International Journal of GEOMATE, April, 2020, Vol.18, Issue 68, pp. 94 - 100
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.68.5721
Special Issue on Science, Engineering and Environment

ANALYSIS OF HABITAT AREA FOR ENDANGERED SPECIES USING MAXENT BY URBANIZATION IN CHIBA, JAPAN

* Hideyuki Ito[1], Koji Hayakawa[2], Makoto Ooba[3] and Takahiro Fujii[4]

[1,4]College of Science and Technology, Nihon University, Japan; [2]Chiba Prefecture, Japan;
[3]National Institute for Environmental Studies, Japan

*Corresponding Author, Received: 10 July 2019, Revised: 28 Nov. 2019, Accepted: 08 Feb. 2020

ABSTRACT: Chiba prefecture in Japan abounds with rich nature and is surrounded by sea and many rivers. But the number of endangered species in Chiba has been increasing since World War II because various habitats have been destroyed by rapid urbanization. However, studies have analyzed the time-series change in the amount of green area and habitat area for endangered species taking into consideration adverse impacts of road construction and residential land development in Chiba, Japan. In this research, we estimated the change of green area and habitat area for some endangered species using MaxEnt (Maximum Entropy Modeling) software for modeling species niches and distributions. As the result, it was shown that the green space area and water environment including rivers, lakes, ponds, and coastal area has decreased while the buildup area has increased from 1976 to 2009. Also, it was concluded that total habitat possibility area of the ruddy crake, red fox, Japanese skink, and Tokyo salamander have decreased by 3.6%, 6.0%, 1.6%, and 0.7%, respectively.

Keywords: MaxEnt, GIS, Endangered Species, Green Area

1. INTRODUCTION

Chiba Prefecture is blessed with water and green nature because it is surrounded by the sea and rivers on all sides. With the rapid development of transportation infrastructure such as the opening of railways, Narita Airport, and Aqua line, urbanization has progressed, resulting in a decrease in habitats such as forests and wetlands, and the number of species which are endangered tends to be increasing.

For the changes in land use, many previous studies have analyzed the area and green coverage depending on the land use classification. For example, Iwasaki et al. [1] discussed the habitat of Japanese monkeys based on the analysis of the temporal changes in land use. Kwon and Miyawaki [2], Ikemi et al. [3] and Ohara et al. [4] have developed methods to comparatively analyze previously documented data and electronic data using GIS (Geographic Information System). However, the land use classifications must be reorganized for accurate comparison, because they change depending on the publication year of the maps. Miyamoto [5] evaluated suitable habitat areas using MaxEnt (Maximum Entropy Modeling), which can estimate the habitat probability of animals.

MaxEnt is an open source tool for modeling in which the habitat area is estimated by modeling the existence probability of species and various environmental factors using the appearance data of organisms whose existence has been confirmed and various environmental data from the whole target area. MaxEnt estimates the parameters of the appearance characteristic function by applying the principle of maximum entropy algorithm (Phillips et al. [6]). In this MaxEnt, the following three analyses are possible: 1) quantification (visualization) of suitable habitat area, 2) calculation of contribution rate for respective environmental factors, and 3) comparison of before and after time series by model construction.

For example, MaxEnt has been utilized to estimate the suitable habitat area of Chinese Alligator--a critically endangered crocodilian--and predicted its distribution in Anhui Province, China (Pan et al. [7]). West et al. [8] developed a presence-only model of invasive cheat grass (*Bromus tectorum*) distribution in Rocky Mountain National Park, Colorado, USA, from 2007 through 2013 fit with limited data to compare with the result of GLM (Generalized Linear Model). Remya et al. [9] reported current and future habitat suitability distribution of *Myristica dactyloides Gaertn*, a medicinally and ecologically important tree species, by using a MaxEnt species distribution model in order to implement sustainable conservation or adaptation strategies.

