Analysis) and logistic regression. DFA requires the assumption that the independent variables have a joint multivariate normal distribution with a common covariance structure across all sites and is not robust when categorical variables are included in the analysis (Hassler et al. 1986). Recently, logistic regression which use maximum likelihood techniques and therefore have less restrictive data requirements than DFA have been proposed for modeling microhabitat selection (Capen et al. 1986; Brennan et al. 1986; Manly et al. 1993). Categorical variables can also be used as independent variable. Therefore, logistic regression method was utilized to develop habitat model in this study.

3. Method

3.1 Data collection

Habitat characteristics and use of Eurasian otter were studied based on presence and absence data of wildlife in field surveys and on literature studies. Because we assumed that otter sign found somewhere within an area was evidence that otters used some habitat within that area, location data of Eurasian otter's signs by GPS were collected with otters' trace surveys in order to analyze characteristics of otter habitat and develop otter's habitat model in the Baekdam valley from Octerber 2000 to March 2002.

We chose 7 variables to represent elements of habitat characteristics (Table 1) and classified into two main categories such as natural environment factors and human disturbances. Natural environmental factors consisted of 'bottom structure', 'velocity', 'width', 'depth of a stream', and 'riparian vegetation types'. And, 'range distance to road' and 'Number of visitors to use road' were selected as Human disturbance factors in this study (Figure 3~9).

