MODELING OF SPECIES GEOGRAPHIC DISTRIBUTION FOR ASSESSING PRESENT NEEDS FOR THE ECOLOGICAL NETWORKS

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KEY WORDS: Ecology, Environment, GIS, Modelling, Algorithms, Landscape, Method, Proposal

ABSTRACT:

In Japan, attention is currently focused on designing ecological networks for wildlife animals. However there is an obvious lack of the species spatial information. This study aims (a) to acquire the potential spatial distribution of Asiatic black bear and Japanese serow to identify core areas, and (b) to propose a methodology for assessing needs for ecological networks. 1836 species' point records and 14 potential predictors were prepared in a GIS environment, split into a train and a test dataset. Screening predictors by statistical analysis, we modeled species geographic distribution by three algorithms: GARP, MaxEnt, and GLMs in Kanagawa and Shizuoka Prefectures. Based on the most accurate maps, assessed by Kappa statistics, population was estimated based on population density and area of habitat patch. For bear, MaxEnt performed best with the predictor variables: altitude, distance to paths and stone steps, distance to wide roads, and vegetation cover types. GARP failed to predict presence in Fuji. Its best GLM equation was log(p/(1-p))=(-1.486e+01)+(7.335e-04)**distance to paths and stone steps*+(9.470e-03)**altitude*. For serow's distribution, GARP performed best with altitude, slope, distance to highways, distance to general roads, distance to paths and stone steps, distance to rivers, and NDVI. Its best GLM equation was log(p/(1-p))=-5.91785430+0.04024136**slope*+0.26478759**square root of altitude*. The estimated numbers of individuals for bear was 5~9 in Mt. Ashitaka, 51~102 in Fuji-Tanzawa, 160~320 in South Alps, 4~8 in Mt. Kenashi, 4~8 in Izu Peninsula, and 6~11 in Hakone; for serow, < 1581 were estimated in Fuji-Tanzawa, and < 537 in other areas. For bear MaxEnt and for serow GARP are the best algorithms, but GLM has good transferability. There is a need for ecological networks in Fuji-Tanzawa for bear, but not for serow.

1. INTRODUCTION

1.1 Biodiversity loss and ecological networks

The New Biodiversity Strategy of Japan (March 27, 2002) stipulates seven major themes for implementing biodiversity conservation policies. The first theme is conservation of priority areas and formation of ecological networks. Its basis is to reinforce the protected-area system. In addition to the perspective of conserving natural landscape of the Natural Parks, measures from the perspective of ecosystem conservation, especially of animal habitat conservation, should be institutionalized. The development of the ecological networks can connect the fragmented habitats of wild animals, stem the biodiversity loss, and promote dispersal and genetic exchange of wild species. Serious fragmentation of habitats has been caused by the industrialization of agriculture, restructuring of land use, the building of huge transport networks and metropolitan (Stanners and Bourdeau, 1995). For fragmented habitats, the theory of island biogeography (MacArthur and Wilson, 2001) can be applied, and connecting the 'islands' through the ecological networks can reduce the risk of extinction of species.

As for the Japanese mammals, the Ministry of Environment of Japan has conducted the national distributional survey of Japanese animals (Biodiversity center of Japan, 2004) in 1978 and in 2003 as a monitoring activity. The main objective was to acquire national distributional maps of ten main mammals, including key wildlife species in this study. Based on survey data from interviews and questionnaires on a sampling grid of 5 by 5 km, these distribution maps were compiled at a national scale (1: 2,500,000).

Although these maps provide insight in species' distribution at a glance, they do not reflect distribution at local population level. An appropriate approach for preparing conservation and zoning plans requires spatially explicit information of species distribution at a local scale with more accurate resolution. With this information, the core area of a suitable habitat can be identified, and ecological networks can be designed if necessary. There are several studies that have integrated habitat models into GIS (for example, see Corsi et al., 1999). However, these have not assessed the need for ecological networks of large mammals. Also, to date, no studies were found on quantitative needs assessment of ecological networks.

In this paper, we present a quantitative methodology for the modeling of the geographic distribution of two key species of large mammals in order to assess the need for ecological networks.

1.2 Research objectives

There are three main objectives of this study: 1) to acquire more accurate potential spatial distribution of habitats of 'key' wildlife species, 2) to identify the 'core areas' of these habitats, and 3) to assess the present needs for ecological networks.

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At present, the most accurate distribution map of the target species has a resolution of 2 by 2.5 km (Ohba, 2002). This study aims to create distribution maps with a resolution of 90 by 90 m, or at best 30 by 30 m. The area of interest is the Fuji and Tanzawa regions located in the central part of Japan's main island. The administrative boundaries of Kanagawa Prefecture and Shizuoka Prefecture have been selected as the study area. The Asiatic black bear and the Japanese serow were identified as the target species.

