EnviroInfo 2010 (Cologne/Bonn)
Integration of Environmental Information in Europe
 ISBN: 978-3-8322-9458-8

Using environmental niche model to study the distribution of Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Northeastern Vietnam under some climate change scenarios

Vu Van Manh, Thach Mai Hoang, Pham Thanh Van
Hanoi University of Science, Vietnam National University, Hanoi
334 Nguyen Trai str., Thanh Xuan dist., Hanoi, VIETNAM
fesvvm@yahoo.com
thachmaihoang1979@yahoo.com
thanhvan3007@gmail.com

Abstract

Environmental niche modeling is a very effective tool for discovery species distribution with only limited observed data. It is used to generate a potential distribution of species in environmental space, which can helps the managers to define the distribution area, make decision for field study and conservation. In this paper, we made effort to apply environmental niche modeling for Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) - an endemic primate animals of Vietnam. We used the BIOCLIM model which is embeded in DIVA-GIS. The research is implemented in the Northeastern Vietnam, which is considered habitat of *Rhinopithecus avunculus*. The result was displayed in potential distribution maps by DIVA-GIS. We have generated three distribution maps with two climate conditions (i.e. current climate and future climate with climate change scenario). According to the output of model, the potential distribution of Tonkin snub-nosed is mostly covered the Northeastern of Vietnam , classified into 6 levels. The suitable area is narrow (36,806 km^2) and will smaller under the climate change scenario (decrease to about 29,000 km^2). The model also shows that, the distribution area of Tonkin snub-nosed monkey is moving to the North in the future climate condition.

Keywords: Environmental niche modeling, GIS, Rhinopithecus avunculus

1. Introduction

The Tonkin snub-nosed monkey (TSNM) *Rhinopithecus avunculus* is one of the 25 most endangered primates in the world (IUCN: http://www.primate-sg.org/T25full07.htm). The TSNM is only found in a small area in Northern Vietnam where it is endemic. This species was named by Dollman in 1912, and in 1986, the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) has considered be extinct (*Mittermeier and Cheney, 1986*). But in 1992, a population of TSNM was rediscovered in Na Hang district, Tuyen Quang province of Vietnam. In 2002, one more population has been found in Du Gia Reserve (Ha Giang province). In April 2008, scientist of Fauna and Flora International (FFI) discovered a population in Northwestern Vietnam. Thus, the number of TSNM individuals all over the world has been up to 250. This species is Critically Endangered in UNCN's Red List and Endangered in Vietnam Red List. Nowadays, it mostly endangered by losing habitat while the forest area is decreasing because of economic development in Vietnam.

Environmental niche modeling (so called ecological niche modeling) is defined as the process of using computer algorithms to generate predictive maps of species distributions in geographic space on the basis of a mathematical representation of the collected distribution data in environmental space, utilizing summarized spatial data of the environmental parameters considered in the model (such as temperature, altitude, and precipitation). BIOCLIM is one of such models, it can be used to analyze and estimate the distribution of living species – animal or plant species or vegetation type – that is influenced by climate. BIOCLIM requires climate surfaces that are used to produce site-specific estimates of monthly temperature and precipitation for places where the entity has been recorded. The climate estimation are aggregated into a 'climate profile', using parameters that are indicative of annual mean, seasonal and monthly extreme value (*Andrew S., 2003*).

Figure 1: Vietnam and Indochina countries

This study used BIOCLIM model, which is embeded in DIVA-GIS, to generate predictive distribution maps of *Rhinopithecus avunculus* in the Northeastern of Vietnam in current and future climate conditions. DIVA-GIS is provided "as is" from http://diva-gis.org. The climate surfaces used in this study is the interpolated data from the observed monthly data all over the world of WorldClim – Global Climate Data (http://www.worldclim.org). The future climate condition is result of CCM3 model, also available at WorldClim. We used the collected data of *Rhinopithecus avunculus* in the Northeastern of Vietnam from 1960s to 2008 as "presence" data for mapping the predictive distribution.

