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Article

Habitat Mapping of the Leopard Cat (*Prionailurus bengalensis*) in South Korea Using GIS

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Abstract: The purpose of this study was to create maps of potentially sustainable leopard cat (*Prionailurus bengalensis*) habitats for all of South Korea. The leopard cat, which is on the International Union for Conservation of Nature (IUCN) Red List, is the only member of the *Felidae* family in Korea. To create habitat potential maps, we selected various environmental factors potentially affecting the species' distribution from a spatial database derived from geographic information system (GIS) data: elevation, slope, distance from a forest stand, road, or drainage, timber type, age, and land cover. We analyzed the spatial relationships between the distribution of the leopard cat and the environmental factors using a frequency ratio model and a logistic regression model. We then overlaid these relationships to produce a habitat potential map with a species potential index (SPI) value. Of the total number of known leopard cat locations, we used 50% for mapping and the remaining 50% for model validation. Our models were relatively successful and showed a high level of accuracy during model validation with existing locations (frequency ratio model 82.15%; logistic regression model 81.48%). The maps can be used to manage and monitor the habitat of mammal species and top predators.

Keywords: leopard cat; *Prionailurus bengalensis*; frequency ratio; logistic regression; geographic information system; South Korea

1. Introduction

Long-term persistence of biodiversity is the ultimate goal of most conservation plans (Minor [1]). Maintaining biodiversity is important because identifying the species critical to the maintenance of ecosystem stability or those that will be useful human resources in the future is not always easy (Burton [2]). The most effective way to conserve biodiversity globally is to focus on the protection of high biodiversity areas (Myers [3]). One method of identifying these areas is to model top predator habitats, which are often biodiversity hot spots (Schmitz [4], Sergio [5], Gavashelishvili [6]).

Carnivores are major predators and scavengers in terrestrial ecosystems. Understanding their status is important for understanding ecosystem integrity in regions of high human disturbance. The leopard cat (*Prionailurus bengalensis*) is a small, wild cat native to North and East Asia. Since 2002, the International Union for Conservation of Nature (IUCN) has listed it as a species of least concern. Although it is widely distributed, it is also threatened by habitat loss and hunting in parts of its range. Of the 12 leopard cat subspecies, which differ widely in appearance (Sanderson [7]) only one exists in South Korea.

GIS is a useful tool for determining the spatial relationships of an event and its controlling factors. GIS has been successfully used for habitat mapping of an event distribution based on probability and statistical models (Kim [8], Lee [9]), Analytic Hierarchy Process (AHP) decision models (Matsuura [10]), fuzzy relations (Choi [11]), and artificial neural networks (Song [12]). More recently, many studies have employed GIS to produce habitat maps for various species. Poplar-Jeffers [13] and Ottaviani [14] used a GIS-based model to quantify and indicate the habitat of mammals. Newton-Cross [15], Tien Bui [16], and Huck [17] mapped the distribution of badgers using a logistic regression model. In the case of bats, some studies have applied statistical models to analyze their habitat distributions Jaberg [18] and Greaves [19], Clement [20]. Northrup [21] used logistic regression models in a geographic information system to map the probability of bear-human conflict and the relative probability of grizzly bear habitat selection based on global positioning system radiotelemetry data. Kuemmerle [22] applied a probabilistic model to habitat mapping of the European bison (*Bison bonasus*), Speed [23] used remote sensing data for habitat mapping of deer, and Gavashelishvili [6] analyzed leopard habitat in central Asia using a logistic regression model. Studies of the spatial relationships between species habitats and various ecological environments have also been attempted (Kocev [24], Meixler [25], Walker [26], Walters [27]). However, none of these studies has analyzed the habitat of the leopard cat in South Korea. Therefore, the purpose of our study was to identify relationships between the distribution of the leopard cat and various environmental factors using probability and statistical models. Furthermore, we used the resulting leopard cat habitat range to map the species in South Korea. We used frequency ratios and logistic regressions as probabilistic and statistical models, respectively.

South Korea is located in North Asia (37°16′32″N, 127°03′05″E), in the southern half of the Korean Peninsula (Figure 1). South Korea is geomorphologically stable and contains three major mountain ranges: the Taebaek Mountains, the Sobaek ranges, and the Jiri Massif. Furthermore, no active volcanoes exist and no strong earthquakes have occurred. It has no extensive plains and its lowlands, which make up approximately 30% of its land area, are the product of mountain erosion. Uplands and mountains comprise the remaining area.

