PREDICTION OF WILDLIFE DISTRIBUTION IN JAPAN USING MODIS DATA

Asuka GOTO*[1], Shota MOCHIZUKI[2], Takuhiko MURAKAMI[3]

[1]*Student, Graduate School of Science and Technology, University of Niigata,*
8050, Ikarashi2-no-cho, Nishi-ku, Niigata-shi, Niigata 950-2181, Japan;
Tel: +81-25-262-6627; FAX: +81-25-262-6627
E-mail: asukagoto2410@gmail.com

[2]*Student, Graduate School of Science and Technology, University of Niigata,*
8050, Ikarashi2-no-cho, Nishi-ku, Niigata-shi, Niigata 950-2181, Japan;
Tel: +81-25-262-6627; FAX: +81-25-262-6627

[3]*Associate Professor, Graduate School of Science and Technology, University of Niigata,*
8050, Ikarashi2-no-cho, Nishi-ku, Niigata-shi, Niigata 950-2181, Japan;
Tel: +81-25-262-6627; FAX: +81-25-262-6627
E-mail: muratac@agr.niigata-u.ac.jp

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Abstract: Appropriate wildlife management is important in order to resolve human-wildlife conflicts. Prediction of wildlife distribution is essential for wildlife management. The objective of this study is clarifying the relationship between animal distribution and environmental variables derived from remote sensing data and geo-information in Honshu (the Mainland of Japan). MODIS data which has the advantage of high observation frequency, multi bands, and swath dimensions was used for preparing land cover data and Normalized Difference Vegetation Index (NDVI) data. Our target species are Sika deer (*Cervus nippon*), Wild boar (*Sus scrofa*), Japanese macaques (*Macaca fuscata*), Asiatic black bear (*Ursus thibetanus*), and Japanese serow (*Capricornis crispus*). Generalized linear model (GLM) was applied to specification of the environmental variables which contributes to distribution of each animal species and predicting animal distributions. There is a similar tendency in the ecological indicator which affects distribution. All species avoided human disturbance as agricultural area and urban area. And they preferred high altitude area and mixed broadleaved forest. However the effect of coniferous forest and snow cover for animal distributions differed with the difference of resource use and the adaptation-to-environment between animal species. Finally, overlay analysis was applied to the distribution maps of target species, and the mammal hot spots in Honshu were extracted.

1. INTRODUCTION

Recently human-wildlife conflicts such as damage to crop, plantation forest and human have been serious by the range expansion of wildlife population in Japan (Miura, 2008). The amount of crop damage is about 20 billion yen (260 million U.S. dollars) to remain high (e.g., Sika deer: 76, Wild boar: 70, Japanese macaques: 20 million U.S. dollars), and forest damage area has remained at 5,000 ~ 7,000 ha (Ministry of Agriculture, Forestry and Fisheries: MAFF, 2010). The management for human-wildlife conflicts such as the lethal control are executed, but it has not been effective. Continued to hunt without taking into account the population dynamics, local populations may be extinct. For appropriate human-wildlife relationship, wildlife management is important; which bases on scientific approaches considered animal behavior, habitat environment and so on. Among them, species distribution is basic information.

To predict animal distribution and evaluate the relationship with habitat environments is essential. Animal distribution models are built with information of target animals and environmental information. Animal distribution models enable application to broad scale and it is very important in the research about biodiversity and wildlife management (Guisan *et al.*, 2007).

The objectives of this study are evaluating the relationship between animal distribution and environmental variables derived from remote sensing data of MODIS and geo-information in Honshu (the Mainland of Japan) and estimating the probability of animal distribution in Honshu. MODIS data which has the advantage of high observation frequency, multi bands, and swath dimensions was used for preparing land cover data and Normalized Difference Vegetation Index (NDVI) data. Our targets are the animals which cause damage in Japan; Sika deer (*Cervus nippon*), Wild boar (*Sus scrofa*), Japanese macaques (*Macaca fuscata*), Asiatic black bear (*Ursus thibetanus*), and Japanese serow (*Capricornis crispus*). Generalized linear model (GLM) was applied to specification of the ecological indicators which affect distribution of each animal species. Furthermore, overlay analysis was applied to the distribution maps of target species, and hot spots of target animals in Honshu were detected.