Matyukhina et al. [10] modeled the geographic distribution of Amur tigers based on the MaxEnt algorithm using a dataset of 1,027 tiger track records and a set of environmental variables, such as distance to rivers, elevation and habitat type, and anthropogenic variables, such as distance to forest and main roads, distance to settlements, and vegetation cover change in the Russian Far East. Moreno et al. [11] identified potential habitats for two endemic birds of high ecological value, the Black throated Huet-Huet (*Pteroptochos tarnii*), and the Ochre-flanked Tapaculo (*Eugralla paradoxa*), and then identified the most important variables that explain the presence of each species. Pratumcharta et al. [12] predicted the distribution of *B. s. goniomphalos* in Thailand on the basis of environmental and climatic factors and also demonstrated that altitude, land cover, normalized difference vegetation index, precipitation in the driest month, land surface temperature, and soil pH affected its distribution.

Khadka and James [13] mapped the distribution of the current and future climatic niches of the endangered *Himalayan musk deer*, a species endemic to Asia. Mohammadi et al. [14] analyzed the current potential distribution of the *Blanford's Jerboa Jaculus blanfordi* and the *Arabian Jerboa Jaculus loftusi* in Iran and predicted the impact of climate change on their future potential distributions using two different modeling software packages: Maxent and Species distribution model.

Existing research using MaxEnt predicts the distribution and suitability of habitat of various endangered animals and plants and then identifies the environmental factors that affect their distribution.

However, especially in Japan, few studies have taken into account changes in transportation infrastructure and urbanization in quantitatively analyzing the changes in the habitat area of many endangered species. Therefore, the purpose of this research is to quantitatively evaluate the effect of expanded transportation infrastructure on the habitat of endangered species, focusing on the changes in land use in Chiba Prefecture, Japan.

2. METHOD

As environmental variables used in MaxEnt, the following seven kinds of data in Chiba Prefecture were used: 1) land use data from 1976, 1987, 1991, 1997, 2006, and 2009, 2) average rainfall amount over 30 years, 3) annual average temperature over 30 years, 4) annual total daylight hours over 30 years, 5) annual average global solar radiation over 30 years, 6) data of average altitudes in 2009 and 7) data of average slope angles in 2009 (Table 1).

Data from 1976 was selected because that was the oldest available GIS data on land use in Chiba Prefecture. The land use data from 2009 and the above data were input into MaxEnt. The change over the years was analyzed by inputting the land use data from the other years using the obtained models and parameters from the analysis result of MaxEnt. Since the land use classification differs depending on the fiscal year of the land use preparation, it was reorganized based on the newly unified land use. The definition of the respective land use was investigated and confirmed, and the land use was organized according to the following nine categories: paddy fields; other agricultural land; forest; wasteland; buildup areas; main transportation sites; rivers, lakes and ponds; coastal areas; and other sites.

For selecting the target species, as endangered species with high conservation priority, the following 11 species were chosen and analyzed from the list of red data book in Chiba Prefecture as the target species: quail, ruddy crake, marsh grass bird, Japanese large-footed bat, red fox, Japanese pond turtle, Japanese skink, Japanese mamushi, Tokyo salamander, Japanese fire belly newt, and wrinkled frog. Plot data wherein the existence in the area has been confirmed is needed to estimate the existence probability of these species in Chiba Prefecture. Therefore, the suitable habitat area of endangered species was analyzed using MaxEnt based on the habitat spot data written in the red data book of the Chiba Prefecture. In this research, we especially focused on the results for the ruddy crake (*Porzana fusca*), red fox (*Vulpes vulpes*), Japanese skink (*Plestiodon japonicus*), and Tokyo salamander (*Hynobius tokyoensis*) as representative species of birds, mammals, reptiles, and amphibians, respectively (Fig.1).

Table 1. Data sets input into MaxEnt

Data	Mesh size	Year	Source
Land use	100m	2009 2006 1997 1991 1987 1976	Geospatial Information Authority of Japan
Average rainfall amount	1km	2012	Japan Meteorological Agency
Annual average temperature			
Annual total daylight hours			
Average annual amount of solar radiation			
Average altitudes	250m	2009	Geospatial Information Authority of Japan
Average slope angles			

Fig.1 Target species

3. RESULTS

3.1 Result of Comparative Analysis of Land Use Area

Table 2 shows the land use area for each year in Chiba Prefecture. The green space consisting of rice paddy, forest, and other agricultural land and water environment including rivers, lakes, ponds, and coastal areas have decreased while the buildup area has increased. Based on these results, there is a possibility that the habitat area for species has been also decreasing due to the expansion of the city area.