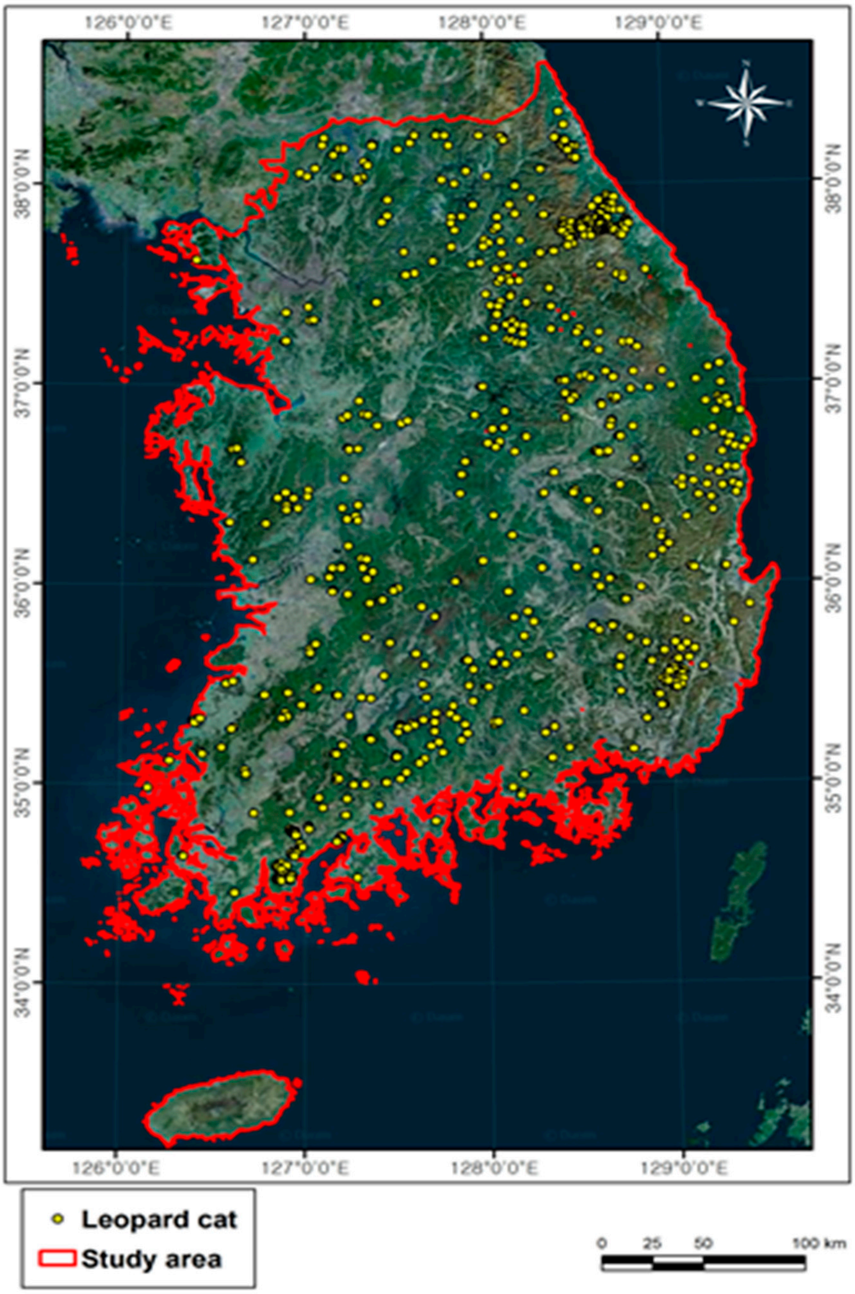


Figure 1. Study area with leopard cat occurrences points.

2. Data

2.1. Leopard Cat Survey

From 1997 to 2005, field experts from the National Institute of Environmental Research, universities, and research institutes conducted surveys on species occurrences and spatial distributions of wildlife via direct observations, surveys of local residents, and field signs such as tracks, feces, and footprints. This study is part of the second national environment survey in South Korea. The leopard cat, or traces of the species, was found at 630 points in the study area. Some of the data were excluded because they identified the locations based on indirect research methods such as a local resident survey based on residents' hearing the animals rather than a direct observation of the species. This resulted in the removal of 201 points, with a further 429 points utilized for modeling and validation.

The leopard cat is one of the top predators in the mountainous regions of Korea, but few habitat models have been developed at the regional level for this animal. The species is designated as an Endangered Species Type II by the Wildlife Conservation Act of Korea. Recent habitat loss and fragmentation are critical factors threatening leopard cat populations in mountainous regions. Despite the leopard cat's wide distribution, little is known about its ecology or behavior in the wild.

Since 1986, Korea has undertaken national environmental research consisting of nine sectors: (1) geography; (2) vegetation; (3) flora; (4) mammals; (5) birds; (6) herptiles; (7) freshwater fishes; (8) land insects; and (9) benthic macroinvertebrates. Under the supervision of the National Institute of Environmental Research (NIER), the first and second national environmental research efforts occurred between 1986 and 1990 and between 1997 and 2005, respectively. Field experts from the National Institute of Environmental Research, universities, and research institutes have conducted surveys on species occurrence and the spatial distributions of wildlife. The third survey has been in progress since 2006, and is expected to conclude in 2015. In the case of mammals, research has been conducted annually from February to October. Literature reviews, and geographical and vegetation statuses were used to determine the most appropriate locations for identifying local mammals. When species identification is difficult in the field, researchers resort to capturing the animals after obtaining necessary permissions. After the investigation, all captured mammals are released at the locations in which they were captured. Since direct observation of mammals is difficult, interviews have been used to complement fieldwork. Through interviews with local mammal experts, museum workers, hunting license issuers, and local residents, these efforts have identified apparent species locations, seasons, and population sizes. Since leopard cats are distributed throughout forested areas, research has focused not only on locations related to agricultural lands, but also on ridges, considering the total forested land. Since direct observation of leopard cats is difficult, trace investigations, including that of excrement, has been necessary. In addition, data have been acquired through interviewing local residents. Locations in which leopard cats have been observed or detected via traces were recorded by a global positioning system (GPS) or map, and used for constructing geographic information system (GIS) data.

2.2. Controlling Factors

The distribution of the leopard cat is the result of the interaction of complex factors. The selection of these factors and the preparation of corresponding thematic data layers are crucial components of any model for leopard cat habitat potential mapping. The important factors for mammalian habitat include ground elevation, slope steepness, aspect, timber distribution, land cover, land use, and human activity (Table 1). These factors were collected from available maps and field investigations. A digital elevation model (DEM) was prepared through the digitization of contours at 5-m intervals from the topographical maps. Using the DEM, the slope gradient and slope aspect were calculated. The forest map is a series of polygons with a scale of 1:25,000 that is published by the Korea Forest Research Institute (KFRI). The land-cover types were identified from a panchromatic SPOT-5 (Système Probatoire d'Observation de la Terre 5) image taken in November 2007.

The land-cover map was also a series of polygons with a scale of 1:5000 that was published by the Korea Ministry of Environment. The diameter, type, density, and age of the timber were obtained from the forest maps. The maps relevant to leopard cat occurrence were constructed in a vector format spatial database using the ArcGIS (ESRI) software package. To calculate the frequency ratio for the class or type of each factor, the scale factors were divided into 10 classes with equal area using ArcGIS. Therefore, the range of each class was automatically determined based on equal areas. Nine factors, both calculated and extracted (Table 1) from the maps, were converted to a 30 × 30-m grid format (ArcGIS GRID type). As a result, the dimensions of the study area grid were 7224 rows by 6792 columns, and the total number of cells was 12,307,439 (except those with no data). Then, the factors were converted to ASCII data for use with the statistics program. All of the factors were placed into one of the 10 classes. Each of the analyzed factors (Table 2) were made by utilizing the data of Table 1.

Table 1. Data layer related to leopard cat of study area.