2. STUDY AREA

The study area is Honshu which is the main land in Japan (Figure 1). In Honshu, recently expansions of distributions of animals that makes critical damages for agriculture and forestry are serious problem (e.g., Crop damage: Sika deer, Wild boar, Japanese macaques. Forestry damage: Sika deer, Asiatic black bear.)

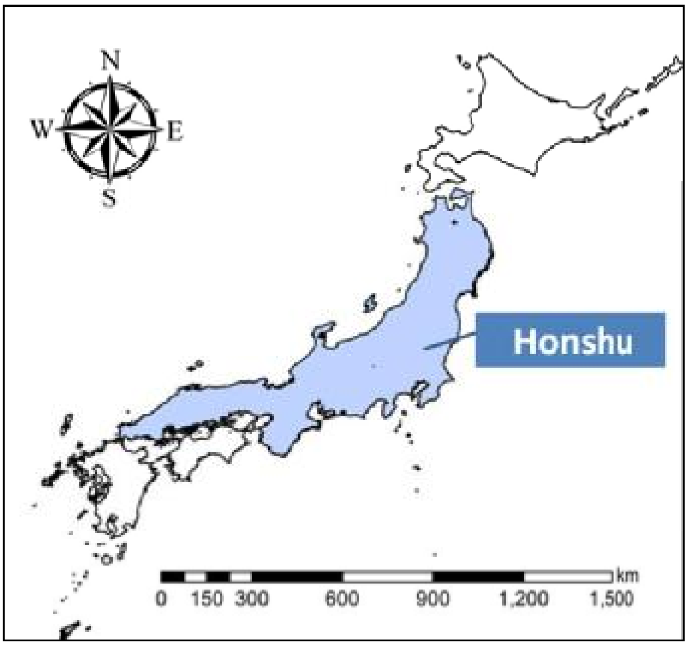

Figure 1: The study area : Honshu in Japan

3. DATA

Terra/MODIS (Tokyo University of Information Sciences), ASTER GDEM (Earth Remote Sensing Data Analysis Center: ERSDAC), Climatic data (Japan Meteorological Business Support Center: JMBSC), Digital map 25000 (Geospatial Information Authority of Japan), and National Land Numerical Information (Ministry of Land, Infrastructure, Transport and Tourism) are applied to detect the ecological indicators which contribute to distribution of each animal species. Moreover animal distribution data (Ministry of the Environment, 2004) is applied for the animal distribution data. It was recorded in 5km×5km meshes. The number of all target meshes was 9,422 in study area, and the number of meshes in occurrence and absence for each animal were shown in Table 1.

Table 1: The number of meshes of target animals.

target species	the number of meshes	
	occurrence	absence
Sika deer	3019	6403
Wild boar	4282	5140
Japanese macaques	2766	6656
Asiatic black bear	4473	4949
Japanese serow	4734	4688

4. METHODS

4.1. Ecological indicators

Thirty-two variables were applied for predicting animal distribution (Table 2): e.g., landcover, Normalized Difference Vegetation Index (NDVI), altitude, slope, climate, distant from road, density of road, and river.

The satellite images (Terra/MODIS) were used to classify land cover and to calculate Normalized Difference Vegetation Index (NDVI). The images were the composite-data that used the satellite image in total 223 scenes captured in July (34 scenes), August (41 scenes), September (51 scenes), October (52 scenes), November (45 scenes) in 2001. It was composited by the method of Maximum Value Composite (MVC) used NDVI (Holben, 1986).

NDVI is defined as

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1),$$

where RED and NIR are the visible red and near-infrared reflectance factors, respectively.