2. Theoretical and technical issues

2.1 Approach 1. Data for mapping the predictive distribution

Base map of Northeastern Vietnam includes 3 layers: Province, District and Commune. These data is derived from Project of Using Geographic Information System for natural resources management and environmental monitoring by Ministry of Science, Technology and Environment of Viet Nam (now is Ministry of Natural Resources and Environment).

Climate data of study area is layers that summarized the climate conditions, including 5 variables (i.e. monthly average mean temperature, maximum temperature, minimum temperature (^{o}C), monthly precipitation and altitude, in meter, above sea level). Climate files (in CLM format) and 19 bioclimatic variables are derived from these data to be used in DIVA-GIS.

Distribution data of Tonkin snub-nosed monkey has been gathered from many different observations in history then be digitalized by conventional GIS software as MapInfo Professional and ArcGIS.

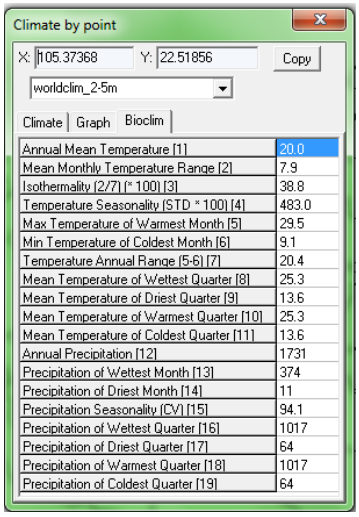

Figure 2: Bioclimatic variables at an observed location in Northeastern of Vietnam

2.2 Approach 2. Environmental niche modeling and its applications

Environmental niche modeling (alternatively known as ecological niche modeling) is used to generate predictive maps of species distributions in geographic space, base on the environmental parameters (such as pollutant concentration, temperature, altitude, wind speed, etc.) and the observed distribution data.
The application of this model includes interpolating between limited available data records; studying the divergence between potential and actual distributions (e.g., the potential spread of invasive species once introduced to a new area, or the area once occupied by a species prior to exploitation by humans); as well as possible alterations to species ranges in the light of climate change or other factors. The extent to which such modeled data reflect the real distributions of species depends on a number of factors, such as the complexity and accuracy of the models used and the quality of environmental data layers; the availability of sufficient and reliable species distribution data as model input; and the influence of other factors such as barriers to dispersion, geologic history, or competing species, that may affect on present day occupation of all potential niches which has identified by the model. Environmental niche modeling may be considered a part of the discipline of biodiversity informatics, or alternatively an end user of the species distribution data that is one output of biodiversity informatics activities.

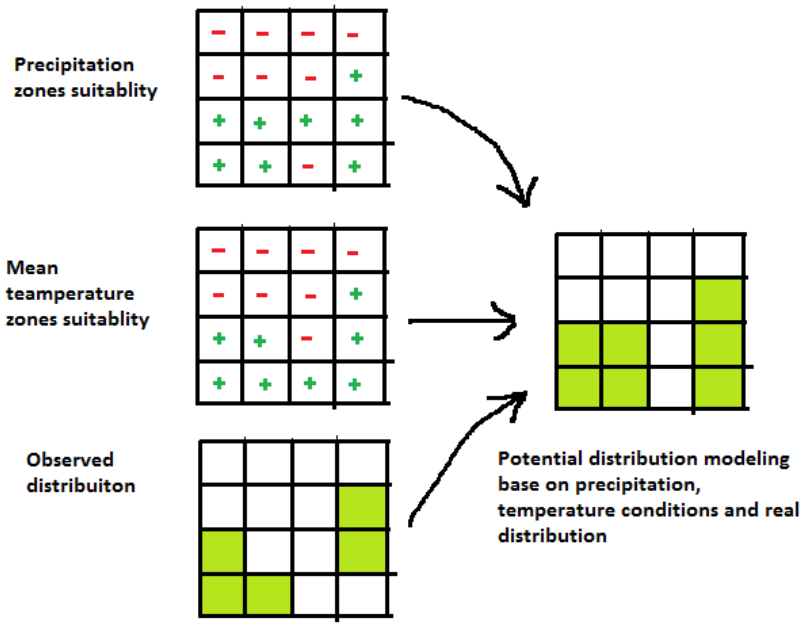

Figure 1: An example of environmental niche modeling with 2 climate variables and observed distribution of species

2.3 Approach 3. DIVA-GIS and its capabilities to generate predictive distribution maps

DIVA-GIS is a computer program for mapping and analyzing spatial data. It is particularly useful for analyzing the distribution of creature to demonstrate geographic and ecological patterns. It is aimed at persons who cannot afford generic commercial geographic information system (GIS) software, or do not have the time to learn how to use these, and for anyone else who wants a GIS tailor-made to analyze biological distributions.