2. METHODOLOGY

2.1 Study area

The following criteria were used in order to select an appropriate area for the study:

- Known fragmentation of habitats
- Variation in landscapes
- High biodiversity
- Presence of endemic species

The area of interest is the 'Fuji region', part of the Fuji-Hakone-Izu National Park and the 'Tanzawa region', Japan. The Fuji-Hakone-Izu National Park covers an area of 121,851 ha, located in four prefectures and consisting of Mt. Fuji (3776 m), Hakone, Izu Peninsula and the Izu Island chain. In the park various types of volcanoes occur, as the park crosses the Fuji volcanic belt from the Pacific Ocean to the central part of the Main Island. Vegetation varies from the warm-temperature vegetation zone on the Izu Island chain to the Alperstein zone of Mt. Fuji. The park contains diverse habitats for mammals and bird species. The Tanzawa region is a mountainous area which consists of Hirugatake (1673 m), Mt. Tanzawa, Sagami oyama and Togadake. It cuts across three prefectures: Kanagawa, Yamanashi, and Shizuoka, and is designated as a Quasi-National Park.

The selected areas are Mt. Fuji and the Tanzawa region. These regions are geographically not far apart. However, because of the recent urbanization and new road constructions, the exchange of genes between the local populations of big mammals, especially Asiatic black bear, in these regions has almost ceased (Japanese Mammals Society, 1997). The area of the National Park is considered an appropriate size for large mammal species. The park contains various landscapes and is characterized by a very high biodiversity including the occurrence of a number of endemic species. The study area is located between 3,830,925 to 3,949,185N and 177,284 to 390,854E in a datum of WGS 1984 and projection of UTM Zone North 54.

2.2 Target species

2.2.1 Selection of target species

In order to select target species the method of the usage of a check list was chosen with the following criteria:

- Their known distribution must be within the study area
- The size of the habitats of a target species should be medium or large (Dawson, 1994)
- Target species should be endangered, umbrella, keystone, endemic (Jongman et al., 2004), or 'natural monument'
- Secondary data sources concerning distribution of species are available

'Natural monuments' are based on the legal designation for highly valued animals, plants, or minerals. The forth criterion is established based on consideration of time, human and financial resources available for this study.

Based on the criteria established above, the Asiatic black bear and Japanese serow were identified as the target species among the Japanese mammal species.

In Japan, 19 local populations of the Asiatic black bear (Japan Wildlife Research Center, 1992) and 40 local populations of Japanese serow (Japan Wildlife Research Center, 1985) are recognized, of which three local populations are considered to exist for both species in our study area: Fuji, Tanzawa and South Alps. The mainstream of the current studies has focus on habitat and food analysis for both species (Deguchi et al., 2002; Hashimoto et al., 2003; Huygens et al., 2003), thus very little is known about the distribution within the sites. Yamaguchi et al. (1998) compiled the point observations of Japanese serow in Tanzawa region. Ohba (2002) mapped serow's distribution in a sampling grid of 5 by 5 km in Shizuoka Prefecture based on questionnaires. Mochizuki et al. (2005) mapped bear's distribution in sampling grid of 2 km by 2.5 km in Fuji local population based on point observation of field signs and mapped point localities of four years of tracked movements of 14 individual bears. To our knowledge, no study attempted to model these species probabilities of occurrence by environmental predictors in Japan.

2.2.2 Asiatic black bear

The Asiatic black bear (*Ursus thibetanus japonicus*) inhabits the islands of Honshu and Shikoku in Japan. The Asiatic black bear is a threatened species - assessed as "vulnerable" - according to the IUCN Red List of Threatened Species. It is also well-known as an umbrella species, which is defined by Fleishman et al. (2000) as a "species whose conservation confers a protective umbrella to numerous co-occurring species".

In Japan, the habitat of the local populations has been fragmented by deforestation because of development of new infrastructure. Especially, the Tanzawa local population of Asiatic black bear is ranked as "a local population which should be protected" because of its small population size (Japanese Mammals Society, 1997). A project, which aims to create a new linkage between the local populations of Tanzawa and Fuji regions, is in progress (Kanagawa Prefectual Museum of Natural History, 2003). According to observations in 1995 and 1999 by Huygens et al. (2003) bears ate oak (*Quercus spp.*) acorns from feeding observations in the previous fall and dwarf bamboo (*Sasa spp.*) leaves and shoots in spring; succulent plants and soft mast, especially the Japanese cluster cherry (*Prunus grayana*) in summer; and hard mast, especially oak acorns, in fall. Bears ate insects in all seasons, with a peak in summer, and also ate Japanese serow (*Naemorhedus crispus*) on at least 6 occasions. In summer, bears that moved to alpine elevations relied on succulent plants; bears that remained at lower elevations relied on soft mast. In fall, all bears moved to hard-mast producing areas in broad-leaved forests at lower elevations in the montane zone. Montane broadleaved forests are recognized as important habitats for Asiatic black bears' survival (Huygens et al., 2003; Kanagawa Prefectual Museum of Natural History, 2003).