Category	Factors	Data Type	Scale
Habitat	Leopard cat	Point	-
Forest map [a]	Timber type Timber age	Polygon	1:25,000
Land Cover	Distance from road (m) Distance from water (m) Distance from forest (m) Land cover	Polygon	1:25,000
Topographic map [b]	Ground elevation (m) Slope gradient (°) Slope aspect	GRID	1:5000

[a] The forest map produced by Korea Forest Service (KFS; the http://www.forest.go.kr); [b] Topographical factors were extracted from digital topographic map by National Geographic Information Institute (NGII; http://www.ngii.go.kr).

3. Methods

The general progression of leopard cat potential habitat mapping is illustrated in Figure 2. The process of mapping the habitat potentials of two leopard cat communities in South Korea included six major steps: (1) a field survey to determine the occurrence of the leopard cat; (2) the determination and construction of a database of the controlling factors, in combination with a GIS analysis; (3) the construction of a spatial database based on the two leopard cat communities and nine factors influencing their distribution; (4) the division of leopard cat individuals into a training set (50%) to analyze habitat potential using models and a test set (50%) to validate the predicted potential habitat map; (5) data processing using the frequency ratio and logistic regression models; and (6) validation of the leopard cat potential habitat maps using the known distributions of leopard cat that were not used in the analysis.

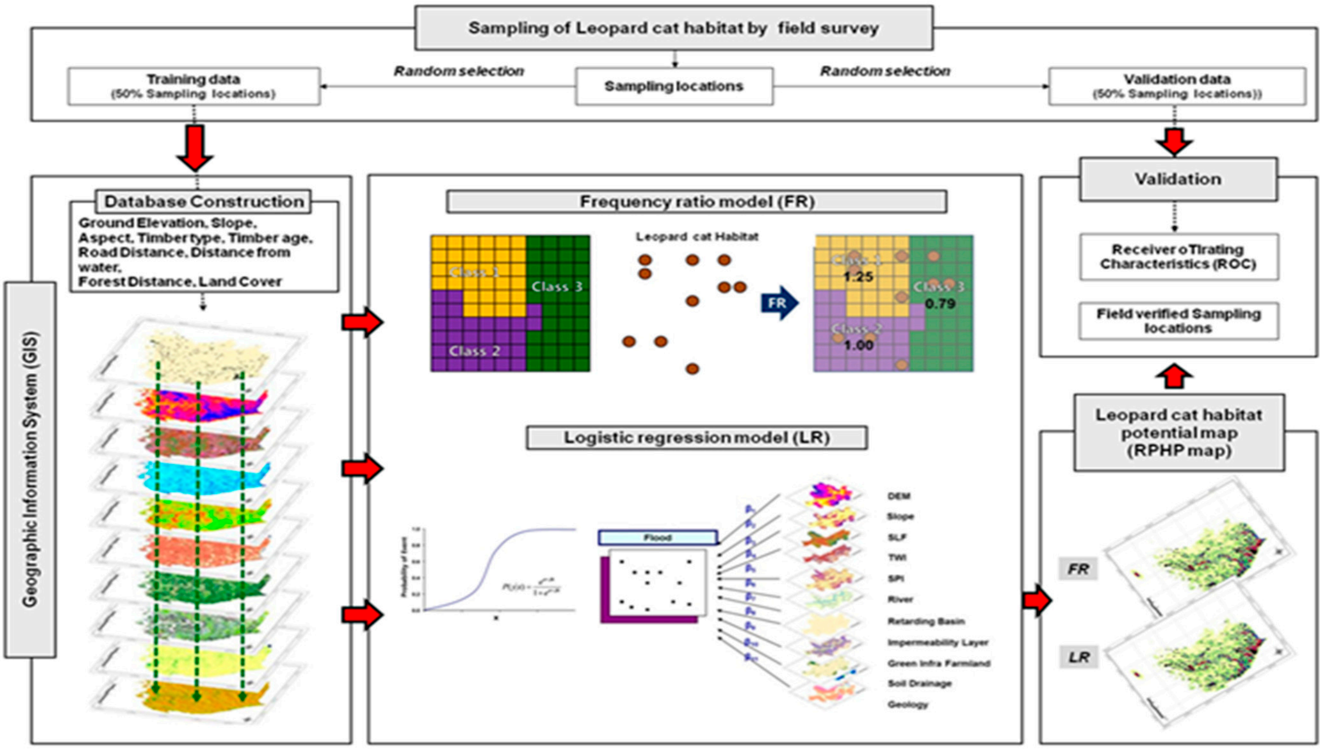


Figure 2. Flowchart of study.

For the application and validation of habitat potential models for the leopard cat, known locations were identified via interviews and field surveys in 2005 (Figure 1). We used these locations as the dependent variable, and nine factors believed to influence leopard cat habitat were set as independent variables: elevation, slope, aspect, timber distribution, land cover, land use, and human activity. Using known locations and calculated or database-extracted factors for model training, we conducted a habitat analysis using a frequency ratio model. A logistic regression model was also used for leopard cat habitat analysis. The frequency ratio model is a simple and basic technique that can be used to explain spatial relationships between known locations and potential habitat-influencing factors. For the application of these models, a statistical package was used in the GIS program. Finally, the resulting models were validated using known leopard cat locations that were not used to train the model.

As stated earlier, the frequency ratio and logistic regression were used as a probabilistic and statistical model, respectively. The frequency ratio, as a probability model, can be easily represented as the frequency ratio of each factor. The frequency ratio is the probability of occurrence of a certain attribute (Bonham-Carter [28]). The frequency ratio is the ratio of the area in which an event in a class or type for a given factor occurs divided by the overall study area. In Equation (1), P(P) denotes the area ratio for the class or type for a given number of unit cells containing a percentage of the pixels in the domain for the class, and P(O) denotes the percentage of occurrence in the total event. The frequency ratio of each factors type or class, C, is then expressed by:

$$FR_C = \frac{P_C(O)}{P_C(P)} \tag{1}$$

Logistic regression enables investigation of multivariate regression relations between one dependent and several independent variables. Logistic regression is limited in that the calculation process cannot be traced because it repeats calculations to find the optimized regression equation for determining the possibility that the dependent variable will occur. However, logistic regression does have the following advantages: (1) the assumption of a normal distribution is not applied for independent variables because the relationship between the dependent variable and independent variables is identified as a non-linear relationship; (2) It is able to explain complex phenomena because a range of data types can be used for the independent variable, including discrete, gradational, nominal, and continuous types. Thus, the method is suitable for analyzing complex spatial relationships in a quantitative manner; (3) The result of a logistic regression analysis includes individual values for each factor related to the habitat. These factor values can be used in similar studies targeting other regions.

