Development of a GIS-based habitat suitability model for wild boar *Sus scrofa* in the Mt. Baekwoonsan region, Korea

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Abstract. We developed a habitat suitability model for wild boar *Sus scrofa* in the Mt. Baekwoonsan region of Korea. We recorded wild boar field signs (dust baths, bedding sites, digging areas, feces and tracks) and habitat variables such as the nearest distance to watercourses (DWATER) and trails (DTRAIL), slope, aspect (ASPECT), forest type and forest age. Field signs and habitat characteristics were assessed within a 25 × 25 m quadrat along seven survey routes from August 1999 to July 2000. We conducted a CATMOD regression analysis based on 416 field signs at 50 points and classified them into 3 levels of habitat importance (high, medium and low) based on the relative importance of field signs. Habitat suitability indices (P) were calculated based on significant relationships between parameters such as DWATER, DTRAIL and ASPECT resulting in the following function: $P = 1/(1 + \exp - (3.82 \times (DWATER) - 1.21 \times (DTRAIL) + 1.35 \times (ASPECT)))$. Important habitats of wild boar were distributed near watercourses and far from trails along east and south-facing slopes.

Key words: bedding sites, dust baths, habitat suitability model, trails, wild boar.

Recent advances in geographic information systems (GIS), remote sensing technologies, and quantitative methods have enabled researchers to incorporate landscape-level measures into ecological studies and to classify suitable habitats for many species (Turner 1989; Forman 1995). The U.S. Fish & Wildlife Service has developed habitat suitability index (HSI) models for some species, and these models have been useful for the management of wildlife and their habitats (Allen 1982; Verner et al. 1986; Sousa 1987; Hodgson et al. 1988; Davis et al. 1990; Breiniger et al. 1991; van Manen and Pelton 1997), and for environmental impact studies (O'Neil et al. 1988; Williams 1988). In Korea, HSI models have been developed for game species such as ring-necked pheasant *Phasianus colchicus* (Yoo and Yang 1994), Korean hare *Lepus coreanus* (Yoo et al. 1995) and spot-billed ducks *Anas poecilorhyncha* (Yoo 1998). HSI models were also developed for wild boar based on autoecological data (Kim 1994) with logistic regression (Seo 2000) on hunting grounds. However, the

ecology of wild boar on hunting grounds may differ from that in natural areas without hunting pressure.

Increased numbers and expanding ranges of wild boar populations have been associated with severe damage to crops in Korea (Korea Forest Service 2000) and Japan (Kodera et al. 2001). Changes in land use by humans and the elimination of large predators may have contributed to this problem (Erkinaro et al. 1982; Saez-Royuela and Telleria 1986; Debernardi et al. 1995; Nores et al. 1995; Peracino and Bassano 1995).

If incorporated in population management programs, habitat suitability models could help determine habitat management priorities, especially in local areas with high densities of wild boar. However, there have been few regional habitat models developed from rigorous field studies. Our study was conducted to produce a HSI model for wild boar based on field observation data, habitat characteristics, and GIS analysis.

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Study area and methods

Our study area (ca. 5,600 ha) was a temperate deciduous forest on Mt. Baekwoonsan (100–1,217 m a.s.l.: 35°06'N, 127°39'E) near Kwangyang City, Chollanamdo Province, Korea. Average annual air temperature is 14.7°C and the mean annual precipitation is 1,650 mm (1946–1995). This area is a well-protected portion of the Seoul National University Forests, and part has been designated as an ecosystem preserve by the Ministry of Environment, Korea (Seoul National University Forests 1996). Overstory vegetation consisted of natural stands of *Quercus serrata*, *Q. mongolica*, *Q. variabilis*, *Carpinus laxiflora*, *Acer pictum*, *A. pseudosieboldianum*, *Fraxinus chiisanensis* and *F. rhynchophylla*, and some planted stands of *Larix kaempferi* and *Pinus koraiensis*. An intermediate layer of major vegetation was composed of *Lindera erythrocarpa*, *Stewartia koreana*, *Meliosma myriantha*, *M. oldhamii*, *Ilex macropoda*, *Sapium japonicum*, *Styrax obassia* and *S. japonica*, while the understory was dominated by *Sasa borealis*, *Deutzia parviflora* and *Stephanandra incisa* (Park 2001).