Land cover was classified into five classes: agricultural area, urban area, coniferous forest, broadleaved forest, and water area. In addition, the ratios of these classes were calculated for each mesh (5km×5km).Altitude and slope were calculated using ASTER GDEM. Snow cover, annual maximum temperature, and annual minimum temperature were calculated using climatic data recorded in 1km×1km meshes. Distance from road, density of road were calculated using Digital map 25000, and density of river using National Land Numerical Information. These data were calculated for each mesh. The ecological indicators show in Table 2.

4.2. Predicting species distribution

To examine the relationships between animal distribution and each ecological indicator, we used a generalized linear model (GLM). The dependent variable was occurrence or absence (Animal distribution data in 2004 by Ministry of the Environment), and the explanatory variables were ecological indicators. We tested for multi-collinearity among variables using the variance inflation factor (VIF), where VIF>10 denotes multi-collinearity. Seven variables were the candidate ecological indicators for the species distribution model (Table 2).

Optimal models were determined on the basis of the minimum Akaike's Information Criterion (AIC) from all combinations of variables. In order to verify the validity of a model, Area under Curve (AUC) of the Receiver Operating Characteristic (ROC) curve was calculated. AUC expresses the area under a ROC curve, when this value is 0.5~0.7, it shows that the accuracy of a model is low, 0.7~0.9 shows that accuracy is appropriate and it shows that this value is very high-precision at 0.9 or more (Pearce and Ferrier, 2000).

4.3. Overlay analysis

Probability distribution obtained was separated by 0.5. Greater than or equal to 0.5 have been regrouped into occurrence, less than 0.5 were reclassified to the absence. By overlaying the data after the reclassification of all target species, showing the diversity of species map is created.

5. RESULTS AND DISCUSSION

5.1. Preference of ecological indicators

The optimal models are shown in Figure 2, which is based on the minimum AIC (the code see Table 2). Furthermore, by determining the probability distribution of the target species in Honshu which were obtained based on the models, the maps of potential distribution were mapped (Figure 3). AUC shown in Table 3 was calculated to evaluate the validity of each model.

In the model of all species, because several environmental variables were selected, a variety of factors are contributing in the broad scale distribution of wildlife. The regional differences as the environment and climate in broad scale may exist. In addition, the variables that were selected for all target species were similar. All species avoided human disturbance as agricultural areas and urban areas, and high river density. Animals preferred high altitude area and mixed broadleaved forest. These were characteristics of forest animals.

However, the regression coefficients differed among the target species model even the same variable. In particular, the difference in the effect of the snow cover was remarkable. Snow cover contributed positively to the distribution of Asiatic black bear and Japanese serow, but Sika deer and Wild boar and Japanese macaques were contributed negatively. This difference can be explained from the behavioral characteristics of animals. Asiatic black bear hibernate in the winter, and then it has less impact by snow and cold (Tsubota, 2011). Besides, Japanese serow inhabits in areas of deep snow often, and snow serves to protect plants which become forage for them from the cold and from desiccating winds (Takatsuki *et al.,* 1995).Ungulates is markedly inhibited by snow over the height of the joint of the hind limbs in general (Gilbert *et al.,* 1970). Snow depth of 50cm by 45cm lead to behavioral inhibition for Sika deer (Maruyama *et al.,* 1977), and about 30cm depth snow cover inhibits for Wild boar (Asahi *et al.,* 1975). This way, snow depth might has contributed negatively to Wild boar and Sika deer because they are sensitive to snow. Snow cover also contributed negatively to Japanese macaques distribution, but importance was smaller than other species. Japanese macaques usually called “snow monkey” in the world. However, snow cover contributed negatively because Japanese macaques can adapt the multiple environments. It may be the reason the validity of the model (AUC) of Japanese macaques is low (Table 3).