2.2.3 **Japanese serow**

The Japanese serow (*Naemorhedus crispus*) is an endemic ungulate, found in the montane regions of Honshu, Shikoku and Kyushu. It is also designated as a Japanese 'natural monument', for which only 2 species are nominated among mammals.

Serow feeds on six plant groups: the deciduous broad-leaved tree, the evergreen broad-leaved tree, the conifer, the forb, the graminoid and the fern (Deguchi et al., 2002). According to Matsumoto et al. (1984), the Japanese serow ate 37 plant species in 28 families including grass and tree species, whereas according to Yamaguchi et al. (1998) bamboo species are part of their diets. According to a study of habitat selection between the Sika deer and the Japanese serow (Nowicki and Koganezawa, 2001), serow selects steep slopes and areas close to roads, seemingly in order to avoid Sika deer. The Japanese serow is known as a species that prefers habitats of greenery steep slopes in a hillside, from 300 to 800 m (Yamaguchi et al., 1998).

2.3 Data management

2.3.1 Species' records extraction

Species' presence data consist of localities of 1) 14 tracked Asiatic black bears in the South Alps region (715 points) and 56 observed field signs of Asiatic black bear in the Fuji region (Mochizuki et al., 2005) and 2) 160 observed Japanese serow in Tanzawa region (Yamaguchi et al., 1998). In total 49 paper maps of the above mentioned sources were scanned; four maps for bears of the Fuji local population, 44 maps for bears of the South Alps local population, and one map for Japanese serow in Tanzawa Mountains. Next, the scanned maps were geo-referenced respectively. The 1st order polynominal affine transformation was conducted to rectify the scanned images within 50 m of the total RMS error for the bear's maps. The maximum total RMS error was 251 m for the distribution maps of the Japanese serow. Thereafter, the rectified images were used to extract species observation points. 931 points were digitized manually. Geographic coordinates were calculated from point features by the ArcMap's VBA built-in function.

The national distributional map of Japanese mammals (Biodiversity center of Japan, 2004) was used to create points representing species' absence data. It was based on interviews and questionnaires in 1978 and in 2003 for grids of 5 by 5 km. Following Corsi et al. (1999), any area where no evidence of stable target species' presence had been gathered in the last 26 years has been defined as species' absent area. Each image was geo-referenced using the intersections of administrative boundaries, whereafter the species' known presence and absence areas was digitized as a polygon. Random points distributed within the absent range for each species were considered to represent each species' absence data. To ensure a balance in the number of species' presence and absence records, the same number of records was plotted for each species: 770 random points for the Asiatic black bear and 160 random points for the Japanese serow.

2.3.2 Geo-database for predictors

Based on known Asiatic black bear's and Japanese serow's ecology, the selected environmental predictors can be categorized in five groups: 1) topographical variables, 2) water-related variables, 3) climatic variables (Guisan and Zimmermann, 2000), 4) variables related to roads (Okumura et al., 2003), 5) variables related to vegetation (Hashimoto et al., 2003; Huygens et al., 2003). All variables were obtained digitally from various sources (Table 1) and stored in a GIS environment. Considering the relatively small size of important landscape elements in the Japanese landscape and the high precision of the species' records, all predictor variables were compiled at a resolution of 30 by 30 m. For calculating NDVI value, Erdas Imagine® 8.7 was used, and for other variables, ArcGIS® 9.0 was used.

1) From SRTM, altitude data were resampled at a target resolution by the nearest neighboring. From this data, slope angle was

Category (Source)		Environmental predictor	Unit	Asiatic black bear			Japanese serow		
				Garp	Maxent	Glm	Garp	Maxent	Glm
Topography (*[1])		Altitude	m	X	X	X	X	X	X
		Slope	°				X	X	X
Water resources (*[1] *[2])		Distance to river streams	m				X	X	
Climate (*[3])		Annual mean precipitation	mm						
		Annual minimum temperature	℃						
		Annual maximum temperature	℃						
Roads (*[4])	All	Distance to all roads	m						
	Type	Distance to highways	m				X	X	
		Distance to general roads	m				X	X	
		Distance to paths and stone steps	m	X	X	X	X	X	
	Width	Distance to wide roads (more than 13 m)	m	X	X				
		Distance to narrow roads (less than 13 m)	m						
Vegetation (*[5] for NDVI and *[6] for vegetation cover)		NDVI	--				X	X	
		Vegetation cover types (at species level)	--		X				

*[1] The CGIAR Consortium for Spatial Information. "SRTM (Shuttle Rader Topography Mission)" http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp (accessed April 2008).
*[2] Geographical Survey Institute of Japan, 2006. "Download of the Global Map Japan Version 1" http://www1.gsi.go.jp/geowww/globalmap-gsi/download/index.html (accessed April 2008).
*[3] WorldClim, "WorldClim Version 1.4", http://www.worldclim.org/ (accessed April 2008).
*[4] The National Land Agency, 2003. Digital Map 25000 (Spatial Data Framework) KANAGAWA/ SHIZUOKA (CD-Rom).
*[5] Earth Science Data Interface, "GLCF(Global Land Cover Facility): Earth Science Data Interface", http://glcf.umiacs.umd.edu/data/ (accessed April 2008).
*[6] Nature Conservation Bureau in Ministry of the Environment, 1997. 14 KANAGAWA/22 SHIZUOKA The dataset for GIS on the Natural Environment, Japan. Nature Conservation Bureau in Ministry of the Environment (CD-Rom).