By determining the frequency ratio, the area ratio for leopard cat habitat was calculated for the range or type of each factor, and the area ratio of the range or type of each factor to the total area was calculated. Finally, the frequency ratios for the range or type of each factor were calculated by dividing the distribution area ratio by the area ratio. The frequency ratio was assigned to each factor's class. The frequency ratio of the habitat potential was created using the overlay functions in the GIS, which were used to merge different factors that were assigned the ratio.

To apply the logistic regression model for analysis of leopard cat habitat potential mapping, the dependent variable was binary, representing the presence or absence of habitat. Quantitatively, the relationship between the occurrence and its dependency on several variables can be expressed as:

$$P(T = 1|X) = \Lambda(X) \tag{2}$$

with the logistic function Λ, and introducing the actual logistic regression model explicitly as:

$$\begin{gathered} \operatorname{logit}\big(P(T = 1|X_0 \ldots X_n)\big) = z \\ P(T = 1|X_0 \ldots X_n) = \Lambda(z) \end{gathered} \tag{3}$$

where P is the probability of an event's occurring, and e is the natural logarithm. In the present situation, P is the estimated probability of a habitat based on intrinsic properties only, which we term "susceptibility." The probability varies from 0 to 1 on an S-shaped curve, and z is the linear combination. It follows that logistic regression involves fitting the data to an equation of the form:

$$z = b_0x_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n \tag{4}$$

where b_0 is the intercept of the model, bi (i = 0, 1, 2, …, n) represents the slope coefficients of the logistic regression model, and xi (i = 0, 1, 2, …, n) are independent variables (Dai [29]). The linear model that is formed is then a logistic regression for the presence or absence of leopard cat habitat (present conditions) on the independent variables (pre-failure conditions).

Using these formulae, a habitat potential map was constructed. The logistic regression analysis was performed by dividing the study area into grid squares of 30 × 30 m. Data for the 11 factors were converted to an ASCII format for use in the statistical package.

Although a "best-fit" equation is found in logistic regression using the same least-squares method as linear regression, the principles on which it does so are rather different. Instead of using least-square deviations criteria for the best fit, logistic regression employs a maximum likelihood method, which maximizes the probability of obtaining the observed results given the fitted regression coefficients. A consequence of this is that the goodness of fit and overall significance statistics used in logistic regression are different from those used in linear regression. Here, logistic regression was used to calculate and map the probability of habitat potential, and logistic regression values for the study area were applied.

Log likelihood is a key concept for understanding the tests used in logistic regression. Normally, overall significance is determined by a chi-square test, which is derived from the likelihood of observing the actual data under the assumption that the model that has been fitted is accurate. Tables 2 and 3 contain the base model results for the frequency ratio and logistic regression analysis.

4. Results

4.1. Factors that Influence Leopard Cat Distributions

We evaluated the spatial data using the frequency ratio model to reveal correlations between the distribution of the leopard cat and various environmental factors (Table 1) in the study area. A positive correlation designates higher habitat potential, while a negative correlation indicates lower habitat potential.

Relationships between the distribution of the leopard cat and topography-related environmental factors derived from the digital elevation model (DEM; Table 2) are as follows. All of the topography-related factors (elevation, slope, and aspect) were positively correlated with the distribution of the leopard cat, indicating that at higher elevations and steeper slopes, habitat potential increases for this species. Higher elevations and steeper slopes may provide a safe habitat from competition, including that from humans. Accordingly, lower elevations and gentler slopes could produce the opposite result. The frequency ratio model results indicated that elevation, slope-related factors, and timber age were positively correlated with leopard cat locations. Areas closer to water and forest and farther from roads had higher habitat potential. With respect to timber type, oak forests showed the most positive correlation, and broad-leaved forest classes presented the most positive correlation among land cover types. In general, grasslands and edge areas formed adjacent to water and forests are known to be productive. These results indicate that the leopard cat uses habitats containing both safe topological features and rich food sources.

Table 2. Frequency ratio values between leopard cat and related factors.

Factor	Class	No. of Leopard Cat	% of Leopard Cat	No. of Pixels in Domain	% of Pixels in Domain	Frequency Ratio
Timber Type	No data	13	6.05	4,804,101	39.03	0.15
	Farmland	2	0.93	63,487	0.52	1.80
	Larch	7	3.26	583,520	4.74	0.69
	Pinus rigida fores	5	2.33	420,983	3.42	0.68
	Non-stocked forest land	0	0.00	17,862	0.15	0.00
	Chestnut artificial forest	0	0.00	57,592	0.47	0.00
	Cut-over area	0	0.00	44	0.00	0.00
	Pinus densiflora Forests	37	17.21	1,961,707	15.94	1.08
	Pinus densiflora artificial forest	0	0.00	17,996	0.15	0.00
	Pinus koraiensis forest	0	0.00	245,009	1.99	0.00
	Left-over area	3	1.40	75,377	0.61	2.28
	Oak forest	3	1.40	25,784	0.21	6.66
	Oak artificial forest	0	0.00	35	0.00	0.00
	Grassland	0	0.00	59,628	0.48	0.00
	Conifer mixed forest	0	0.00	928	0.01	0.00
	Mixed forest of soft and hardwood	45	20.93	1,971,628	16.02	1.31
	Poplar forest	7	3.26	154,432	1.25	2.59
	Water	0	0.00	10	0.00	0.00
	Broadleaved forest	93	43.26	1,838,135	14.94	2.90
	Denuded land	0	0.00	119	0.00	0.00
	Bamboo stand	0	0.00	8276	0.07	0.00
	Other	0	0.00	786	0.01	0.00
Timber age	Non forest area	20	9.30	4,807,568	39.06	0.24
	1st age	8	3.72	348,170	2.83	1.31
	2nd age	11	5.12	1,119,393	9.10	0.56
	3rd age	73	33.95	3,093,566	25.14	1.35
	4th age	60	27.91	2,229,052	18.11	1.54
	5th age	24	11.16	558,152	4.54	2.46
	6th age	19	8.84	151,538	1.23	7.18