Wild boar habitat survey

To ensure coverage of the major habitats of wild boar (Won 1967; Erkinaro et al. 1982; Debernardi et al. 1995) we established 7 survey routes that included valley, slope and ridge areas with and without trails. Total length of survey routes was approximately 57 km, ranging from 15 to 1,217 m in elevation. Surveys were conducted along the following routes: (1) Kumchonri (150 m a.s.l.) to Maebong (867 m a.s.l.); (2) Kumchonri to Gitdaebong (860 m a.s.l.); (3) Nonshil (300 m a.s.l.) to Hanjae (1,000 m a.s.l.) via Dosolbong (1,127 m a.s.l.) and Ttaribong (1,100 m a.s.l.); (4) Tunnongol (400 m a.s.l.) to Byongam (300 m a.s.l.) via Mt. Baekwoonsan (1,217 m a.s.l.), (5) Naehoi (400 m a.s.l.) to Eokbulbong (1,050 m a.s.l.) via Mt. Bawkwoonsan; (6) Naehoi to Byongam via Mt. Baekwoonsan; and (7) Nonsil to Jungdaeri (450 m a.s.l.) via Hanjae (Fig. 1). We recorded wild boar field signs encountered along the survey routes twice in August, November, and January of 1999 and in June 2000 (Table 1, Fig. 1). We measured habitat variables including forest type (FTYPE; D-deciduous forest, O-other types), age class (FAGE; OL-over 50 years, L-40–50 years) and slope (SLOPE; H-over 30 degrees, M-19–30 degrees, L-below 18 degrees) within a 25 × 25 m

Fig. 1. Location of study areas and survey routes on trails (thick solid line) and off trails (dashed line), and distribution of fifty wild boar field points observed on Mt. Baekwoonsan, Korea. Numbers near each field point denote relative habitat importance values (1-low, 2-medium, 3-high). Triangles indicate mountain summits and circles represent valleys or villages.

Table 1. Analysis of maximum likelihood estimates of full and final models.

Variables	β	SE	Chi-Square	-2LogLR	P
Full model			68.85	117.40	<0.0001
FTYPE	0.0159	0.6139	0.00		NS
FAGE	-0.1824	0.6201	0.09		NS
SLOPE	0.4564	0.6686	0.47		NS
DWATER	2.4598	0.5308	21.48		<0.0001
DTRAIL	-1.1758	0.6636	4.14		<0.05
ASPECT	0.8612	0.3342	6.64		<0.05
Final model			36.85	125.76	<0.05
DWATER	3.8153	0.6458	34.91		<0.0001
DTRAIL	-1.2099	0.6814	4.04		<0.05
ASPECT	1.3519	0.4701	8.27		<0.05

FTYPE; forest type, FAGE; age class of forest, SLOPE; slope, DWATER; distance from watercourse, DTRAIL; distance from trail and ASPECT; aspect

quadrat around signs. We also recorded the distance from watercourses (DWATER; H-over 1,000 m, M-100~999 m, L-below 100 m), distance from trails (DTRAIL; H-over 1,000 m, M-100~999 m, L-below 100 m) and aspect (ASPECT; N-north, S-south).

Classification of field signs

Areas with field signs were classified into three levels of relative habitat importance (H-high, M-medium, L-low) based on the presence of dust baths, bedding sites, digging sites, feces and tracks (Won 1967; Erkinaro et al. 1982; Debernardi et al. 1995). Because of the dominance of productive hardwood forests, we assumed that the availability of wild boar foods was similar throughout the study area and did not try to account for their influence on habitat selection in this analysis. However, because of the importance of dust baths and bedding sites for determining wild boar habitat preferences, they were assigned the highest importance values (H) in our model (Erkinaro et al. 1982; Debernardi et al. 1995). Areas with only a dust bath or a bedding site, or barren fields with digging signs, or areas near group feces with no dust baths or bedding sites were assigned medium values (M). Low values (L) were assigned to areas with only digging signs and tracks within a quadrat (Fig. 1).

Data analysis

A spatial database was constructed and data were analyzed with ArcView version 3.2 (ESRI). We derived independent values from two sources: a 1:5,000-scale digital map for watercourses, trails, slope, and aspect; and a 1:5,000-scale forest vegetation map produced by the Korea Forest Research Institute. For inclusion of aspect azimuth values in the regression analysis, we

transformed the aspect parameter into a cosine function. All variables were similarly transformed into nominal values, and multinomial logistic regression was performed using the PROC CATMOD tools of SAS version 8.1 (SAS Institute, Cary, NC). An algorithm was applied to build models using the residual maximum likelihood (REML) method of data analysis for unbalanced parameters (Robinson 1987). Initially all variables were applied to model development, and a 5% significance level was used as the criterion to accept or reject variables in final model equation. Predicted values for the final model were compared with observed values for each range of habitat importance based on a Chi-square test ($P < 0.05$).