Table 1 Potential spatial predictors and selected predictors for final models calculated. 2) From the Global Map Japan, the main streams of rivers were derived in a national scale of 1:250,000. In order to acquire the streams in a regional scale of 1:25,000, the DEM was used to calculate river streams using the Hydrology tool in ArcMap® 9.0's Spatial Analyst. Next, the two river streams were combined and the distance to streams variable was calculated by the Euclidean distance in the Spatial Analyst of ArcMap®. 3) All climatic variables were derived in ESRI grid format at a resolution of 1 km by 1 km (30 arc~seconds) from WorldClim database (Hijmans et al., 2005). The annual precipitation was calculated from the precipitation data for 12 months. The minimum - and maximum temperature per month was also derived, and from that data the annual minimum - and maximum temperature was calculated. 4) The data of the roads were decoded to the XML files, and then converted to shape files in ESRI formats. Six different layers of roads were prepared based on types and width (See Table 1 for detail categorization.) The distance to each road was calculated by the same method as for river streams. 5) Vegetation cover was directly derived from the dataset for GIS on the Natural Environment, Japan (CD-Rom; the source is indicated in Table 1) and contains 57 classes at species level; species level is from this dataset. Four scenes of Landsat-7 ETM+ imagery (dated 12 Oct 1999, 13 Nov 1999, 8 Nov 2000, and 24 Sep 2001) were geo-referenced with a maximum error of 100m and ortho-rectified. Scenes were mosaicked by histogram matching using overlapping areas. After creating a subset of a mosaicked image, the NDVI was calculated and resampled.

2.3.3 Preparation for test and train data

Plotting 1861 species records, 25 records fell outside the study area. These records were discarded so that the total number became 1836. From all layers of environmental predictor variables, pixel values were extracted for the geographic coordinates of species' presence and absence records by ArcMap 9.0 ®'s in-built function.

Subsequently the dataset, containing species presence-absence records, geographic coordinates, and each environmental predictor's value, was split into a train and a test dataset. The train dataset was used to make predictive models. Then, the test dataset was used to assess the accuracy of these models. An independent dataset is ideal for testing the models. Thus for Asiatic black bear, all records in the South Alps were used for training and all records in Fuji area were used for testing the models. By this method, also the model's transferability can be tested whether models developed on one local population, South Alps, can be applied to another neighboring local population in Fuji. To maintain a balance in presence and absence data, approximately the same number of records was taken from absence data for training and testing. Because no independent dataset for the Japanese serow was available, its records were randomly partitioned into two subsamples. One subsample was used as the train dataset and another subsample was kept for testing models. This method is known as "split-sample approach" (Guisan and Zimmermann, 2000).

2.3.4 Statistical analysis for screening predictors

The choice of predictors is a major concern for building any predictive model. Therefore a set of chosen predictors was screened prior to creation of the predictive models using statistical analysis with R-software, version 2.4.0.

Inter-correlation among environmental predictors may cause bias, such as overfit and multicollinearity (Grahama, 2003). Because the environmental variables were not normally distributed, the Spearman's rank correlation coefficient ρ was adopted. In the preliminary data survey, we eliminated high collinearity within the environmental variables (exclusion of the variables in case of the Spearman $\rho > 0.85$). A similar approach was carried out in studies of habitat-models by Bonn and Schröder (2001) and Fielding and Haworth (1995).

Jackknife tests were carried out to determine the relative importance of variables by running an "experimental" model of MaxEnt with all environmental variables. The variables which did not have relative importance were eliminated.

The screened variables were used for building the final models and are shown in Table 1.

2.4 Modeling

There are a number of modeling techniques and algorithms to predict the probability of species occurrences by the environmental variables as limiting factors for species' survival. Three modeling algorithms: GARP - Genetic Algorithm for Rule-set Production (Stockwell and Peters, 1999), MaxEnt -Maximum Entropy (Phillips et al., 2006), and GLMs - Generalized Linear Models (logistic regression models) (Nelder and McCullagh, 1989) were used in this research.

2.5 Validation and comparison of the predictive models

The accuracy of the predictive models was measured using the test dataset by the Kappa statistics (Landis and Koch, 1977). The pixel values of the predictive maps generated by different modeling algorithms were extracted to the points of both train and test datasets for each species respectively by ArcMap 9.0®. A database with presence-absence data (value is either 0 or 1) as the ground truth, and predicted values by each modeling algorithm was prepared for each test dataset respectively.