The effect of interaction term between the ratio of coniferous forest and standard error of NDVI for animal distributions differed between animal species. The interaction term between the coniferous forest and standard error of NDVI was not selected in the model of Japanese macaques. However, it contributed to the distributions of Sika deer, Asiatic black bear, and Japanese serow positively, and it contributed to the distribution of Wild boar negatively. The reason of the interaction term between the coniferous forest and standard error of NDVI did not contribute positively in Wild boar and Japanese macaques may be fewer food resources in the coniferous forest. However, Sika deer, Asiatic black bear, and Japanese serow used coniferous forest, as they are known for stripping bark and feeding damage. The effect of interaction term between the ratio of conifer and standard error of NDVI for animal distributions differed with the difference of resource selection in coniferous forest between animal species. The various adaptation to environment of animals lead to the difference of the potential distribution.

5.2. Diversity of target animals

Figure 4 shows the diversity of target species. Table 5 shows its diversity, the number of meshes, and the ratio. In addition, the ratios of overlap for each species were calculated (Table 6).

Focusing on the meshes which were confirmed target species, the most number of meshes had diversity value “two”, was 31.9% of whole meshes. Many of them were in the mountains on side of the Sea of Japan. Here is an area that is inhabited mainly Asiatic black bear and Japanese serow. Asiatic black bear and Japanese serow have a high overlap rate in comparison with other animals (Table 6). The region facing the Sea of Japan is a snowy area, and there are only species adapting such environments. In addition, the majority of the habitat of Sika deer overlapped it of wild boar. The characteristic of ungulate which are weak to snow affected the selection of similar habitat. However, because that the habitat of Wild boar is larger than it of Sika deer, the overlapping area with Sika deer is not so large for the habitat of Wild boar. The overlapping rate with other animals habitats of Japanese macaques habitats were high, and Japanese macaques might have flexible adaptable to several environments.

Hot spots which five species inhabit were the Japan Alps which is located in the central part of Japan and surrounding the Kanto Mountains is greater, and it is also distributed in the Shikoku Mountains (Figures 1 and 4). As the reason of highly hot spot area, these areas have high altitude and low snow cover. We propose that estimating of hot spot detects a significance of continuous wildlife management with various species and preservation of biodiversity.

Table 2: The ecological indicators. Code X denote the candidate ecological indicators to build model.

Category	Ecological indicators	Code
Land cover	The tatio of Agriculutural area	X1
	The ratio of Urban area	X2
	The ratio of Conifer forest	
	The ratio of Broadleaved forest	
	The ratio of Water area	
Vegetation	Average value of NDVI	
	Standard error of NDVI	
	Interaction term between the ratio of Conifer forest and standard error of NDVI	X3
	Interaction term between the ratio of Broadleaved forest and standard error of NDVI	X4
Altitude	Average value of altitude	X5
	Standard error of altitude	
Slope	Average value of slope	
	Standard error of slope	
Rivers	Density of rivers	X6
Climate	Average value of snow cover	X7
	Standard error of snow cover	
	Average value of maximum temperature	
	Standard error of maximum temperature	
	Average value of minimum temperature	
	Standard error of minimum tmperature	
Distance to roads	Distance to all roads	
	Distance to sidewalks	
	Distance to main roads	
	Distance to highways	
	Distance to narrow roads (less than 13m)	
	Distance to wide roads (more than 13m)	
Density of roads	Density of all roads	
	Density of sidewallks	
	Density of main roads	
	Density of highways	
	Density of narrow roads (less thyan 13m)	
	Density of wide roads (more than 13m)	

