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Valuation of Forest Habitat Functions of Endangered Mammals Using Species Distribution Model

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Abstract

It is estimated that there is a total of approximately 100,000 species in Korea. However, the number is currently about 30,000 and only 16,027 species are listed in the 'Species Korea' (as of December, 2014). Of the listed species, 51 species are designated as the Endangered Species Class I while 195 species are in the Class II, totaling 246 endangered species including 20 mammals. Under the circumstances that development (e.g., roads) is increasingly threatening the persistence of endangered mammals, it is significant to identify and preserve suitable habitats for them. In this context, evaluating the values of the suitable habitat environment would serve as essential information for development decision making. This study estimated the values of endangered mammals' forest habitats through spatialization of habitat services. In doing so, a species distribution model, Maximum Entropy Model (MaxEnt) was utilized for a group of endangered mammals including, mountain goat, wildcat, marten cat, and flying squirrel. To calculate the values per unit area, a benefit transfer method was used based on the point-estimate technique with the best available values estimated previously. The range of discount rate of 3.0 to 5.5 percent was applied taking the notion of social discount rate into account. As a result, the province with the highest values for endangered mammal habitats appeared to be Gangwon, followed by Gyeongbuk and Gyeongnam. The monetary values of the endangered mammal habitats were estimated to be 330 billion to 421 billion won per year.

Key Words: endangered mammals, habitat, values per unit area, benefit transfer method, social discount rate

Introduction

The Korea Natural Environmental Conservation Law defines ecosystem as a dynamic complex of plants, animals and microorganism communities interacting with abiotic environments as a functional unit. Ecosystem services were defined by Daily (1997) as a status and process through ecosystems and meeting human's life by plant and animal species. While Costanza et al. (1997) described it as human's benefits directly or indirectly obtained from ecosystems, the Millenium Ecosystem Assessment (2005) represented it as benefits from ecosystems contributing to human's quality of life. Putting these concepts together, ecosystem services can be defined as a status manifested in functions that provide human benefits resulting from not only biological ecosystem circulation movement in nature but non-biological existence.

The demand for value assessment has increased as part

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of quantitative evaluation for rational decision making for ecosystem services. The ecosystem services valuation research has conducted comprehensive value evaluation along with various types and functions as described in Costanza et al. (1998) and Millenium Ecosystem Assessment (2003) (State of New Jersey 2007; Jeon et al. 2013). TEEB (2010) categorizes ecosystem services into provisioning, regulating, habitat, and cultural services, where 'habitat' is represented by a role as living space of biological organisms.[1)]

Approximately 1.75 million species were observed worldwide including microorganisms and most of them consists of small insect species. The number of species is estimated ranging from three million to one hundred million but generally 13 million species are estimated (CBD 2000). According to OECD (2011), it is expected that biodiversity would likely be decreasing by about 10 percent in 2030 due to climate change, pollution, and anthropogenic activities. Furthermore, IUCN (http:www.iucn.org) announced that 80 percent of habitats of birds, mammals, and amphibians is being threatened and six million of primeval forests serving as wildlife habitat have been lost since 2000. Up until now, about 48,000 species are listed in IUCN's red list. The Aichi Target 20 established in Biological Diversity Convention suggested that 17% of terrestrial areas and 10% of coastal and marine areas need to be extended as conservation areas by 2020 in order to maintain and enhance biodiversity.

The number of species in Korea was estimated about 0.1 million and currently there are 30,000 species in the country including 16,027 species listed in the Korea Biological Resources Portal (as of December, 2014). The endangered species include 51 species for Class I and 195 species for Class II, totaling 246 species. There are 20 endangered mammals including 11 species for Class I (e.g., Goral) and 9 species for Class II (e.g., Marten). Those 11 endangered mammals at Class I are considered in the category of the IUCN's Red List (http:www.iucnredlist.org): five least concern (LC) species (wolf, sika deer, lynx, red bat, fox), two near threatened (NT) species (European otter, leopard), three vulnerable (VU) species (goat, Asiatic black bear, musk deer), and one endangered (EN) species (tiger).

Since the relatively large amount of forests have allowed multipurpose development activities, 6,120 ha of forested areas in Korea are annually in decline from 2000 to 2010. Accordingly, wildlife habitats have been on the decrease and even the habitats of endemic species that are gaining attention around the world are being threatened.