2.6 Estimation of population size within habitat patches

Based on the comparison of the predictive models, the predictive maps by the best modeling algorithm for each species were chosen to estimate the population size. First, the predictive raster maps were reclassified into predicted presence and predicted absence using optimum probability as cutoff values. The predicted present location was considered to represent the "core area" which may consist of the ecological networks if needed. Then, the reclassified raster maps were converted to the ESRI®'s shape files in order to calculate the area of core area in km^2 using ArcMap® 9.0's VBA built-in function. Finally the population of the target species was estimated based on known population density and area in km^2, derived by a following equation.

$$N = A * PD$$

(Equation 1)

where N is estimated population (head-count), A is area (km^2), and PD is population density (head-count/km^2).

2.6.1 Estimation of population for the Asiatic black bear

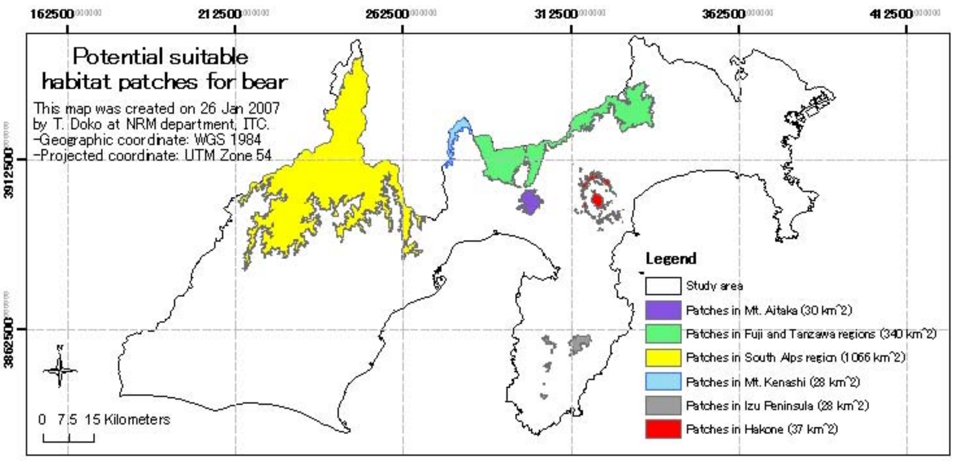
The home range of Asiatic black bear is known to vary between 50 km^2 and 70 km^2 for adult male and approximately 30 km^2 for adult female (Yoneda, 2001). Considering this minimum home range, patches smaller than 30 km^2 were eliminated from the core area and the other patches were grouped into potential suitable habitat patches. Since their home ranges are not exclu-

	algorithm	*p* as a cutoff	*K*	*PA*	*BI*	*PI*	sensitivity	specificity
Asiatic black bear	MaxEnt	***p***=0.5	0	0.53	-0.47	-0.53	0	1
		optimized *p*=0.005	0.75	0.88	-0.12	-0.18	0.7347	1
	GARP	*p*=0.5	0	0.53	-0.47	-0.53	0	1
	GLM	*p*=0.5	0.36	0.69	-0.31	-0.37	0.3469	1
		optimized *p*=0.033	0.69	0.85	-0.12	-0.17	0.7143	0.9636
Japanese serow	MaxEnt	*p*=0.5	0.56	0.78	-0.22	-0.22	0.5625	1
		optimized *p*=0.04	0.88	0.94	0	0	0.9375	0.9375
	GARP	*p*=0.5	1	1	0	0	1	1
	GLM	*p*=0.5	0.81	0.91	0.03	0.03	0.9375	0.875
		optimized *p*=0.63	0.75	0.88	0	0	0.875	0.875

P as a cutoff: probability, *K*: Kappa, *PA*: proportion agreement, *BI*: bias index, *PI*: prevalence index

Table 2 Results of Kappa statistics, sensitivity and specificity for distribution models of Asiatic black bear and Japanese serow predicted by MaxEnt, GARP, and GLMs, for test dataset