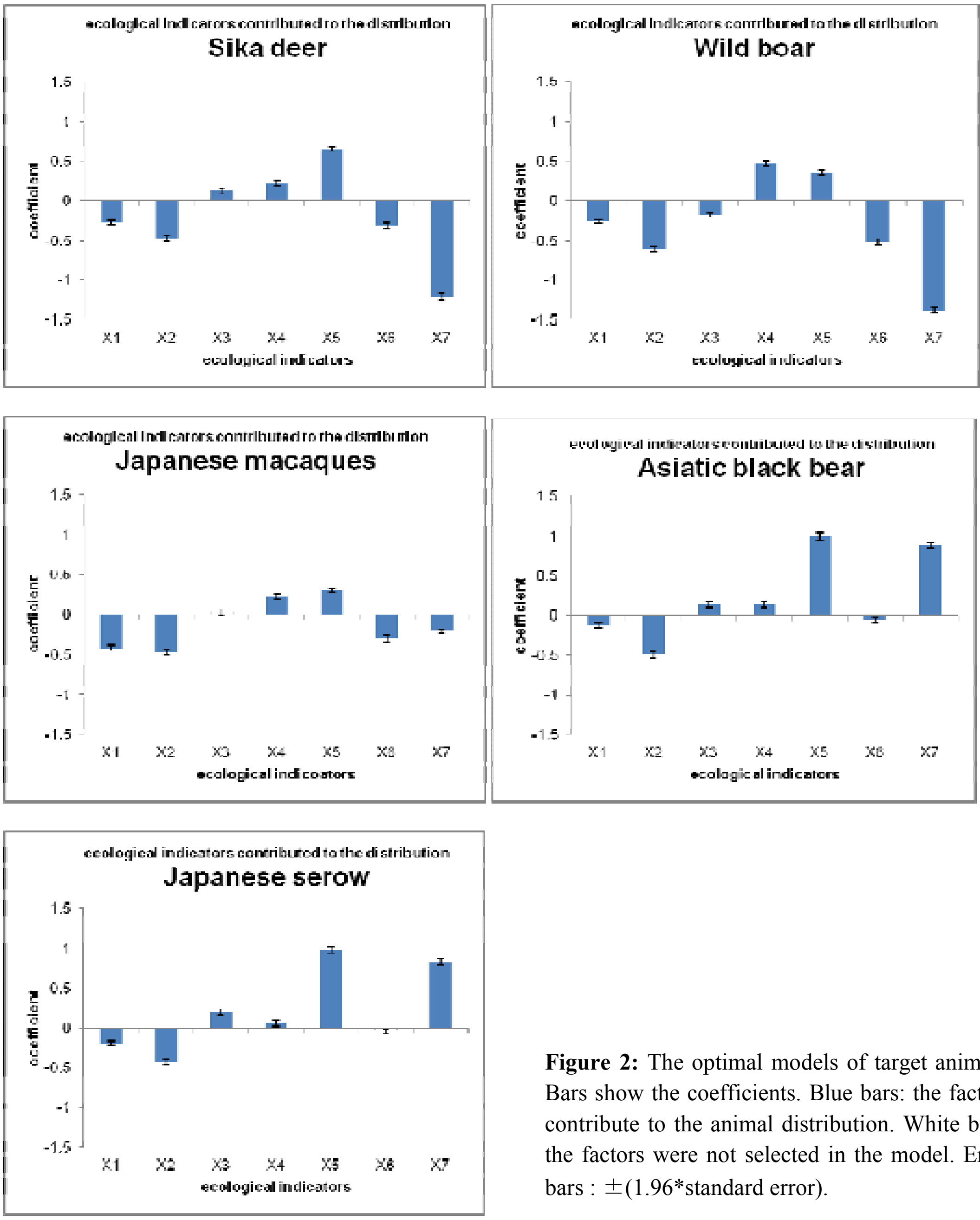

Figure 2: The optimal models of target animals. Bars show the coefficients. Blue bars: the factors contribute to the animal distribution. White bars: the factors were not selected in the model. Error bars : ±(1.96*standard error).