DIVA-GIS supports vector (point, line, polygon), raster and other grid data types. It can help improve data quality by finding the coordinates of localities using gazetteers, and by checking existing coordinates using overlays (spatial queries) of the collection sites and administrative boundary databases. Distribution maps can then be made. DIVA-GIS can also extract climate data for all locations on land.

Environmental niche modeling can be carried out using the BIOCLIM and DOMAIN algorithms. On other word, DIVA-GIS is the program that integrates GIS analysis and environmental niche modeling technique. Therefore, it is very good tool for modeling and mapping the distribution data.

3. Using environmental niche model to generate the predictive distribution of Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Northeastern of Vietnam under current and future climate conditions

3.1 Overview

The studied objective of this paper is Tonkin snub-nosed monkey (*Rhinopithecus avunculus*), with the following taxonomy (*Groves, Colin 2001*)

Order	Primate
Sub-order	Haplorrhini
Infra-order	Eumiiformes
	Catarrhini
Super-family	Cercopithecioidea
Family	Cercopithecidae
Sub-family	Colobinae
Genus	*Rhinopithecus* Milne-Edwards, 1872
Species	*Rhinopithecus avunculus* Dollman, 1912

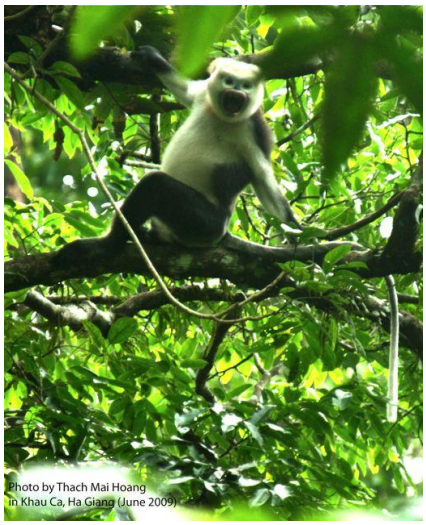

Figure 2: Tonkin snub-nosed monkey (TSNM) Rhinopithecus avunculus in Vietnam

Table 1. Size and weight of Tonkin snub-nosed monkey (Nhat, P. 1993)

Index	Male	Female	Average
Length (body and head) (L) (mm)	658.33	520.00	561.50
Length of tail (T) (mm)	823.00	685.71	726.90
Length of hind foot (HF) (mm)	217.67	173.29	186.60
Height of ear (A) (mm)	44.00	28.00	32.80
Weight (W) (kg)	14.90	7.90	10.20

The TSNM is classified as Critically Endangered (CR) on the 2007 IUCN's Red List of Threatened Species and listed on Appendix I of CITES. In Vietnam Red Book, it classified as Endangered (E).

3.2 The collected historical data of TSN monkey in the Northeastern of Vietnam

The Tonkin snub-nosed monkey distribution data used in this study includes many records of observations from 1960s to present. We prepared a data set with 42 records of 42 observations of many collectors (even unknown collectors). The data set includes 3 periods of observations: 1960s, 1990s and in 2008.

Figure 3: Map of Rhinoithecus avunculus specimens collected in 1960s, 1990s and 2008

3.3 Predictive distribution of Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Northeastern of Vietnam

We used the BIOCLIM models which is integrated in DIVA-GIS to calculate the potential distribution of *Rhinopithecus avunculus*.

The 30-second resolution climate data has been transformed into CLM files. We used 2 types of climate data:

- The current data (represent climate condition in the period of 1950-2000) and
- The future data (represent climate condition derived from global climate model with scenario of IPCC's Third Assessment Report, 2000).