According to the statistical yearbook of Chiba Prefecture, total road length has been increasing every year, but a decrease of the "Area of main roads" is shown in Table 2. This is because, due to urbanization, the concentration of "buildup area" been increasing, constricting the possibility of land use for "Area of main roads."

3.2 Result of Suitable Habitat Area Predicted by MaxEnt

The suitable habitat area of four endangered species determined by MaxEnt for 1976 and 2009 is shown in Fig.2. In these figures, the habitat possibility is represented in colors according to 0–1 values per each mesh (100 m × 100 m) based on the plot data for which the habitat was confirmed and based on the environmental variables.

Ruddy crake lives in common reed, Manchurian wild rice (*Zizania latifolia*), and the grass near wetlands such as lakes, rivers, and paddy fields. It is reported that many ruddy crake are found in the north of Chiba [15]. As shown in Fig.2, the high habitat possibility area is concentrated in the north coastal area and riverside. Comparing between the north and south areas in Chiba, the north area has a higher habitat possibility than the south one.

Red fox prefers an area mixed with forest,

Table 2. Comparison result of area of each land use

Land Use	1976	1987	1991	1997	2006	2009	Comparison between 1976 and 2009
Rice Paddy	127.3	121.3	121.4	119.1	112.1	108.9	-14.4%
Other Agricultural Land	80.8	75.6	75.5	72.5	69.2	68.1	-15.7%
Forest	187.9	179.4	174.9	167.6	161.3	170.8	-9.1%
Waste Land	8.0	15.0	13.8	10.6	12.3	8.9	+11.0%
Buildup Area	53.6	71.5	73.1	86.4	95.3	111.2	+107.4%
Area of Main Roads	1.7	2.9	3.2	4.0	5.7	1.3	-22.9%
Rivers, Lakes and Ponds	16.2	16.0	14.7	14.8	14.8	12.6	-22.7%
Coastal Area	3.9	2.3	2.3	2.3	2.0	1.7	-57.9%
Others	35.4	31.0	36.0	37.6	42.2	31.5	-11.1%