Table 2. *Cont.*

Factor	Class	No. of Leopard Cat	% of Leopard Cat	No. of Pixels in Domain	% of Pixels in Domain	Frequency Ratio
Distance from forest (m)	0	200	93.02	7,599,556	61.75	1.51
	0–376	15	6.98	3,758,175	30.54	0.23
	376–752	0	0.00	590,022	4.79	0.00
	752–1129	0	0.00	173,595	1.41	0.00
	1129–1505	0	0.00	56,364	0.46	0.00
	1505–1881	0	0.00	47,662	0.39	0.00
	1881–2633	0	0.00	39,695	0.32	0.00
	2633–5266	0	0.00	17,803	0.14	0.00
	5266–9780	0	0.00	11,995	0.10	0.00
	9780–96,299	0	0.00	12,572	0.10	0.00
Distance from road (m)	0	1	0.47	998,165	8.11	0.06
	0–892	42	19.53	7,167,235	58.23	0.34
	892–1783	73	33.95	2,503,822	20.34	1.67
	1783–2675	56	26.05	878,584	7.14	3.65
	2675–3566	26	12.09	321,628	2.61	4.63
	3566–5346	12	5.58	204,622	1.66	3.36
	5346–8024	5	2.33	76,207	0.62	3.76
	8024–12,481	0	0.00	62,533	0.51	0.00
	12,481–21,396	0	0.00	50,792	0.41	0.00
	21,396–228,225	0	0.00	43,851	0.36	0.00
Distance from Water (m)	0–300	49	22.79	6,341,839	51.53	0.44
	300–600	132	61.40	4,277,696	34.76	1.77
	600–900	33	15.35	1,307,761	10.63	1.44
	900–1200	1	0.47	228,651	1.86	0.25
	1200–1500	0	0.00	75,739	0.62	0.00
	1500–1800	0	0.00	47,220	0.38	0.00
	1800–2200	0	0.00	7338	0.06	0.00
	2200–2900	0	0.00	3196	0.03	0.00
	2900–4100	0	0.00	9733	0.08	0.00
	4100–231,600	0	0.00	8266	0.07	0.00

Table 2. *Cont.*

Factor	Class	No. of Leopard Cat	% of Leopard Cat	No. of Pixels in Domain	% of Pixels in Domain	Frequency Ratio
Land Cover	No Data	0	0.00	25,366	0.21	0.00
	Other	0	0.00	6	0.00	0.00
	Residential Area	1	0.47	368,259	2.99	0.16
	Manufacturing Area	0	0.00	87,177	0.71	0.00
	Commercial Area	0	0.00	51,080	0.42	0.00
	Recreational Area	0	0.00	7266	0.06	0.00
	Trafficker Area	1	0.47	150,279	1.22	0.38
	Public Area	0	0.00	63,623	0.52	0.00
	Agricultural Area	0	0.00	30	0.00	0.00
	Paddy	4	1.86	1,673,342	13.60	0.14
	Field	7	3.26	1,086,507	8.83	0.37
	Growing in Plastic Greenhouse	0	0.00	55,590	0.45	0.00
	Orchard	0	0.00	166,213	1.35	0.00
	Other Plantations	0	0.00	44,730	0.36	0.00
	Broadleaved Forest	87	40.47	2,121,556	17.24	2.35
	Coniferous Forest	56	26.05	3,398,502	27.61	0.94
	Mixed Forest	57	26.51	2,038,541	16.56	1.60
	Forest Area	0	0.00	12	0.00	0.00
	Natural Grassland	0	0.00	64,109	0.52	0.00
	Artificial Pasture	0	0.00	14,778	0.12	0.00
	Other Grassland	1	0.47	201,126	1.63	0.29
	Wetland	0	0.00	4	0.00	0.00
	Inland Wetland	1	0.47	84,990	0.69	0.68
	Coastal Wetland	0	0.00	43,714	0.36	0.00
	Bare Land	0	0.00	20	0.00	0.00
	Natural Bare Land	0	0.00	10,630	0.09	0.00
	Other Bare Land	0	0.00	207,758	1.69	0.00
	Beach	0	0.00	1	0.00	0.00
	Inland Water	0	0.00	271,565	2.21	0.00
	Marine Water	0	0.00	70,665	0.57	0.00
Ground Elevation (m)	1–20	1	0.47	1,477,428	12.00	0.04
	20–60	3	1.40	1,528,017	12.42	0.11
	60–100	6	2.79	1,252,322	10.18	0.27
	100–149	10	4.65	1,162,504	9.45	0.49
	149–200	15	6.98	1,215,807	9.88	0.71
	200–264	9	4.19	1,145,797	9.31	0.45
	264–342	15	6.98	1,133,705	9.21	0.76
	342–456	42	19.53	1,135,628	9.23	2.12
	456–640	41	19.07	1,135,580	9.23	2.07
	640–1940	73	33.95	1,120,651	9.11	3.73

Table 2. *Cont.*

Factor	Class	No. of Leopard Cat	% of Leopard Cat	No. of Pixels in Domain	% of Pixels in Domain	Frequency Ratio
Slope gradient (°)	0	0	0.00	1,598,779	12.99	0.00
	0–2.7	6	2.79	1,221,822	9.93	0.28
	2.7–5.3	12	5.58	1,227,435	9.97	0.56
	5.3–8.0	16	7.44	1,187,745	9.65	0.77
	8.0–11.0	26	12.09	1,175,879	9.55	1.27
	11.0–13.8	28	13.02	1,166,970	9.48	1.37
	13.8–17.0	38	17.67	1,227,353	9.97	1.77
	17.0–20.0	20	9.30	1,188,780	9.66	0.96
	20.0–24.5	30	13.95	1,167,277	9.48	1.47
	24.5–56.6	39	18.14	1,145,399	9.31	1.95
Slope aspect	Flat	0	0.00	1,598,779	12.99	0.00
	N	21	9.77	1,212,664	9.85	0.99
	NE	36	16.74	1,358,789	11.04	1.52
	E	29	13.49	1,395,191	11.34	1.19
	SE	31	14.42	1,367,292	11.11	1.30
	S	16	7.44	1,235,557	10.04	0.74
	SW	24	11.16	1,389,112	11.29	0.99
	W	27	12.56	1,396,318	11.35	1.11
	NW	31	14.42	1,353,737	11.00	1.31