(a) Asiatic black bear predicted by MaxEnt



(b) Japanese serow predicted by GARP

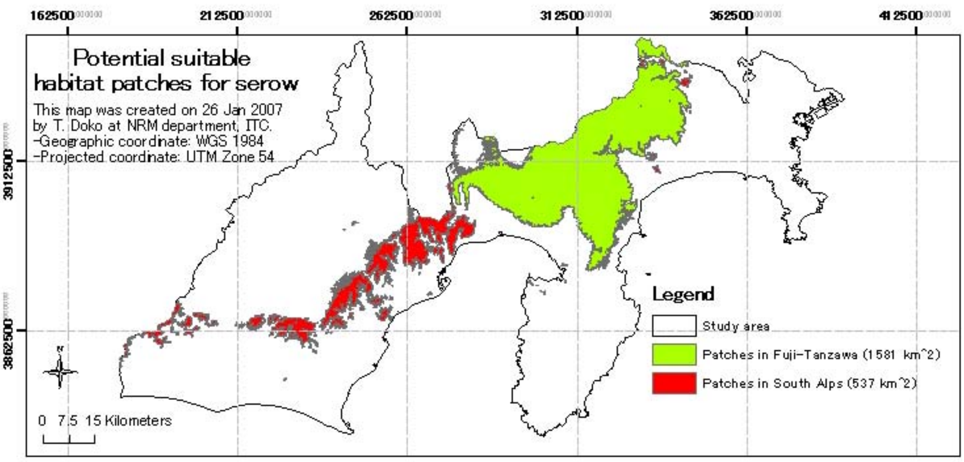


Figure 1 Potential suitable habitat patches as predicted by the best model

	Location	Area (km^2)	Estimated population	Needs assessment of ecological networks
Asiatic black bear	Mt. Ashitaka	30	5~9	serious danger of extinction
	Fuji and Tanzawa regions	340	51~102	serious danger of extinction
	South Alps region	1066	160~320	endangered
	Mt. Kenashi	28	4~8	serious danger of extinction
	Izu Peninsula	28	4~8	serious danger of extinction
	Hakone	37	6~11	serious danger of extinction
Japanese serow	Fuji and Tanzawa regions	1581	< 1581	healthy
	South Alps region	537	< 537	healthy

Table 3 Estimated population size of Asiatic black bear and Japanese serow

2.6.2 Estimation of population for the Japanese serow

The Japanese serow is known as a solitary ungulate (Ochiai and Susaki, 2002). The typical mating unit consists of a monogamous pair (1 male with 1 female), but polygamous units (1 male with 2 or 3 females) also exist (Ochiai and Susaki, 2002). The territory size is larger for males (10.4 ha to 22.8 ha) than for females (6.9 ha to 14.1 ha) (Ochiai and Susaki, 2002). Considering this minimum territory size, patches smaller than approximately 6.9 ha were eliminated from the core area and the other patches were grouped into potential suitable habitat patches. Ochiai et al. (1993a) found that a serow population maintained a stable density in a stable environment, in which food supply remained fairly constant. Contrary to this, in an unstable environment in which food supply fluctuated significantly the serow density was also fluctuating (Ochiai et al., 1993b). For instance, the density was stable from 11.7 to 16.7 / km^2 in a stable environment in Aomori Prefecture (Ochiai and Susaki, 2002), but on the other hand it did not exceed 1.0 / km^2 in a competitive environment with Sika deer in Nikko National Park (Nowicki and Koganezawa, 2001). In this research, it is assumed that the Japanese serow occurs in a competitive environment with Sika deer in the study area, based on the known national distributional maps of Japanese serow and Sika deer (Biodiversity center of Japan (2004) and Ohba, (2002)). From the maps in Aomori Prefecture, it looks like that there was no competition between the Japanese serow and Sika deer. Contrary to this, in Nikko National Park and in the study area, the habitat seems to be shared with Sika deer. Therefore, the population was estimated based on the population density found in Nikko National Park (Nowicki and Koganezawa, 2001).

2.7 Needs assessment for ecological networks

Inbreeding and loss of genetic diversity is a conservation concern as they increase the risk of extinction. Inbreeding increases the risk of extinction in captive populations, and there is now strong evidence that it is one of the factors causing extinctions of wild populations (Frankham, 2003). Loss of genetic diversity reduces the ability of species to evolve and cope with environmental change. Inappropriate management and allocation of resources is likely to result in endangering the animal populations, if genetic factors are ignored in management of threatened species (Frankham, 2003). Because of lack of accurate data concerning the minimum population size to be sufficient to maintain healthy local population for each species, the assessment criteria, established by the Ministry of Environment of Japan (Nature Conservation Bureau in Ministry of the Environment, 2000), was followed: the habitat patches with a population number under 100 were labeled as patches in a *serious danger of extinction*, the habitat patches with a population size from 100 to 400 as *endangered* patches, and those with a population size over 400 as *healthy* patches.

3. RESULTS

3.1 Asiatic black bear

3.1.1 The best logistic regression model (GLM)

The best logistic regression model for Asiatic black bear was considered to be predicted by distance to paths and stone steps and altitude without interaction, derived by the following predictive equation:

$$\log(p/(1-p))=(-1.486e+01)+(7.335e-04)*x_1 + (9.470e-03)*x_2$$

(Equation 2)

where x_1 is the distance to paths and stone steps (m), x_2 is altitude (m) and p is the probability of Asiatic black bear's occurrences.

3.1.2 Accuracy assessment and comparison of models

Table 2 shows the results of accuracy assessment by Kappa statistics. As in GARP all actual presence points were predicted absent wrongly in the test dataset, the Kappa showed no discrimination (K=0). For the train data, at a threshold of optimized probability, all modeling algorithms' prediction was almost perfect in Kappa statistics (K=0.98 for MaxEnt, K=1 for GARP, K=0.99 for GLM). Compared to a threshold of the probability of 0.5, all indices were much better in optimized probability. At a threshold of optimized probability of the test data, all indices except prevalence index scored better in MaxEnt than GLM. In conclusion, the accuracy assessment of three modeling algorithms showed that MaxEnt was performing slightly better than GLM for predicting Asiatic black bear's distribution while GARP failed to predict species' occurrences in the test area.