Most of the valuation research focusing on animal species calculated the conservation values using contingent valuation method (CVM) (Hegeman 1985; Samples and Hollyer 1990; Olsen et al. 1991; Stevens et al. 1991; Loomis and Larson 1994; Kotchen and Reiling 2000; Kristin and Andrew 2001; Tisdell et al. 2005). Likewise, some of the domestic research addressed habitats or wildlife in a given areas through contingent valuation method (CVM) (Youn and Jang 1994; Han and Choi 1998; Lee 2002; Yeo and Bang 2007; Yeo and Jang 2007; Han 2008; Yu and Kim 2008).

Since existing valuation research tends to yield economic values only for the existence of species in a particular area, they are hardly utilized as general information for cost estimation of regional development. In order to have realistic measures and financial support for habitat provision service of forest ecosystem, it is significant to make spatially differentiated evaluation for the entire area.

Meanwhile, the research regarding habitat field survey and prediction model have been conducted in the area of animal ecology. In Korea, field survey for a particular species began in earnest around 2000 (Han 1998; Yang 1999; Son 2000; Cha 2001), which made a basis for further research on species distribution model (Choi 2002; Joo 2002; Lee and Song 2008; Kwon et al. 2012). Seo et al. (2008) found that Artificial Neural Network is the most appropriate by comparing and analyzing four models of GLM (Generalized Linear Model), GAM (Generalized Addictive Model), CART (Classification and Regression Tree), and ANN (Artificial Neural Network). Kim et al. (2012) indicated that Maxent (Maximum Entropy Model) has advantages compared to GAM (Generalized Additive Model) from a comprehensive perspective.

The goal of this study is to estimate the area-based values of forest ecosystem endangered mammals using species distribution model.

[1)] In the evaluation of ecosystem services, we used "support" instead of using "habitat" for inclusive application.

Materials and Methods

Species distribution probability was developed based on the third National Ecological Survey data and using the estimated outcomes from Maxent (Jeon et al. 2014) based on topography, land cover, and forest type. The point-estimate technique, one of the benefit transfer method was applied for the values for endangered mammal species.

Previous literature focused on habitat valuation using the benefit transfer for endangered mammal species includes a research that estimates unit values (won/year/household) of maximum willingness to pay per average household for Asiatic black bears in Jirisan National Park (Han and Choi 1998) and mountain goats inhabited in Woraksan National Park (Han 2008). The values were generalized based on the premise that the target species of mountain goats and Asiatic black bears would likely to be considered nationally significant endangered mammals rather than the conservation values of a particular species to the general survey respondents.

In the cost-benefit analysis for large-scale national project, it is common to use the discount rate of 5.5% (KDI, 2008). However, Kim (2013) asserts that the proper social discount rate should be 2.9-4.9%. With a baseline of 2014, this study conducted the cost-benefit analysis with a minimum discount rate of 3.0% and a maximum rate of 5.5% which is common in national public work investment analysis. The values (won/year/household) from previous research were converted to areal unit values (won/year/ha) using the discount rate and the number of households.

$$V_{t_s} = \frac{V_{t_0} \cdot (1+r)^{(t_s - t_0)} \cdot F_{t_s}}{A_{100\%}}$$

V_{t_S}: unit area value (won/year/ha) in year t_s
V_{t_0}: unit area value (won/year/household) in year t_0
r: discount rate
t_0: evaluation year
t_s: baseline year
F_{t_S}: number of households in year t_s
p: distribution probability
$A_{100\%}$: forest area (ha) with 100% of distribution probability

Results

As a result of overlaying Land Cover revised in 2009 with the fourth Forest Type map, the forested areas are

Table 1. Distribution probabilities endangered mammals in the forest

Gion	Apply area (ha)	Distribution probabilities					Total	Ratio
		100%	80%	60%	40%	20%		
Gangwon	1,247,083	829,783	99,711	63,237	49,713	60,889	1,103,333	88.5
Gyeonggi	466,973	171,836	16,982	16,815	14,873	20,410	240,915	51.6
Gyeongnam	634,540	280,773	36,032	27,677	20,345	32,507	397,335	62.6
Gyeongbuk	1,261,804	651,035	80,579	56,356	45,507	77,568	911,046	72.2
Gwangju	16,233	5,158	555	398	437	771	7,320	45.1
Daegu	45,111	20,632	3,024	1,629	1,404	2,655	29,344	65.0
Daejeon	25,448	6,887	754	989	843	1,336	10,809	42.5
Busan	31,750	11,573	1,163	818	935	1,435	15,924	50.2
Seoul	10,538	2,913	259	214	311	384	4,080	38.7
Ulsan	61,546	26,470	2,711	2,033	2,003	3,044	36,261	58.9
Incheon	20,971	4,885	642	362	571	590	7,050	33.6
Jeonnam	592,898	227,065	29,729	23,451	18,267	28,486	326,999	55.2
Jeonbuk	385,344	214,244	25,476	19,342	14,171	19,923	293,157	76.1
Jeju	58,079	33,427	5,996	2,873	2,530	2,447	47,272	81.4
Chungnam	348,576	91,392	12,295	10,626	10,260	15,570	140,144	40.2
Chungbuk	449,964	223,370	26,222	24,268	17,592	28,064	319,515	71.0
Total	5,656,859	2,801,442	342,129	251,091	199,764	296,078	3,890,504	68.8