Results

Signs of wild boar

In 8 survey periods, we observed 416 signs of wild boar at 50 points, including ten bedding sites, 19 dust baths, 59 fecal groups, 107 digging sites and 221 tracks (Fig. 1). Signs were located 5 to 1,200 m from the nearest watercourse, and 5 to 2,000 m from nearest trail. These signs were located at aspects ranging from 20 to 310 degrees, and on slopes ranging from 0 to 44.2 degrees. All signs were found in deciduous forests except at two points, and all signs were located in forests >50 years old except at 6 points.

Development and application of a habitat suitability model for wild boar

Results from the full model using all variables (eighteen groups with 3 response levels) were significant ($d.f. = 18$, $\chi^2 = 68.85$, $P < 0.0001$). However, FTYPE ($d.f. = 2$, Wald - $\chi^2 = 0.00$, NS), FAGE ($d.f. = 2$, Wald - χ^2

Fig. 2. Spatial distribution of predicted habitat suitability indices for 10×10 m cells.

Table 2. Average probability of eighteen groups and validity analysis of predicted models.

Relative importance of habitat	Observed		Predicted		Chi-Square
	Probability	SE	Probability	SE	
High	0.3287	0.0136	0.3373	0.0600	$d.f. = 2,$ $\chi^2 = 0.02,$ $P = 0.9904$
Medium	0.3565	0.0211	0.3351	0.0793	
Low	0.3148	0.0076	0.3286	0.0695	

= 0.09, NS) and SLOPE ($d.f. = 4$, Wald - $\chi^2 = 0.47$, NS) did not contribute strongly to the equation (Table 1), and were not included in the final model ($d.f. = 12$, $\chi^2 = 36.85$, $P = 0.0002$). According to the model, important wild boar habitats are on south-facing slopes near watercourses and far from trails. This is expressed in our model for habitat suitability as follows:

$$P = 1 / (1 + \exp(-Y)),$$

$$\text{Where } Y = 3.82 (\text{DWATER}) - 1.21 (\text{DTRAIL}) + 1.35 (\text{ASPECT})$$

When we applied the model to the study area; habitat suitability indices ranged from 0 to 1. We generated GIS layers for five equally divided categories of habitat suitability indices and compared them with observed wild boar habitat usage (Fig. 2). The study area included lands with HSI values as follows: HSI from 0.8001 to 1.0000 was 999 ha (17.8%); from 0.6001 to 0.8000 was 636 ha (11.3%); from 0.4001 to 0.6000 was 1,999 ha (35.8%); from 0.2001 to 0.4000 was 673 ha (12.0%); and below 0.2000 was 1,293 ha (23.1%). Predicted values of habitat importance were not significantly different from the observed values ($d.f. = 2$, $\chi^2 = 0.02$, $P = 0.9904$, Table 2).

Discussion

Wild boar did not show a preference for trails in our study as had been reported in other studies (Kim 1994; Seo 2000). This difference could reflect the artificial feeding of wild boar by the manager of commercial hunting area near trails in the study areas of Kim (1994) and Seo (2000). However, in our study area trails are regularly used for hiking. Avoidance of hikers by wild boar may have influenced our determination of habitat suitability. Over the last twenty years in Korea, timber extraction has declined, but hiking has become increasingly popular. Changes in human activity and potential disturbance should be considered in any regional habitat models for wild boar.

Kim et al. (1998) used forest type, age class, aspect, slope, distance from watercourses and trails to model habitat suitability for wild boar. In that study, wild boar preferred coniferous forests as well as deciduous forests, but artificial feeding probably influenced these preferences. Japanese wild boar preferred deciduous forests in natural areas (Kodera et al. 2001). At Mt. Baekwoonsan, which is dominated by deciduous forests, forest type did not contribute strongly to the model (Table 1), but further research should be conducted to clarify preferences for deciduous and coniferous forest in natural areas.

Based on our model, highly suitable habitats were those along east-facing to southeast-facing slopes (86.1 to 143.8 degrees), 5.4 to 10.6 m from watercourses, and over 310 m from trails. Neither slopes nor aspects of suitable habitats showed differences with previous models (Kim 1994; Kim et al. 1998; Seo 2000).

Although Chi-square tests showed strong correlation between predicted and observed values, our model is limited because we did not consider wild boar food preferences and availability. Inclusion of food availability and telemetry-based foraging data could make the model more accurate and broadly applicable. Such refinements of the model would help predict distributions of wild boar populations, allowing for more effective population management.

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