4.2. Habitat Potential Mapping

The frequency model was used to derive and calculate correlation ratings between the leopard cat distribution and each factor influencing habitat. Each factor's rating was assigned as the relationship between leopard cat distribution and each factor's type or range (Table 2). The ratio of the number of cells where the leopard cat was not founded to the number of cells where the leopard cat was founded is shown in Table 2. The habitat potential index (HPIFR), Equation (5), was calculated by a summation of each factor ratio value, as shown in Table 2 (Lee [30]):

$$HPI_{FR} = \Sigma FR \quad (5)$$

where FR is the rating of each factor type or range. A FR of 1 indicates that the class has a density of habitat area proportional to the size of the class in the map. If the value is greater than 1, then there is a high correlation, and a value of less than 1 means a lower correlation.

Table 3. Logistic regression coefficient between leopard cat and related factors.

Factor	Class	Logistic Regression Coefficient	Significance Level
Timber Type	No data	0.000000	0.000
	Farmland	2.147514	
	Larch	2.502028	
	Pinus rigida fores	0.948505	
	Non-stocked forest land	2.462551	
	Chestnut artificial forest	4.025706	
	Cut-over area	1.895348	
	Pinus densiflora forest	−18.043562	
	Pinus densiflora artificial forest	3.942215	
	Pinus koraiensis forest	−16.933439	
	Left-over area	0.000000	
	Oak forest	2.252224	
	Oak artificial forest	2.532997	
	Grassland	−22.151046	
	Conifer mixed forest	2.291914	
	Mixed forest of soft and hardwood	0.000000	
	Poplar forest	0.000000	
	Water	0.000000	
	Broadleaved forest	0.000000	
	Denuded land	0.000000	
	Bamboo stand	0.000000	
	Other	0.000000	
Timber age	Non forest area	−0.305775	0.002
	1st age	0.874957	
	2nd age	−0.260902	
	3rd age	−0.081416	
	4th age	0.087840	
	5th age	−0.655312	
	6th age	0.000000	
Distance from forest (m)	-	0.00442	0.935
Distance from road (m)	-	−0.00026	0.480
Distance from Water (m)	-	−0.000133	0.001

Table 3. *Cont.*

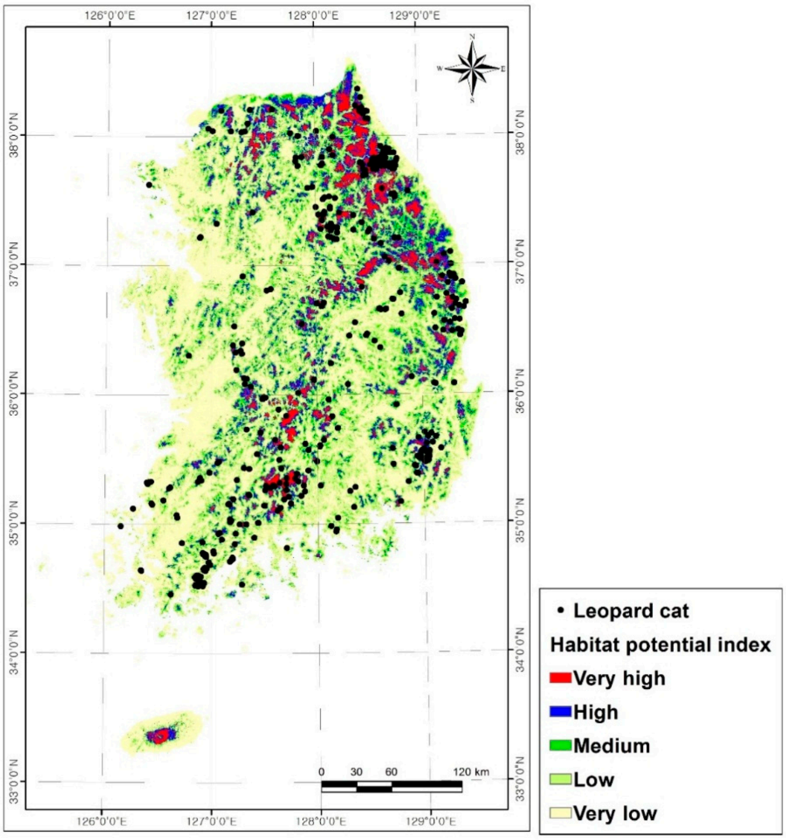
Factor	Class	Logistic Regression Coefficient	Significance Level
Land Cover	No Data	0.000000	0.722
	Other	0.000000	
	Residential Area	1.252586	
	Manufacturing Area	2.305031	
	Commercial Area	2.030913	
	Recreational Area	2.078151	
	Trafficker Area	19.626055	
	Public Area	20.999587	
	Agricultural Area	0.000000	
	Paddy	18.571218	
	Field	18.817534	
	Growing in Plastic Greenhouse	0.000000	
	Orchard	1.801892	
	Other Plantations	3.061980	
	Broadleaved Forest	18.682290	
	Coniferous Forest	19.251522	
	Mixed Forest	19.127733	
	Forest Area	0.000000	
	Natural Grassland	17.532816	
	Artificial Pasture	−0.795913	
	Other Grassland	17.843009	
	Wetland	0.000000	
	Inland Wetland	21.357972	
	Coastal Wetland	0.000000	
	Bare Land	0.000000	
	Natural Bare Land	0.442838	
	Other Bare Land	18.492102	
	Beach	0.000000	
	Inland Water	19.498249	
	Marine Water	0.000000	
Ground Elevation (m)	-	0.003815	0.000
Slope gradient (°)	-	−0.013209	0.130
Slope aspect	-	−0.001690	0.004