Table 3: Area under Curve (AUC) of the each model.

species	AUC
Sika deer	0.792
Wild boar	0.825
Japanese macaques	0.713
Asiatic black bear	0.861
Japanese serow	0.849

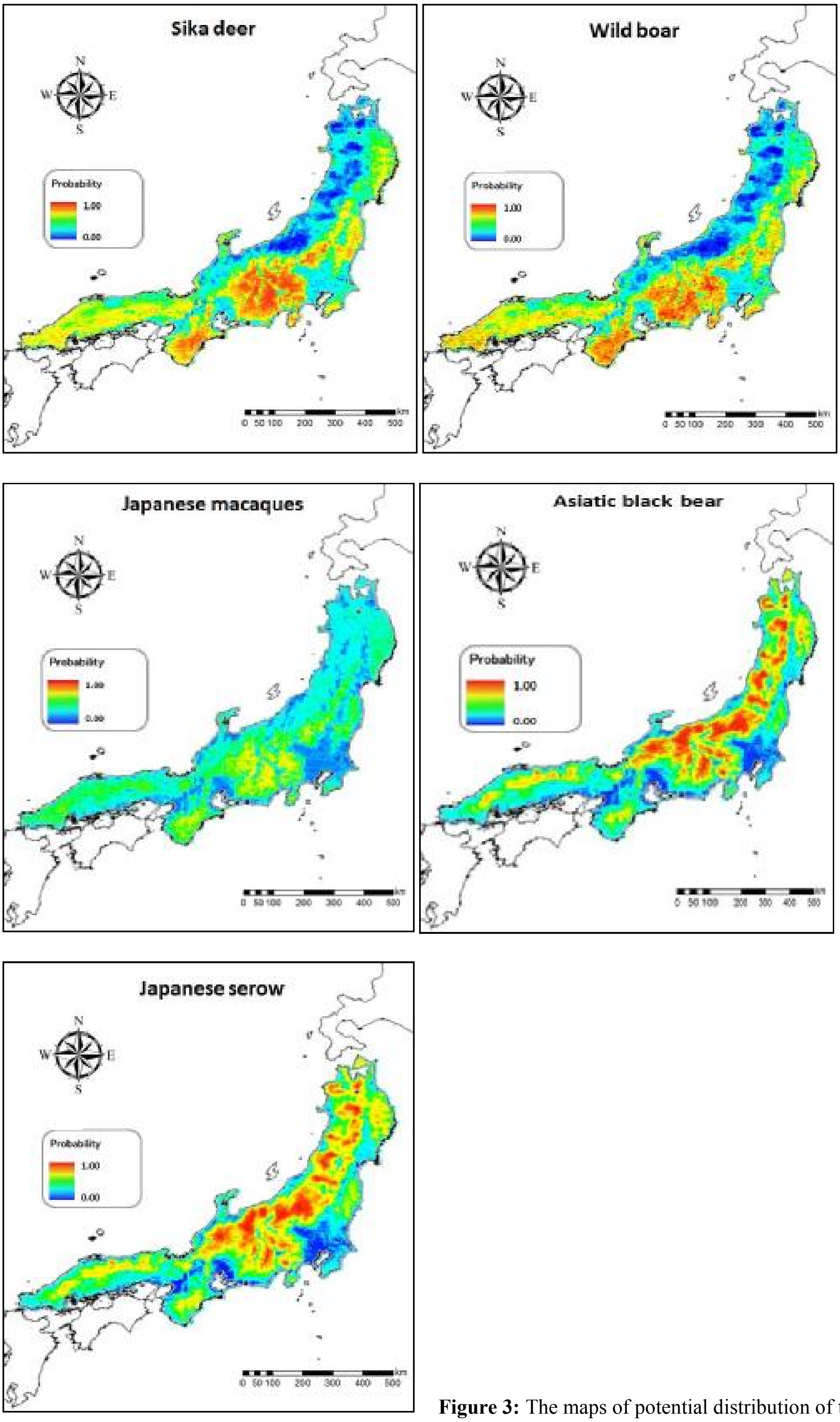

Figure 3: The maps of potential distribution of target animals.