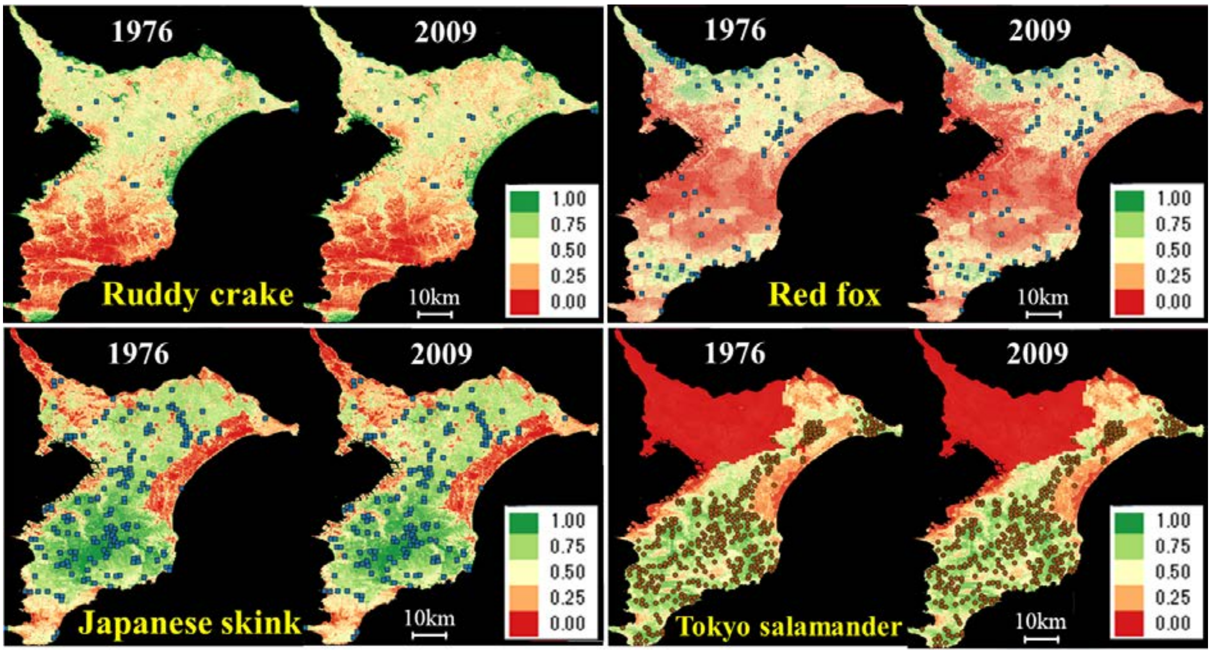

Fig.2 Result of suitable habitat area of each endangered species determined by MaxEnt

grassland and agricultural land, and riverside and grassland are usually used as a resting place [15]. Since there are many rivers, lakes, and ponds in the north of Chiba in particular, the habitat possibility area covers mainly the north area and part of the south area as shown in Fig.2. However, the low habitat possibility area expanded slightly from 1976 to 2009.

Japanese skink usually lives in grasslands and the slope of mountainous areas with good exposure to sunlight. The suitable habitat area of Japanese skink predicted by MaxEnt is concentrated in the south area that includes the Kazusa-hills, whereas Japanese skink does not prefer the east coastal area and west urban area.

Tokyo salamander generally inhabits broad-leaved forests and artificial forests covered by planted Japanese cedar and cypress in hilly areas and low mountains. For spawning, it also requires an aquatic environment near forest. The suitable habitat area predicted by MaxEnt is seen in the south and east area that includes forested and hilly environments.

3.3 Result of AUC and Contribution Rate

Table 3 shows the AUC (Area under the receiver operator curve [6]) and contribution rate of respective environmental factors. AUC is the expectation value, meaning the ratio between the area identified as actually containing the targeted species and the habitat area predicted by MaxEnt. This ratio is indicated as a value from 0 to 1. Since the results of AUC for all species were over 0.7, all predicted models by MaxEnt were assessed good fit models.

Contribution rate is the rate that each environmental variable affects the habitat probability. As indicated on Table 3, the “annual total daylight hours” and “land use” considerably affect the habitat probability of the red fox, while the “average rainfall amount” influences the habitat probability of the Tokyo salamander because this species prefers a water environment. Many Japanese skinks were confirmed in the south area where the slope angle is large, while many ruddy crakes were confirmed in the north area with a small slope angle. These results

Table 3. Result of AUC and contribution rate of respective environmental factors

	AUC	Land use (%)	Average rainfall amount (%)	Annual average temperature (%)	Annual total daylight hours (%)	Average annual amount of solar radiation (%)	Average altitudes (%)	Average slope angles (%)
Ruddy crake	0.789	16.5	0.4	6.1	18.7	0.0	17.7	40.6
Red fox	0.797	28.7	16.7	16.4	29.1	1.2	5.8	2.0
Japanese skink	0.713	6.4	12.1	1.0	16.9	2.8	12.2	48.5
Tokyo salamander	0.789	1.5	61.8	5.1	1.1	0.0	6.1	24.5