3.1.3 The estimated population size

Figure 1 (a) shows the potential suitable habitat patches for Asiatic black bear predicted by MaxEnt, which was the most accurate among the three algorithms. The grouped patches were considered to represent the local population or sub-local population of the Asiatic black bear. The population within each habitat was estimated as indicated in Table 3. These results showed that there are six main patches in the study area.

In the South Alps region, the estimated population size was from 160 to 320. The map showed a united large habitat (1066 km^2) in this region. It is known that Fuji local population of the Asiatic black bear consist of four sub-local populations: Mt. Fuji, Mt. Ashitaka, Mt. Furo, and Mt. Kenashi (Ohba and Mochizuki, 2001). As for the area of interest, a linear corridor seemed to exist to connect two local populations: the Fuji local population and the Tanzawa local population. The estimated population size was 51 to 102. From the map, it seemed that the connected patch contained the Tanzawa local population, sub-local population of Mt. Fuji, and Mt. Furo. However, the predictive map showed that Mt.Ashitaka and Mt. Kenashi were isolated from other sub-local populations. The estimated population size in Mt. Kenashi ranged from 4 to 8; and in Mt. Ashitaka from 5 to 9. The predictive map also showed species' suitable habitat patches in Izu Peninsula and Hakone volcano. Compared to the habitat in South Alps and the one in Fuji-Tanzawa, the habitats in this area seemed to be small and fragmented. Estimated population size in Izu Peninsula was 4 to 8 and in Hakone volcano 6 to 11. A map, which overlays the boundaries of Fuji-Hakone-Izu National Park and Tanzawa Quasi-national Park, with environmental predictors used for the bear in MaxEnt, showed that the potential suitable habitat patches were geographically distant from the wide roads, paths and stone steps.

The bear's predicted distribution was almost covered by the National Park and Quasi-national Park. However, the habitats around Mt. Ashitaka were not covered by the Fuji-Hakone-Izu National Park. Even more, the patch which consists of a linear corridor between Fuji and Tanzawa was not covered by the Fuji-Hakone-Izu National Park and Tanzawa Quasi-national Park. In general, the predicted distribution of the bear ranged from 600 to 1800 m both in South Alps and in Fuji-Tanzawa regions. Around Mt. Fuji the predicted habitat was located mainly in the montane zone, but included even top of the mountain (3742 m).

3.2 Japanese serow

3.2.1 The best logistic regression model (GLM)

The best logistic regression model was considered to be predicted by the square root of altitude and slope without interaction, derived from the following predictive equation:

$$\log(p/(1-p))=-5.91785430+0.04024136*x_1+0.26478759*x_2, \quad \textbf{(Equation 3)}$$

where x_1 is slope (°), x_2 is square root of altitude (m^2) and p is the probability of Japanese serow's occurrences.

3.2.2 Accuracy assessment and comparison of models

Table 2 shows the results of accuracy assessment by Kappa statistics. In general the score of indices was better at an optimized probability than at a threshold of probability of 0.5 except a case of GLM for the test data. For the Japanese serow's prediction, GARP was the best algorithm to fit the distribution; all indices were perfect at a threshold of a probability of 0.5.

3.2.3 The estimated population size

Figure 1 (b) shows the potential suitable habitat patches for Japanese serow predicted by GARP, which was the most accurate among three algorithms. The patches were grouped into two local populations: the area of interest and others. Population size was estimated as indicated in Table 3. As for the area of interest, the predictive map showed a large connected habitat (1581 km^2) which covered Tanzawa region, Hakone region and part of Fuji region and the estimated population size was under 1581. This large patch in Tanzawa, Hakone, and Fuji ranged from 250 to 1800 m asl. The habitat in Fuji region was not predicted in the higher altitude range of Mt. Fuji (1800 to 3742 m) but it seemed to surround Mt. Fuji and was concentrated around the lower part of the mountain. The slope steepness ranged from 16 to 30 °in general, but included some parts with a gentle slope of 0 to 15 °. The patches in South Alps were of a size of about 537 km^2 and the estimated population size was under 537. Despite their patchy appearance, the habitats were not distant from each other. The predicted suitable habitat surrounded the mountains in South Alps region. Also here it showed serow's presence in slopes ranging from 16 to 30 ° and in lower altitude areas from 250 to 600 m. The boundaries of Fuji-Hakone-Izu National Park and Tanzawa Quasi-national Park were overlayed with environmental predictors used for Japanese serow in GARP. This revealed that the Hakone National Park and Tanzawa Quasi-national Park were fully covered by suitable habitat, but that only a small part of the Fuji National Park was suitable habitat. In general, the potential suitable habitat seemed located along the highways. However, the suitable habitat was distant from the paths and stone steps.