These climate data were downloaded (free for academic purposes) and then processed by ArcGIS 9.2 and DIVA-GIS 7.1 to form in CLM format that can be used for modeling.

The potential distribution is divided into 6 levels: Excellent, Very high, High, Medium, Low and Not suitable

Under current climate condition, the result shows that the potential distribution area of *Rhinopithecus avunculus* covers the Northeastern provinces of Vietnam, except a small area in the Northwestern (Yen Bai province). It is because of one specimen was observed by Collin Groves in Yen Bai province in 1970. Moreover, the distribution area reaches to Vietnamese-Chinese frontier.

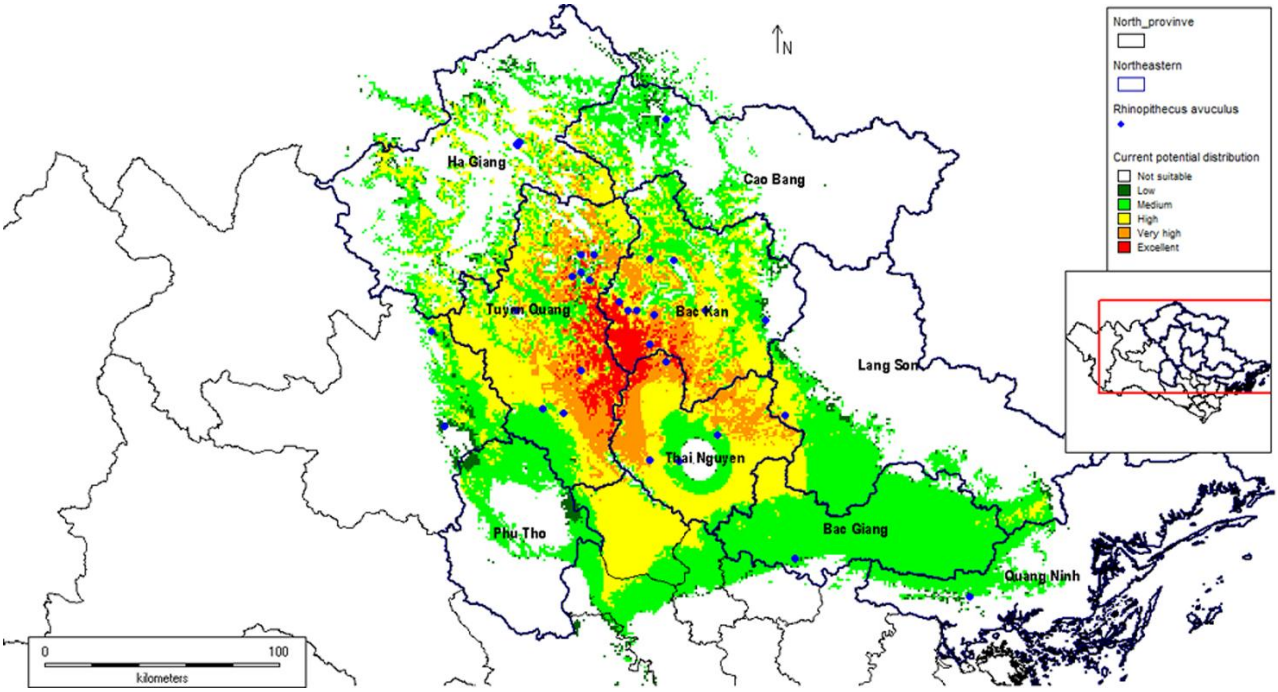

Figure 4: Predictive map of potential distribution of Tonkin snub-nosed monkey under current climate condition

The High potention distribution area for the TSNM mainly covers the provinces of Tuyen Quang, Thai Nguyen and Bac Kan. The Excellent potention distribution area (red) located on the border among the provinces of Tuyen Quang, Bac Kan and Thai Nguyen. Total area is 36,806km^2.

The potential distribution map suggests that, this area might have populations of Tonkin snub-nosed monkey, because of the suitable climate condition. The potential distribution map helps to define the area of field study to discover and conserve this endemic species.