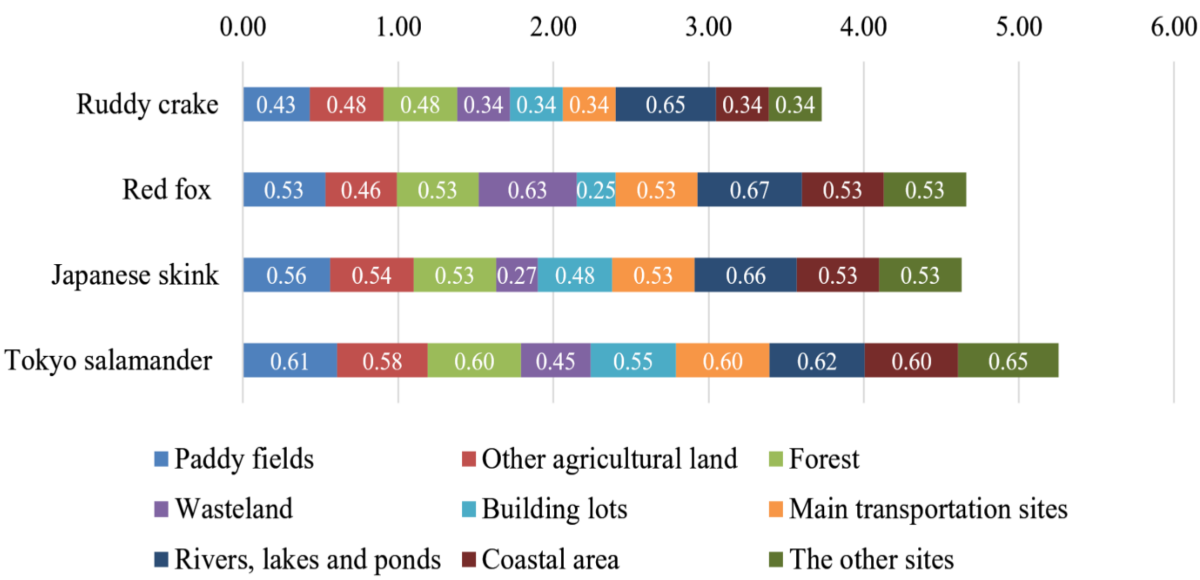

Fig.3 Result of response curve on each land use

showed that the contribution rate of the slope angle is high for these species. Thus, it was found that there were differences in preference of habitat among targeted species.

Fig.3 represents the result of response curve on each land use. This response curve estimated by MaxEnt was able to reproduce the characteristics of habitat for each species. “Rivers, lakes and ponds” and “Paddy fields” commonly had an influence on almost all species because they prefer a freshwater environment near their habitat. “Other agricultural land” and “Forest” are also indicated as suitable habitats for many species.

3.4 Result of Time-series Change of Potential Suitable Habitat Area

The area of potential suitable habitat considering the existence probability was estimated by multiplying the suitable habitat area rate 0–1, obtained by MaxEnt, by the area of each mesh (Fig.4 and Table 4).

As a result, it was shown that when comparing the results in 1976 with those in 2009, total habitat possibility area of the ruddy crake, red fox, Japanese skink, and Tokyo salamander have decreased by 3.6%, 6.0%, 1.6%, and 0.7%, respectively. Since the residential land area and road length has increased by 74.5% and 13.6% respectively in this period, the suitable habitat area of each species is considered to have decreased with the expansion of the city area. Significantly, the habitat for the red fox has decreased considerably over 33 years because its habitat is near