5,657 thousand ha.[2] As a species distribution probability method, Maxent model analyzed presence (1) versus non-presence (0) data with the basis of "Maximum training sensitivity plus specificity" values that minimizes the average of the observed values and estimated values. Target species include four endangered mammal species such as mountain goats (Class I), martens (Class II), wildcats (Class II), flying squirrels (Class II). To reduce uncertainty, five repetitive analysis was performed for each species and the probability of most frequency appearance was considered to indicate the distribution ratios (1/5-5/5) for each area (Table 1).

The most potential region per unit area where target species would likely to be present indicated Gangwon Province (88.5%) followed by Jeju island and Gyeongbuk. Incheon appeared to have the least likelihood of the species presence. The space where endangered mammals can inhabit (higher than 20% of distribution probability) appeared to be 68.8% of the entire area. Nearly 50% of the entire area demonstrated 100% of distribution probability, while 10% to 20% of the entire area showed the distribution probability ranging from 20% to 80%. Fig. 1 shows the estimated distribution map on which higher probability areas are concentrated along the Baekdudaegan.[3] Especially, the hot spots are located in Soraksan, Taebaeksan, Jirisan.

The information for per-unit values were converted into 2014 base price by applying for social discount rates with minimum 3.0% and maximum 5.5% based on previous studies focused on mountain goats and Asiatic black bears (Table 2).

Since the unit of the base price is won/year/household, we applied 18,457,628 of the estimated number of households in the baseline year 2014 and converted the original values to unit area values with the assumption of 100% habitation probability. The total values of endangered mammals were divided by 2,801,442 ha which is 100% habitation probability. As a result, when habitation probability is 100% the unit-area values were 98,070 won/year/ha to 125,202 won/year/ha based on the number of households in 2014 and discount rates (3.0-5.5%). The results from the benefit transfer technique using the point estimate transfer were applied in the following equation:

The total value of habitat function for endangered mammal species could be estimated using the unit area value and distributed probability area as follows:

$$TV_h = \sum_{i=1}^{5} V_i \cdot S_i \cdot p_i$$

TV_h: total value of habitat function (won/year)
V_i: unit area value (won/year/ha)

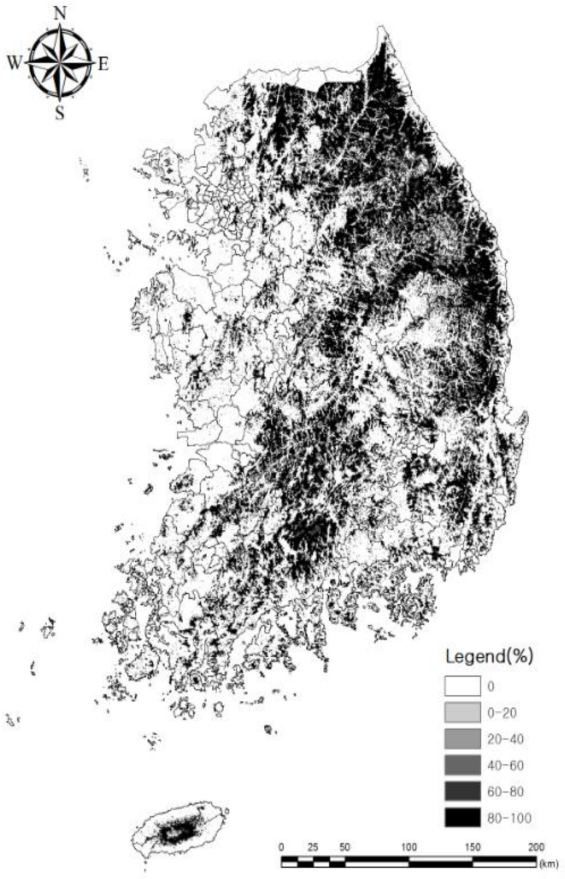

Fig. 1. Distribution probabilities of endangered mammals.