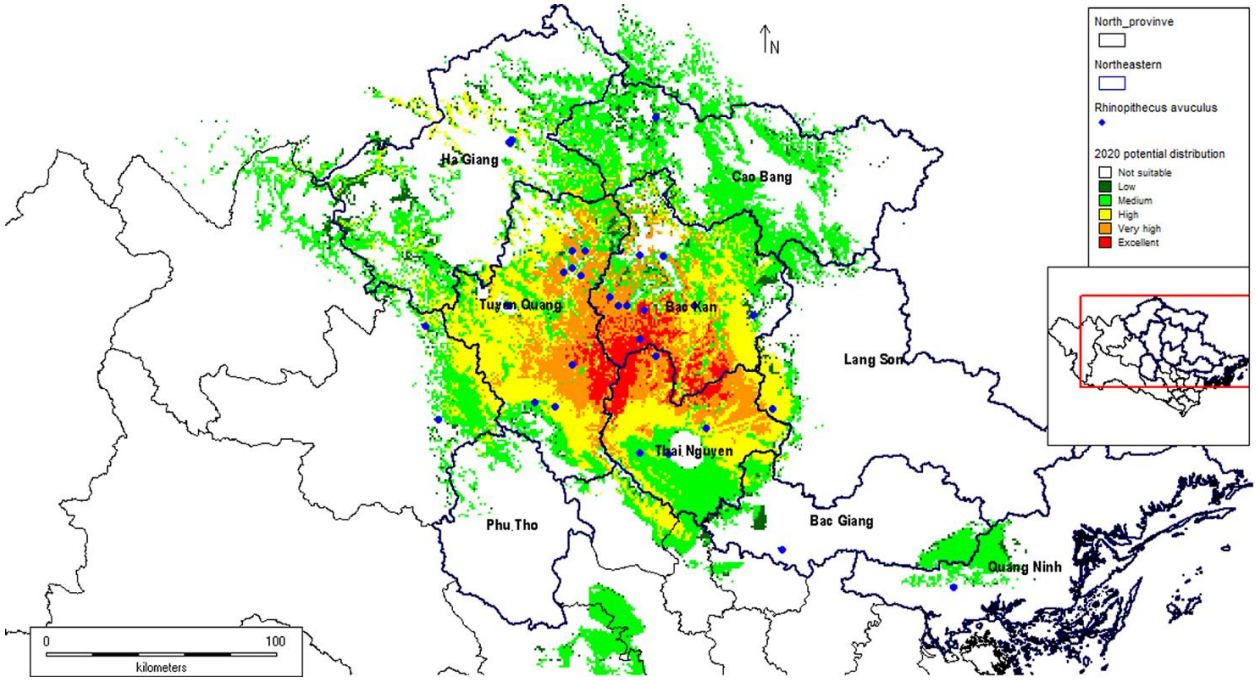

Figure 5: Predictive map of potential distribution of Tonkin snub-nosed monkey under climate condition of the year 2020