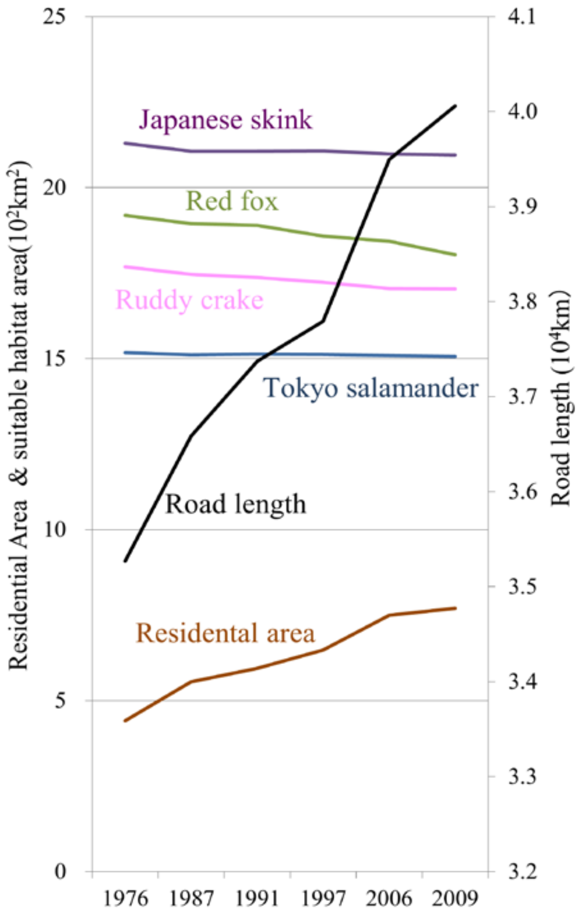

Fig.4 Relationship between potential suitable habitat area, residential area, and road length

Table 4. Result of detailed potential suitable habitat area between 1976 and 2009

		1976	1987	1991	1997	2006	2009	Comparison between 1976 and 2009
Road length(10^4km)		3.5	3.7	3.7	3.8	3.9	4.0	13.6%
Buildup area (10^2km^2)		4.4	5.5	5.9	6.5	7.5	7.7	74.5%
Species	Area	Potential suitable habitat area (10^2km^2)						
Ruddy crake	Whole area	17.7	17.5	17.4	17.2	17.1	17.0	-3.6%
	Northwestern	7.8	7.7	7.6	7.5	7.4	7.4	-4.8%
	Northeastern	6.1	6.1	6.1	6.0	5.9	6.0	-3.0%
	South	3.7	3.7	3.7	3.7	3.7	3.7	-2.3%
Red fox	Whole area	19.2	18.9	18.9	18.6	18.4	18.0	-6.0%
	Northwestern	7.8	7.6	7.6	7.4	7.3	7.0	-9.8%
	Northeastern	5.6	5.5	5.5	5.4	5.4	5.3	-4.4%
	South	5.8	5.8	5.8	5.8	5.8	5.7	-2.4%
Japanese skink	Whole area	21.3	21.1	21.1	21.1	21.0	21.0	-1.6%
	Northwestern	7.8	7.6	7.6	7.7	7.6	7.6	-2.2%
	Northeastern	5.3	5.3	5.3	5.3	5.2	5.2	-1.3%
	South	8.2	8.1	8.2	8.2	8.1	8.1	-1.2%
Tokyo salamander	Whole area	15.2	15.1	15.1	15.1	15.1	15.1	-0.7%
	Northwestern	2.3	2.3	2.3	2.3	2.3	2.3	-1.3%
	Northeastern	4.5	4.5	4.5	4.5	4.5	4.5	-0.6%
	South	8.3	8.2	8.3	8.3	8.2	8.2	-0.7%

land containing expanding housing development. Also, in the northwestern area of Chiba in particular, the total potential suitable habitat area for all species has decreased remarkably.

4. CONCLUSION

In this study, we analyzed the environmental factors that affected the habitat probability and estimated the possible habitat area for endangered species using MaxEnt in Chiba Prefecture, Japan.

In Japan, the process of einvironmental impact assessment does not legally require developers to conduct compensatory mitigation. Thus, the number of endangered species has been increasing every year due to destruction of the natural environment including their valuable habitat. To solve this problem, it is necessary to consider how to avoid, minimize, and compensate the adverse impact to habitat at the planning phase of development, based on the potential habitat area predicted by MaxEnt in this research. Since it is impossible to survey the existence of all plants and animals in an entire area, potential habitat area estimated by MaxEnt is valuable information to consider in taking environment conservation countermeasures.

Further research is needed to improve the accuracy of the plot data for habitat places by collecting more data and by including other environmental variables for MaxEnt to improve the accuracy of the contribution rate.

5. REFERENCES

[1] N. Iwasaki and S. David, A study of the land use history in the Japanese macaque habitat expansion area of the Boso Peninsula, Japan. Journal of Rural Planning Association. Vol.24, Special issue, 2005, pp.S1-S6.