The spatial databases of each variable were converted to ASCII files using ArcGIS for use in the statistical package SPSS 20. Using this approach, logistic multiple regression coefficients (B), standard errors of slope coefficients (S.E), the Wals tests (Wals), the significance levels (Sig.), and the exponentiated slope coefficients (Exp(B)) of the related variables were calculated (Table 3). The coefficients were estimated using the maximum-likelihood model. Because the relationship between the independent variables and the probability was nonlinear in the logistic multiple regression model, an iterative algorithm was necessary for parameter estimation (Oh [31]). Coefficients denote the meaning of the influences of related factors or classes to habitat potential. A negative value means that the factor or class has a negative effect on the occupancy of the leopard cat at the study site, such as slope gradient, timber type (*Pinus densiflora* and *Pinus koraiensis* forest, and grassland), road distance, and distance from water.

$$Z = TIMBER\_TYPE + TIMBER\_AGE + (-0.0003 \times DIST\_ROAD) + (-0.0001 \times DIST\_WATER) + (0.004 \times DIST\_FOREST) + LAND\_COVER + (0.004 \times DEM) + (-0.013 \times SLOPE) + (-0.002 \times ASPECT) - 21.853 \quad (6)$$

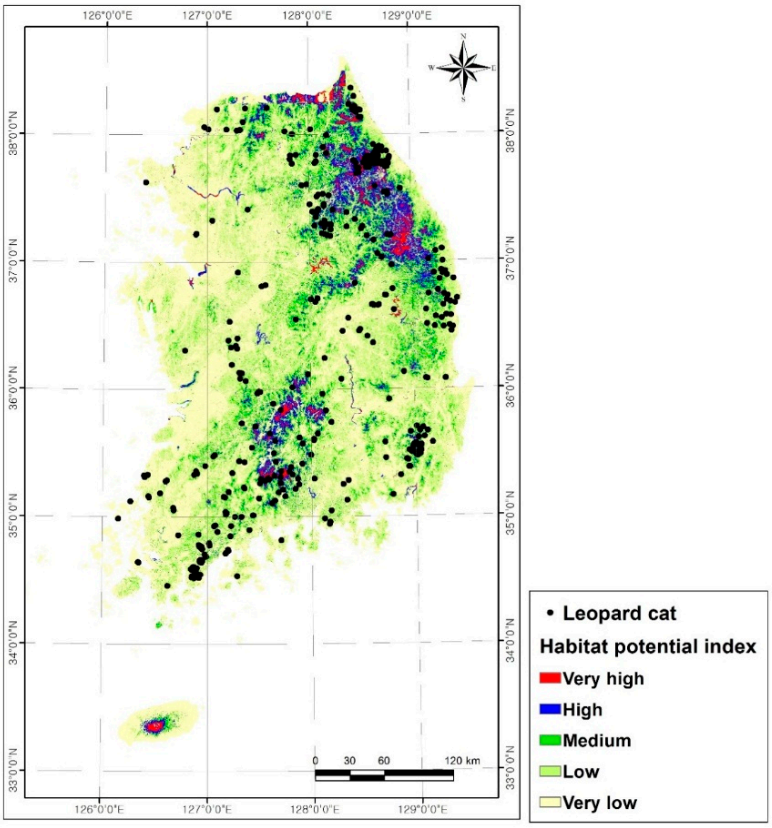
Here, DEM is the intertidal ground elevation value, SLOPE is the slope gradient value, ASPECT is the slope aspect value, DIST_ROAD is the distance from a road, DIST_WATER is the distance from water, and DIST_FOREST is the distance from forest area. TIMBER_TYPE, TIMBER_AGE, and LAND_COVER are the values of each categorical factor in Table 3, and Z is a prediction parameter. Using the logistic regression coefficient (Table 3), the probability of a species was computed and mapped as the habitat potential index (HPI).

Leopard cat habitat potential maps were quantitatively developed using the HPI values. These were calculated using the logistic regression and frequency ratio models for the interpretation (Figure 3). Figure 3a is result of applying frequency ratio (Table 2) and Figure 3b is result of applying logistic regression (Table 3). The index was composed of five classes based on area for easy visual interpretation. Index ranges of very high, high, moderate, low, and very low in 5%, 10%, 15%, 20%, and 50% of the study area, respectively, were used. The classification was useful to visually delineate the predicted habitat potential areas.



(a)

Figure 3. *Cont.*



(**b**)

Figure 3. Leopard cat habitat potential map (**a**) Frequency Ratio; (**b**) Logistic Regression.

4.3. Validation

A leopard cat habitat potential map should effectively predict future leopard cat potential habitat areas. This could be validated using new potential locations as the cats become distributed. In the study, many locations of leopard cats were detected from survey data. These locations were divided into a training set to analyze the habitat potential using the frequency ratio and logistic regression models, and a validation set to validate the predicted habitat potential map. The leopard cat habitat potential analysis result was validated using a validation set that was not used for training the model. Validation was performed by comparing the known leopard cat distribution locations with the habitat potential maps.

A rate curve was created, and the area under the curve was calculated. The rate explains how well the model and factors predict leopard cat distribution. The area under the curve qualitatively assesses the accuracy of the prediction. To obtain the relative ranks for each prediction pattern, the calculated index values of all cells in the study area were sorted in descending order. The ordered cell values were then divided into 100 classes with accumulated 1% intervals. The rate validation result appears as a line in Figure 4. For example, in the case of the logistic regression model, an index rank above 10% of the HPI could explain 33% of all the leopard locations. To obtain quantitative results, the areas under the curve were recalculated as if the total area were 1.0, which would mean perfect prediction accuracy. Using this method, the area under a curve can be used to assess the prediction accuracy qualitatively. In the case of the frequency ratio, the area under the curve was 0.821, and the prediction accuracy was 82.15%. In the case of the logistic regression, the area under the curve was 0.8148, and the prediction accuracy was 81.48%, as shown in Figure 4.