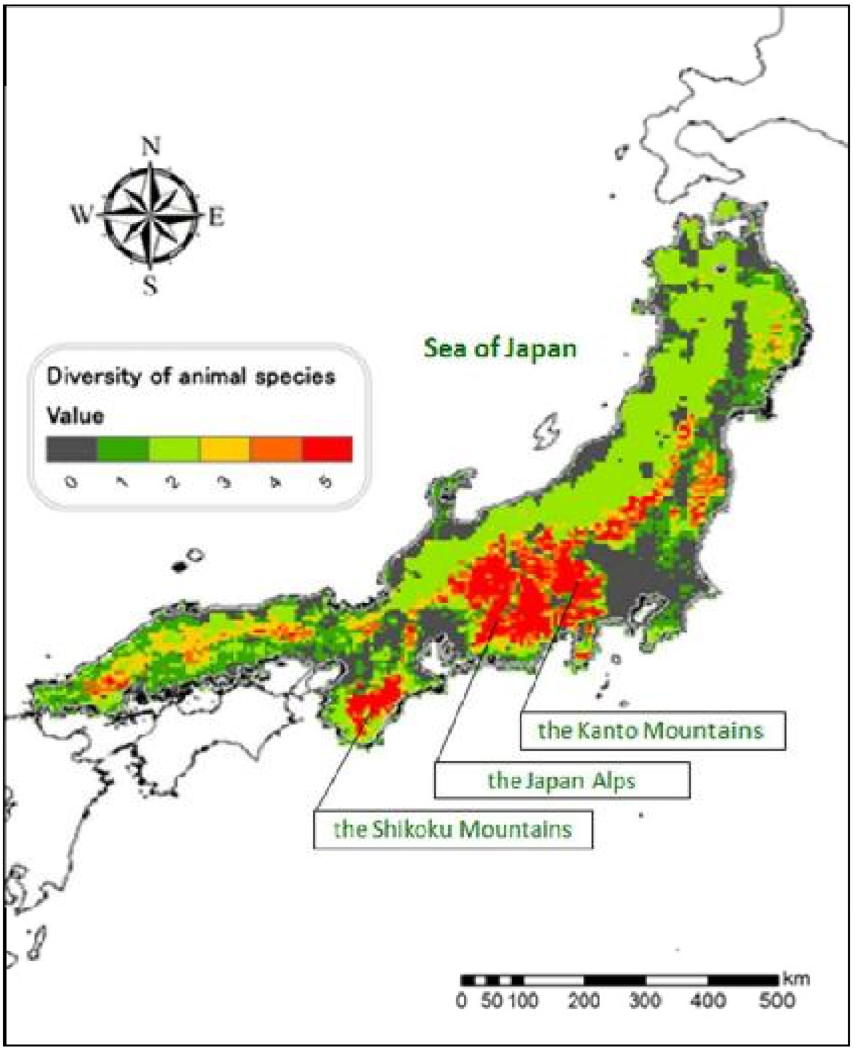

Figure 4: Diversity of target animals.

Table 5: The number of meshes and the ratio for each value of animal diversity.

diversity of animal species	the number of meshes	ratio
0	2592	0.275
1	1818	0.193
2	3001	0.319
3	664	0.070
4	556	0.059
5	791	0.084
sum	9422	

Table 6: When the overlaying the occurrence of each animal and other animals, the number of overlapping meshes.

			overlay species occurrence				
			Sika deer	Wild boar	Snow monkey	Asiatic black bear	Japanese serow
species occurrence	Sika deer	ratio	1.000	0.985	0.411	0.608	0.664
		the number of meshes	2184	2152	897	1328	1451
	Wild boar	ratio	0.494	1.000	0.208	0.402	0.448
		the number of meshes	2152	4356	906	1749	1952
	Snow monkey	ratio	0.944	0.954	1.000	0.902	0.918
		the number of meshes	897	906	950	857	872
	Asiatic black bear	ratio	0.325	0.429	0.210	1.000	0.999
		the number of meshes	1328	1749	857	4080	4075
	Japanese serow	ratio	0.328	0.442	0.197	0.922	1.000
		the number of meshes	1451	1952	872	4075	4421

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