4. DISCUSSION

The population estimations were based on area in km^2 and population density. The results revealed that there are 5~9 bears in Mt. Ashitaka, 51~102 bears in Fuji and Tanzawa regions, 160~320 in South Alps region, 4~8 in Mt. Kenashi, 4~8 in Izu Peninsula, and 6~11 in Hakone. In fact Izu Peninsula was the place where the bear was extinct (Japan Wildlife Research Center, 1980; Ohba and Mochizuki, 2001) between in 1980 and in 2003. Similarly, in past it is believed that the bear inhabited Hakone but now it is extinct (Kanagawa Prefectual Museum of Natural History, 2003). Since the predictive model mapped the bear's potential suitable habitat, it is reasonable that it shows the area of extinction. The fragmentation pattern in the map indicates the causes of extinction. First, the habitat in Izu Peninsula is too patchy and isolated from other local population. Hakone is not geographically distant to the other local populations, such as Fuji and Tanzawa local populations (Kanagawa Prefectual Museum of Natural History, 2003), but there are wide roads and highways among them. It suggests that these roads might be the main barriers which blocked the bear's passage between Hakone local population and others. Several bear's road kills are reported in the study area (Okumura et al., 2003). Therefore, the creation of green corridors for bear is recommended. For Hakone and Izu Peninsula habitat patches, estimated population is ranked as "in serious danger of extinction". The South Alps local population is ranked "endangered". Mt. Ashitaka and Mt. Kenashi are considered to be part of Fuji local population. There is concern about isolation of these sub-local populations, especially the one in Mt. Ashitaka (Ohba and Mochizuki, 2001). The outcome of this research reveals that there is serious danger of extinction for the sub-local populations in Mt. Ashitaka and Mt. Kenashi. The results also confirms concern for isolation in Mt. Ashitaka (Ohba and Mochizuki, 2001). Also it is not a part of the National Park. Therefore, it is recommended to include this area in an appropriate zoning plan. However, the local population of Mt. Kenashi seems to have a connection with adjacent Fuji local population. For the area of interest, the predictive map showed an existing linear corridor which connects Fuji and Tanzawa local population. Also this patch is ranked "in serious danger of extinction". Since the patch connected by the corridor has a low potential population, it is suggested that, even after designing ecological networks, the size of the habitat may still not be sufficient. Also, this linear linkage is not part of National Park or Quasi-National Park. It is recommended to protect this linkage by creating a new zoning plan. Given that the sum of the populations of Kenashi and Fuji and Tanzawa still ranks 'in serious danger of extinction' it is recommended to extend the corridor further to link up the larger population of South Alps.

For Japanese serow, in Fuji and Tanzawa regions population was estimated less than 1581, and in South Alps less than 537. From the assessment criteria, the number of individuals for both local populations is considered sufficient. Serow's predictive map showed that in South Alps the local population occurred in lower altitudes than in the Fuji-Hakone-Tanzawa local populations. In general the predicted suitable habitat is located along the highways and distant from paths and stone steps. The habitat selection of geographic proximity of highways and lower altitude may suggest the results of competition with Sika deer. Also when considering prey-predator relationship between Asiatic black bear and Japanese serow (Huygens et al., 2003), the serow may select the habitat where bear's presence is avoidable.

5. CONCLUSIONS

Based on the most accurate predictive map for each species, potentially suitable habitat was identified as the 'core areas' which may include ecological networks, if necessary. Then the population has been estimated in order to assess the needs for ecological networks. In the case of Asiatic black bear, the habitat patch in the area of interest, Fuji region and Tanzawa region, showed a linear corridor connecting two local populations. However the population size is considered not to be sufficient to maintain a healthy local population; it is ranked as "serious danger of extinction." Also, the two sub-local populations in Mt. Ashitaka and Mt. Kenashi which consist of Fuji local population are considered isolated from other local populations. Therefore, it is recommended 1) to prepare an appropriate zoning plan, which could protect the habitat of Mt. Ashitaka, Mt. Kenashi, including a corridor to Tanzawa and Fuji, and onwards via Mt Kenashi to South Alps, and 2) to reinforce this corridor's functionality. For the Japanese serow, the population size in Fuji and Tanzawa is considered sufficient to avoid inbreeding and loss of genetic diversity. Thus the outcome of the research can be summarized as follows: "There is a need for ecological networks in Fuji and Tanzawa regions for Asiatic black bear, but not necessarily for Japanese serow."

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ACKNOWLEDGEMENTS

The authors gratefully thank Dr. D.G. Rossiter for insightful comments and practical foundation for statistical software R, and Dr. F. Corsi for providing basis of ecological modelling with GIS. Funding for this research was provided by International Institute for Geo-information Science and Earth Observation (ITC), "Research promotion fund in remembrance of Mori Taikichiro in 2007" of Keio University and "Grant-in-Aid for Project by SFC Research Institute in 2007" of Keio University.