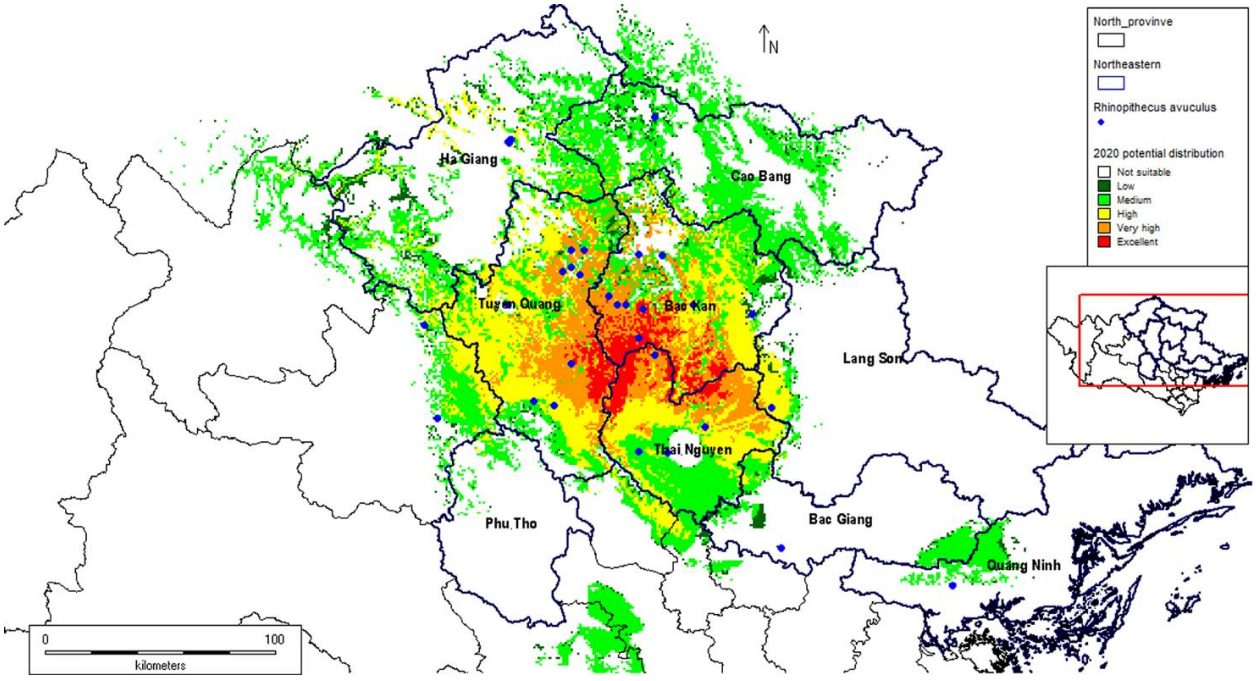

Figure 6: Predictive map of potential distribution of Tonkin snub-nosed monkey under climate condition of the year 2050

Under climate change scenarios, the model results showed that the distribution area is narrowed and shifted to Northward (Figure 7). By 2020, most of these areas are downgrade to a lower level. A number of distribution areas in the South had completely disappeared (eg. area in Low potention distribution level in Bac Giang province). The potention distribution area is 29.614km^2, 20% less than current climate condition. Under the same climate model for A2 scenario, we have map of potential distribution of TSNM by the year 2050 (Figure 8) with the approximated area.

Table 2: Detail changes of potential distribution between two climate condition

Area (km^2) / Level	Current (1950-2000)	Future (2000-2020)	Change
Excellent	1,334	1,422	+7%
Very High	3,586	4,136	+15%
High	12,205	7,740	-37%
Medium	18,393	14,350	-22%
Low	1,288	1,966	+53%
Total	**36,806**	**29,614**	**-20%**

Table 2 showed that the most decreasing area is High and Medium areas (37% and 22% respectively) while the Low area rose by 53%. The Excellent and Very high areas also increased, but not significantly.
Compare the changes between Figure 6 and Figure 7, we can see that the potention distribution area in future trends is narrower and move to the North. Almost of the levels is narrowed and downgraded into lower level. Some of potention distribution areas in the South are disappeared.
The reason of this situation is climate change and global warming which caused by increasing CO_2 concentration in the atmosphere. Tonkin snub-nosed monkey prefer to live in the cool areas. Moreover, this species is an herbivore, so their life depends on the vegetation situation. Besides losing habitat caused by development actions of people, the global warming is a very serious risk for this species existence.
This such trends may be considered that have been happened in the past, while in the previous reports, Ha Giang was not considered as the distribution area of TSNM (*Quyet, 2008*), but in 2001, 2004 and 2 surveys in 2007 and 2008, scientists of FFI and Hanoi University of Science have discovered TSNM populations in Quan Ba and Khau Ca district (Ha Giang province) (*Quyet, 2008; Hoang, 2001*). This may be the trend of distribution area change under climate change influences in 50 years.
In addition, the potential distribution now has many discrete areas, not focus. Large and focus areas are little. Therefore, even though the area is not reduced too much but the useful distribution areas for the TSNM are very limited. This is a disadvantage for planning protected areas for TSNM.
However, we can see that the specimens collected in history are not totally match with the Excellent area. Among of many reasons, we mention a most important reason, in our point of view: the distribution depends on what land-use of that grid cell is. As we said, the life of Tonkin snub-nosed monkey is completely related with vegetation (i.e. forest), and the vegetation distribution depends on pedology characteristics. Therefore, we must compare this map with land-use map for a best result.