[2] J. Kwon and M. Miyawaki, A STUDY ABOUT THE STABILITY OF LANDSCAPE BASED ON LAND-USE BY GIS, Journal of architecture, planning and environmental engineering, Vol.75, No.658, 2010, pp.2863-2872.

[3] H. Ikemi, T. Esaki, Y. Mitani and T. Tran, Spatial Distribution of Human Impacts on Terrain Based On Landuse Change Analysis Development and GIS Analysis of Landuse Maps since 1900 in the Fukuoka Prefecture Area, Journal of the Japan Society of Engineering Geology, Vol.52, No.3, 2011, pp.97-108.

[4] Y. Ohara and A. Yamashita, Mesh Data Analysis on Land Use Change and Its Correlation with Topographic Condition in Sapporo, Tokyo and Osaka Metropolitan Areas, Geographical Studies, No.86, No.1, 2011, pp.55-71.

[5] M. Miyamoto, Attempts to estimate habitat of cold-water corals, Aquabiology, Vol.36(5), 2014, pp.461-468.

[6] S. J. Phillips, R. P. Anderson, R. E. Schapire, Maximum entropy modeling of species geographic distributions, Ecological Modelling 190, 2006, pp.231-259.

[7] T. Pan, H. Wang, S. Duan, I. Ali, P. Yan, R. Cai, M. Wang, J. Zhang, H. Zhang, B. Zhang and X. Wu, Historical population decline and habitat loss in a critically endangered species, the Chinese alligator (Alligator sinensis), Global Ecology and Conservation, Vol.20, e00692, 2019, pp.1-10.

[8] A. M. West, S. Kumar, C. S. Brown, T. J. Stohlgren and J. Bromberg, Field validation of an invasive species MaxEnt model, Ecological Informatics, Vol.36, 2016, pp.126-134.

[9] K. Remya, A. Ramachandran and S. Jayakumar, Predicting the current and future suitable habitat distribution of Myristica dactyloides Gaertn using MaxEnt model in the Eastern Ghats, India, Ecological Engineering, Vol.82, 2015, pp.184-188.

[10] D.S. Matyukhina, D. G. Miquelle, A. A. Murzin, D. G. Pikunov, P. V. Fomenko, V. V. Aramilev, M. N. Litvinov, G. P. Salkina, I. V. Seryodkin, I. G. Nikolaev, A. V. Kostyria, V. V. Gaponov, V. G. Yudin, Y. M. Dunishenko, E. N. Smirnov, V. G. Korkishko, J. Marino, Assessing the Influence of Environmental Parameters on Amur Tiger Distribution in the Russian Far East Using a MaxEnt Modeling Approach, Achievements in the Life Sciences, Vol.8, Issue 2, 2014, pp.95-100.

[11] R. Moreno, R. Zamora, J. R. Molina, A. Vasquez, M. Á. Herrera, Predictive modeling of microhabitats for endemic birds in South Chilean temperate forests using Maximum entropy (MaxEnt), Ecological Informatics, Vol.6, Issue 6, 2011, pp.364-370.

[12] K. Pratumcharta, K. Suwannatrai, C. Sereewong, K. Thinkhamrop, J. Chaiyos, T. Boonmars and A. T. Suwannatrai, Ecological Niche Model based on Maximum Entropy for mapping distribution of Bithynia siamensis goniomphalos, first intermediate host snail of Opisthorchis viverrini in Thailand, Acta Tropica, Vol.193, 2019, pp.183-191.

[13] K. K. Khadka and D. A. James, Modeling and mapping the current and future climatic-niche of endangered Himalayan musk deer, Ecological Informatics, Vol.40, 2017, PP.1-7.

[14] S. Mohammadi, E. Ebrahimi, M. S. Shahriari, L. Bosso, Modelling current and future potential

distributions of two desert jerboas under climate change in Iran, Ecological Informatics, Vol.52, 2019, pp.7-13.

[15] Chiba prefecture’s historical sources research foundation, Natural History of Chiba Prefecture, Vol6, No.45, 2002.