[2] This is the results of the forested areas (6,196,184 ha) in Land Cover map including coniferous, deciduous, and mixed forest superimposed on the layers of the forested and other areas (bamboo grove and unstocked land) of the Fourth Forest Type map (6,163,224 ha).

[3] The Baekdudaegan is a mountain range and watershed-crestline which runs through most of the length of the Korea Peninsula, from Baekdusan in the north to Jirisan in the south (from Wikipedia)

Table 2. Values per unit of habitat function (in 2014)

Target Species	Base Price (won/yr/household)	Evaluation Year	Discount rate		Source
			3.0%	5.5%	
Endangered Species					
Asiatic black bear	7,226	1998	11,596	17,019	Han and Choi (1998)
Mountain goat	15,221	2008	18,175	20,987	Han (2008)
Mean			14,885	19,003	

Table 3. Value of Endangered mammal species distribution probabilities (Unit: million ₩/yr)

Species distribution probabilities	100%	80%	60%	40%	20%	Total
Apply Area (ha)	2,801,442	342,129	251,091	199,764	296,078	
Discount rate						
3.0%	274,737	26,842	14,775	7,836	5,807	329,998
5.5%	350,746	34,268	18,862	10,004	7,414	421,295

Table 4. Values per region of endangered mammals species

Region	Total value (million won/year)		Value per area (won/year/ha)	
	3.0%	5.5%	3.0%	5.5%
Gangwon	96,065	122,642	77,032	98,343
Gyeonggi	20,157	25,734	43,166	55,109
Gyeongnam	33,427	42,674	52,678	67,252
Gyeongbuk	76,792	98,037	60,859	77,696
Gwangju	605	773	37,279	47,593
Daegu	2,464	3,145	54,613	69,722
Daejeon	852	1,088	33,480	42,743
Busan	1,339	1,710	42,177	53,846
Seoul	338	432	32,102	40,983
Ulsan	3,066	3,915	49,824	63,608
Incheon	585	747	27,884	35,599
Jeonnam	27,256	34,797	45,971	58,689
Jeonbuk	25,095	32,037	65,122	83,139
Jeju	4,065	5,189	69,988	89,351
Chungnam	11,261	14,376	32,305	41,242
Chungbuk	26,632	34,000	59,186	75,561
Total	329,998	421,295	58,336	74,475

S_i: distribution possible area (ha)
p_i: distribution probability

Based on the unit-area values and potential distribution areas, the total values of endangered mammal species were estimated as 3,300 million won (discount rate 3.0%) - 4,213 million won (discount rate 5.5%) each year (Table 3). The areas with 100% distribution probability have the values of 2,747 million won (discount rate 3.0%)-3,507 million won (discount rate 5.5%) which accounts for about 83.0% of the entire values including the rest of the probability measures.

Gangwon Province has the highest total value by regions followed by Gyeongbuk, together which accounts for 1,727 million won (3.0% discount rate)-2,207 million won (5.5% discount rate) arriving at the half of the total values of the endangered mammals (Table 4).

In terms of the mean value per unit area which is calculated the total values by region divided by forested areas, Gangwon Province was ranked top followed by Jeju island and Gyeongbuk.

Discussion

With the emergence of new analytic methods, along with the availability of various spatial data and information, analysis-driven decision making has been increasingly made in related profession. Furthermore, there are growing demands for assessment that reflects site characteristics of study area, as the technological advancement allows more sophisticated spatial analysis for ecosystem services.

This study attempts to derive the values of the entire forest habitat functions by generalizing the previous findings on endangered mammal species in Korea. In order to de-

cide the suitability of habitat functions depending on spatial properties, we utilized the outcomes of distribution probability and thus derived spatially differentiated values.

The most likely habitable region for endangered mammals per unit area appeared to be Gangwon Province, followed by Jeju Island and Gyeongbuk Province. Overall, the Baekdudaegan and surrounding areas have higher potential for these species. The total value of the entire endangered mammal species in Korea was estimated as 421,300 million KRW at a given discount rate of 5.5%. The per-area mean values of endangered mammal species for the entire forest in Korea indicated 66,000 won/ha each year.

There are a total of 246 endangered species including the 20 endangered mammals considered in this study. This study has a limitation that the value estimation was only based on the endangered mammals and thus the monetary values do not represent the values of the entire potential habitats. Furthermore, there might be different views on the comprehensive analysis without differentiation for habitats between mountain goats and Asiatic black bears. However, this study presents a way of supporting decision making ecosystem services. Further research should be needed, expanding the scope of the research into other biological taxa such as avian and amphibian species distributed in the terrestrial ecosystem. The research findings are expected to be utilized in forest conservation and development planning.

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