4. Conclusion

In previous studies, environmental niche modeling has proved to be a powerful tool for studying on the lower animals, which life depends on climate totally. In this study, with a primate animal, we made effort to use environmental niche modeling for a species which is influenced directly and indirectly by climate conditions. The result shows that the distribution area of Tonkin snub-nosed monkey is mostly in the Nor-

theastern Vietnam. This is confirmed by previous studies on ecological characteristics of this species. It suggests that the BIOCLIM model can be applied to higher animals such as mammals, birds, etc.
This is very meaningful because it helps managers to define the area for making field study, contributing reserve plan for threatened species. It also makes an overview about response of species when the climate conditions changed in the future. We can study on the change in distribution range of species, and compare with land-use and planning map to understand what we must do to protect that species from harmful effect of human development actions.
However, as we know, the life of higher animals does not completely depend on climate conditions. It also depends on many other non-niche factors such as the complexity of the model (i.e. the number of variable used in model), or competing species. Our study also has some problem in the result that cannot be explained only by using bioclimatic variables. Therefore, it is necessary to establish more appropriate model for studying potential distribution of higher animals.

5. Literature

Andrew Skidmore (2003) (reprinted): Environmental modeling with GIS and remote sensing, Taylor & Francis, London.

DIVA-GIS, Internet: http://www.diva-gis.org, last access: 30.04.2010.

Dollman, G. (1912), A new snub-nosed monkey. *Proceedings of the Zoological Society of London 1912* Abstr. 106, p.18; Proc., pp. 503-504

Groves, Colin P. Primate Taxonomy. Washington DC: Smithsonian Institute Press, 2001.

Hoang, T.M (2001): History of research on Tonkin snub-nosed monkeys in Vietnam and an analysis of their daily ranging behavior in Khau Ca, Ha Giang province, University of Colorado at Boulder.

IUCN/SSC Primate Specialist Group, Internet: http://www.primate-sg.org/T25full07.htm, last access: 30.4.2010

Mittermeier, R. A., Cheney, D. L. (1986), Conservation of primates and their habitats, pp 477-490, in Smuts, B. B., Cheney, D. L., Seyfarth, R. M., Wrangham, R. W., Strusaker, T. T. (eds.): Primate Societies. Chicago, University of Chicago Press .

Mittermeier, R. A. et al.: Primates in Peril: The World's 25 Most Endangered Primates, 2006 – 2008

Nhat, P. (1993): Contribute to studies on primate animal and morphological characteristics, biology, ecology of Rhesus monkey (Macaca mulatta Zimmerman, 1780), Stump-tailed macaque (Macaca arctoides Geoffroy, 1831), Red-shanked douc (Pygathrix nemaeus nemaeus Linnaeus, 1771) and Tonkin snub-nosed monkeys (Rhinopithecus avunculus, Dollman, 1912) in Vietnam, Doctorate Dissertation of Biology.

Quyet, L.K (2008): Summary report on surveys of Tonkin Snub-nosed Monkey (Rhinopithecus avunculus) and other primates in Ha Giang province in 2007. Fauna and Flora International – Vietnam Conservation Support Programme.

Robert J. Hijmans et al. (2005): DIVA-GIS 5.2 Manual.

The IUCN Red List of Threatened Species 2010.1, Internet: http://www.iucnredlist.org/, last access: 30.4.2010

WorldClim, Internet: http://worldclim.org, last access: 30.4.2010

Ren, R. M., Kirkpatrick, R. C., Jablonski, N. G.,Bleisch, W. V. and Le Xuan Canh (1997): Conservation status and prospects for the snub-nosed langurs (Colobinae: Rhinopithecus). Primate Conservation 17: 152-159.