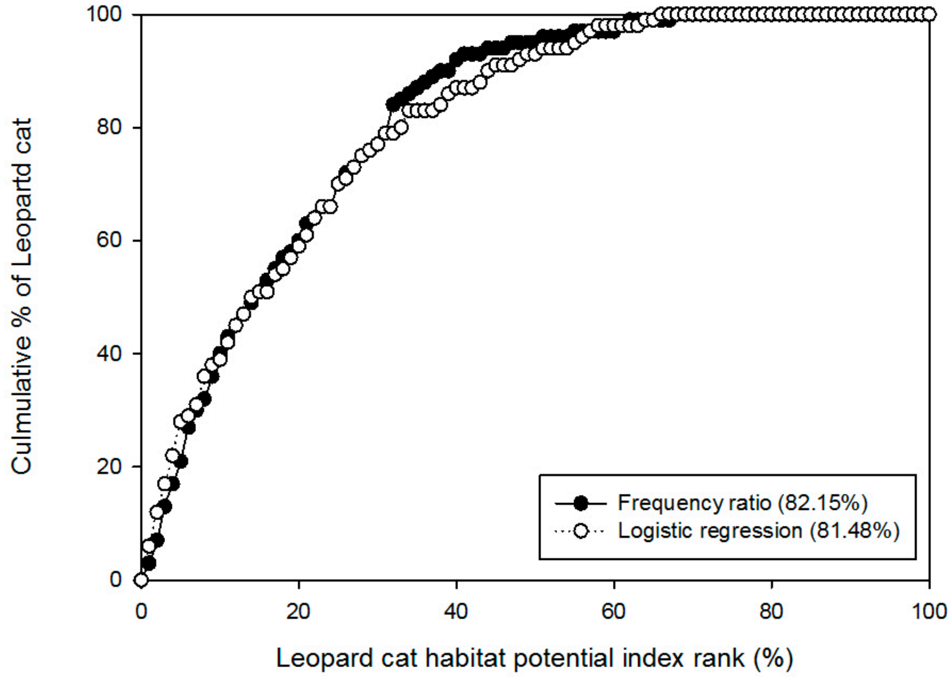


Figure 4. Success rate curves showing the cumulative percentage of each species occurrence (y-axis) for the descending ordered species potential index (SPI) rank (x-axis).

5. Conclusions and Discussion

In this study, we applied the frequency ratio and logistic regression models to habitat potential mapping for the leopard cat. The first step was to select the nine most important variables potentially affecting leopard cat habitat. We then mapped habitat potential using frequency ratio and logistic regression models representing the relationships between leopard cat distribution and environmental variables. We assembled factors associated with habitat potential in a spatial database and created habitat potential maps for the leopard cat. Finally, we validated the maps using location data that had not been used for model training. We arrived at the following conclusions:

(1) The results of the frequency ratio model indicated that elevation, slope-related factors, and timber age had a positive correlation with locations used by the leopard cat. Areas closer to water and forest and farther from roads, oak forests, and broad-leaved forest classes showed the most positive correlations.

(2) According to the logistic regression coefficients, the factors of slope gradient, timber type (*Pinus densiflora* and *Pinus koraiensis* forests, and Grassland), the distance from roads and distance from water were negatively correlated with the locations used by the leopard cat. In contrast, the factors of ground elevation and distance from a forest had a positive effect on leopard cat habitat potential. Some factors contrasted with the results of the frequency ratio, *i.e.*, slope gradient and distance from water.

(3) Generally, the maps resulting from the frequency ratio and logistic regression models had similar spatial distribution patterns. The central south and northeastern parts of the inland area of South Korea and the central part of Jeju Island were expected to have high and very high potential. The results of this study can be used in future studies of predator reintroduction on Jeju Island. In particular, the reintroduction of the leopard cat is being considered because it can play the role of top predator on Jeju Island. This study indicated high availability of potential habitat. These areas have high elevation, steep slopes, and forest, and they are hilly or mountainous. Such areas of high and very high potential should be given priority during land-use or wildlife management planning. The western and eastern coastal parts of the site were shown to have low and very low potential in all of the habitat potential maps. Almost all areas in this region are low-lying, with coastal and non-forest habitat.

(4) Using the frequency ratio and logistic regression models, we created leopard cat habitat potential maps. Half of known leopard cat locations were used as training data and the remaining half was used to validate the maps. The resulting frequency ratio and logistic regression models were 82.15 and 81.48% accurate, respectively. Therefore, the results had an overall agreement of more than 80%, which we regarded as satisfactory.

Some limitations exist to detecting exact leopard cat locations, and the locations used in this study were based on surveys, not exact figures. Inaccurate location data can lead to difficulties in spatial analysis.

The frequency ratio model is somewhat simplistic, but the process of input, calculation, and output can be easily understood. Moreover, large amounts of data can be quickly and easily processed in the GIS environment. The spatial database can be used in other studies. The logistic regression model requires the conversion of the data to ASCII or other formats for use in the statistical package and subsequent re-conversion to incorporate them into the GIS database. It is hard to process the large amounts of data in the statistical package. However, the correlations of leopard cat locations with other factors can be analyzed qualitatively in the statistical package. The frequency ratio model had better accuracy than the logistic regression model used in this study, and the use of all factors produced better results. In the case of a similar statistical model (discriminant analysis), the factors must have a normal distribution, and in the case of multi-regression analysis, the factors must be numerical. However, for logistical regression, the dependent variable must be input as 0 or 1; therefore, the model applies well to habitat potential analysis.

Remote sensing technology and GIS provide ways to introduce information from various data sources into the decision-making process and aid in the handling and manipulation of classified remote sensing data (Adinarayana [32]). Using GIS enables quantitative assessment of the consequences of heterogeneity in ecological systems over a broad range of spatial and temporal scales. The integration of several surface features that indicate mammal habitat potential is an important aspect of ecological management studies.

This study identified factors that may be associated with leopard cat habitat, and our methods and results can also be applied to habitat potential mapping of other mammalian species. Moreover, the resulting habitat potential map can be used as basic data for establishing plans to manage mammalian species, such as locating monitoring sites. However, more case studies and models are needed to generalize factors associated with mammalian habitats.

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Author Contributions

Moung-Jin Lee suggested the idea. In addition, he collected data and processed input data. Wonkyong Song interpreted the input data and this resulted in the habitat aspect. Saro Lee organized the paperwork and applied the frequency ratio and logistic models. All of authors contributed to the writing of each part.

Conflicts of Interest

The authors declare no conflict of interest.

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