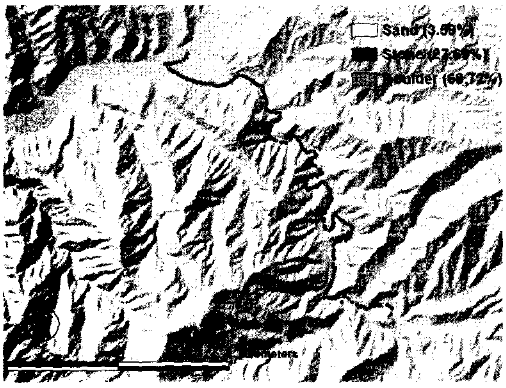

Figure 3. Bottom structure map;
( ): percent of frequency of otter's presence

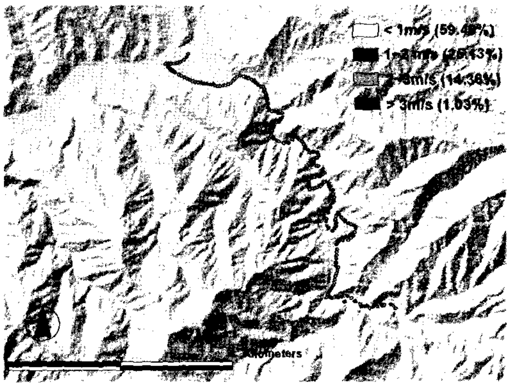

Figure 4. Water velocity map

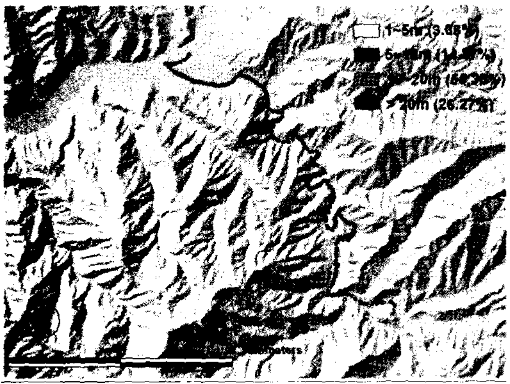

Figure 5. Stream width map

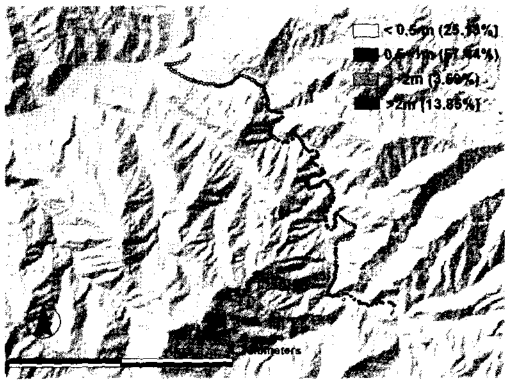

Figure 6. Stream depth map

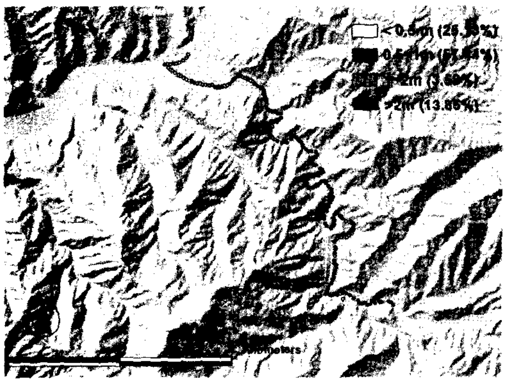

Figure 7. Vegetation type map

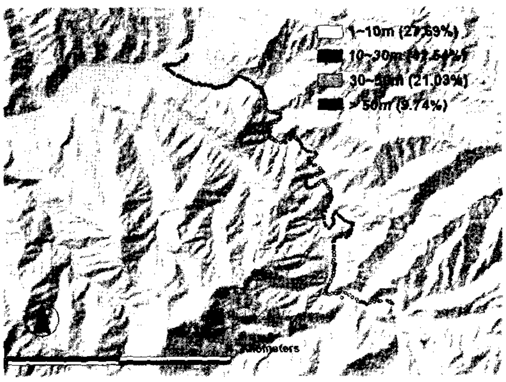

Figure 8. Range distance map

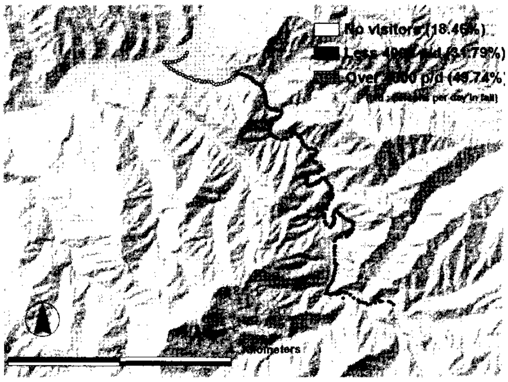

Figure 9. Number of visitors map

In order to analyze natural and human disturbance factors of the Eurasian otter habitat, Digital Elevation Model (DEM), 1: 25,000 stream and road maps were used. And 195 sectors one sector per 50m was totally surveyed in Baekdam valley. An analysis unit was determined as a circular polygon of 50m diameter for data collection and classification, because error degree of GPS receivers was 5 ~15 m and a cell unit of DEM was 30m.

In natural environmental factors, 'the bottom structure of streams' was classified into three categories, 'Sand', 'Stone' (radius <15 cm), and 'Boulders' (radius> 15cm). Sand bottom structure occupied 3.59% - percent of frequency of otter's presence in the site, stone 27.69 %, and boulders the largest portion (68.72%) of the stream. 'Water velocity' was classified into four categories, 'Below 1 m/s', '1~2 m/s', '2~3 m/s', and 'Above 3 m/s'. Below 1 m/s accounted for 59.49%, 1~2 m/s 25.13%, 2~3 m/s 14.36%, and Above 3 m/s 1.03% of the stream. 'Stream width' was classified into four categories as '1~5m', '5~10m', '10~20m', and 'Above 20m'. Stream width of 1~5m accounted for 3.08%, 5~10m 14.87, 10~20 m for 55.38%, and above 20 m for 26.67% of the stream. 'Stream depth' was classified into four categories as follows: 'Below 0.5m', '0.5~1m', '1~2m', and 'Above 2m'. Depth of below 0.5m accounted for 25.13%, 0.5~1m for 57.44 %, 1~2m for 3.59%, and above 2 m for 13.85% of the stream. 'Riparian vegetation types' were classified into three categories as 'Tree', 'Reed', and 'Tree and shrub'. Tree vegetation type occupied 57.95%, reed 31.80%, tree and shrub have 10.26% of the stream.

In human disturbance factors, on the other hand, 'Range distance to road' was classified into four categories according to range distance from stream to road. The distance was calculated by both horizontal and vertical distance. Categories were '1~10m', '10~30m', '30~50m', and 'Above 50m'. 1~10m sectors accounted for 27.69%, 10~30m sectors having the largest portion (41.54%) at the site, and 30~50m for 21.03%, and Above 50m for 9.74%. We also classified 'Number of visitors' by whom the road next to the stream was used on Oct. 7, 2001 - it was when the most people visited Soraksan National Park in 2001 - into three categories such as 'No visitors', 'Less 4000 visitors', and 'Over 4000 visitors'.

Table 1. Habitat factors of Eurasian otter at Baekdam site

Factors	Contents	Categories
Natural environment	Bottom structure of stream	Sandy Stone boulder
	Stream velocity	< 1 m/s 1~2 m/s 2~3 m/s 3~4 m/s
	Stream width	1~5m 5~10m 10~20m above 20m
	Stream depth	Below 0.5m 0.5~1m 1~2m
	Riparian vegetation type	Tree Reed Tree & shrub
Human disturbance	Range distance to road	1~10m 10~30m 30~50m above 50m
	Number of visitors	No visitors Less 4000 visitors Over 4000 visitors

3.2 Statistic analyses

Environmental factors with statistic significance were selected as variables using chi-square test to develop the habitat suitability model. The probability from the model predicts the suitable area for habitat. A logistic regression method was employed to analyze Eurasian otter habitat suitability. The model used two types of sample data, such as presence and absence of otter's signs. Presence data of 88 and absence data of 107 otter's signs at the site were selected for habitat modeling. Explanatory variables should be a value of 0 or 1 because of using logistic regression for the model (Seo 2000). Variables with n data consist of binominal y_v and response variable z_{ji} with j:

$$(y_v, z_{v1}, z_{v2}, \cdots, z_{vj}), v=1,2,\cdots n .$$

Response variable in logistic regression satisfy the following condition.

$$Y_v = \begin{cases} 1, & \textit{probability } p_v \\ 0, & \textit{probability } 1 - p_v \end{cases},$$

Here

$$p_v = \frac{\exp\left[\beta_0 + \sum_{j=1}^{p} \beta_j z_{vj}\right]}{\left\{1 + \exp\left[\beta_0 + \sum_{j=1}^{p} \beta_j z_{vj}\right]\right\}}, \quad i = 1, 2, \cdots, n, \tag{1}$$

and model 1 is

$$\log\left(\frac{p_v}{1-p_v}\right) = \beta_0 + \sum_{j=1}^{p} \beta_j z_{vj} \tag{2}$$

Y_v is supposed to be independent (Stokes 1997).

Backward selection which is one of the stepwise selection method was used for model selection process of this study. The Hosmer and Lemeshow statistic was used as goodness of fit of the model. This criterion can be used as a measure of goodness of fit for the strictly qualitative explanatory variable situation. Cutoff value of 0.5 was set as the classification accuracy of the model.

4. Results and Discussion

In the result of habitat availability analysis using a chi-square test, Table 3. shows factors affecting otter habitat selection were bottom structure of stream, stream width, stream depth, vegetation type of stream bank zone, and range distance to road, number of visitors These factors were defined as Variables with statistical significance to develop a habitat suitability model. We considered variables with P values below 0.25 as reliable (Manen and Pelton 1997).

Table 2. Environmental variables affecting Eurasian otter habitat selection.

Variables	DF	*X2 value*	*P value*
Bottom sturcutre(Sand, Stone)	2	24.40	**<0.001**
Water velocity	3	1.38	0.71
Stream width	3	22.99	**<0.001**
Stream depth	3	15.92	**0.001**
Vegetation type(Tree, Tree & Shrub)	2	21.60	**<0.001**
Distance to road	3	5.00	**0.08**
Number of visitors (No, Less)	2	25.86	**<0.001**

( ) : dummy variables

Table 3. Classification accuracy of the Logistic regression for the cover habitat using cutoff value of 0.5

True category	Predicted category		Accuracy(%)
	Presence	Absence	
Presence	43	45	51.1
Absence	7	100	93.5
		Overall	74.4

The selected habitat suitability model is as follows.

$$Y = -0.1595+1.0205\times STONE-1.0136\times TREE+2.3284\times NO$$

The habitat suitability model had a high classification accuracy of 74.4 % for habitat at cutoff value of 0.5, So this model is reliable (Table 3). The result shows that the predicted habitat for Eurasian otter is where bottom structure of a stream consists of stone (radius <15 cm), riparian vegetation type is reed or shrub, and there are no visitors

To validate the model, we applied it to Wolchung valley in Odaesan National Park (ONP) where environmental characteristics are similar to Baedam valley in SNP and Eurasian otter signs were found. Model validation showed the classification accuracy

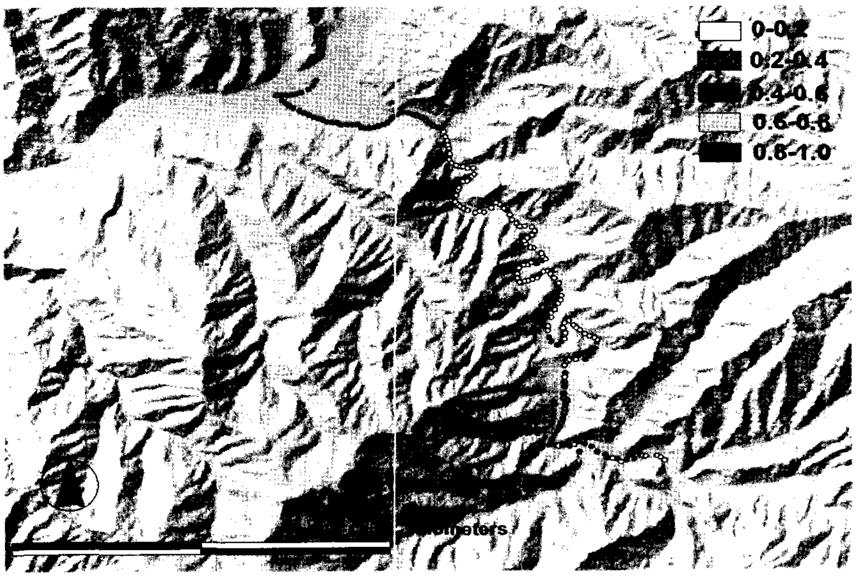

Figure 10. Habitat suitability map of Eurasian otter at Baekdam valley

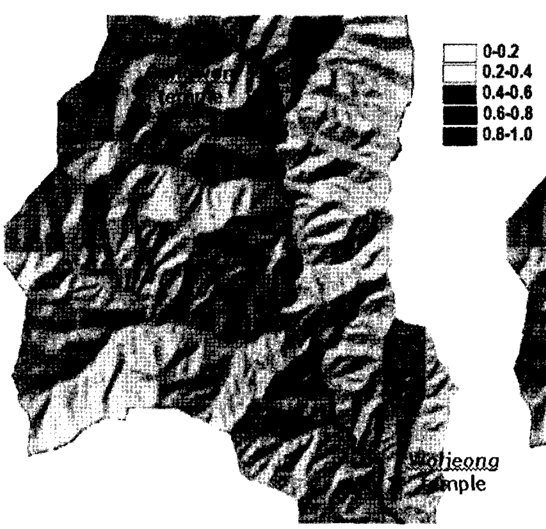

Figure 11. The habitat suitability map in Odaesan Nationlal Park, in order to validate the model which was developed in Soraksan National Park

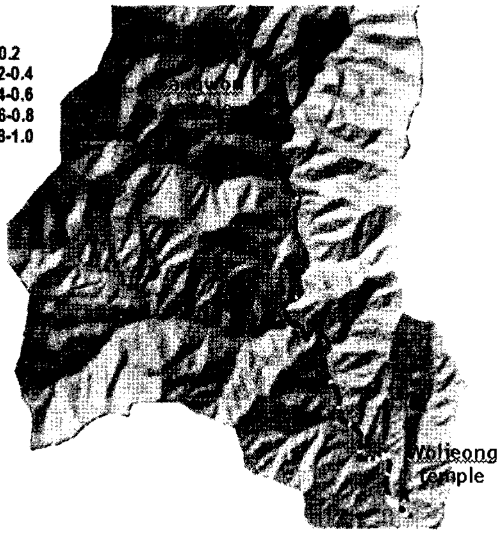

Figure 12. Eurasian otter signs on the habitat suitability map. The white dots represent Eurasian otter signs in Odaesan National Park

of 86.6 % at a cutoff value of 0.5. The validation reports that Eurasian otter habitat suitability model is considered significantly reliable (Figure 11, 12).

5. Conclusions

This study was employed in order to analyze environmental factors affecting Eurasian otter habitats, develop a model predicting habitat suitability, and validate otter habitat model. Further, a habitat suitability map was made to support environmental decision making such as ecological management of habitat.

As the result of the study, First, in habitat availability analysis, bottom structure, width, depth of stream and vegetation type of stream bank area were statistically significant natural environmental factors affecting otter habitat selection, it was also found that human disturbance factors affecting otter habitat selection are range distance to road and number of visitors. Second, the habitat suitability model had a classification accuracy of 74.4% at a cutoff value of 0.5 in the Baekdam valley. Model validation showed a classification accuracy of 86.6% at a cut off value of 0.5 in Odaesan National Park. Therefore, it could be concluded that this model was considered reliable.

In this study, environmental factors used in the model were so specific and detailed that the model has a limit to apply and evaluate to all potential habitat where Eurasian otters live. To develop better Eurasian otter habitat suitability model, it is important to find some factors which enable otter' s habitat to be evaluated and mapped with larger scale. One the other hand, social behavioral factors of otters could not be exactly identified by trace survey. Some additional survey methods such as a radio-telemetry survey will be carried out with trace surveys in future study. Studies for more various habitat modeling and assessment mapping are needed for several endangered and protected wildlife species

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