ISSN 0126-1754
Volume 11 Nomor 1, April 2012
Terakreditasi Peringkat A
SK Kepala LIPI
Nomor 180/AU1/P2MBI/08/2009

LIPI

Berita Biologi

Jurnal Ilmu-ilmu Hayati

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Pusat Penelitian Biologi–LIPI
Kompleks Cibinong Science Center (CSC-LIPI)
Jln Raya Jakarta-Bogor Km 46,
Cibinong 16911, Bogor - Indonesia
Telepon (021) 8765066 - 8765067
Faksimili (021) 8765059
e-mail: berita.biologi@mail.lipi.go.id
ksama_p2biologi@yahoo.com
herbogor@indo.net.id

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i. Jurnal

Premachandra GS, H Saneko, K Fujita and S Ogata. 1992. Leaf Water Relations, Osmotic Adjustment, Cell Membrane Stability, Epicuticular Wax Load and Growth as Affected by Increasing Water Deficits in Sorghum. *Journal of Experimental Botany* **43,** 1559-1576.

ii. Buku

Kramer PJ. 1983. *Plant Water Relationship*, 76. Academic, New York.

iii. Prosiding atau hasil Simposium/Seminar/Lokakarya dan sebagainya

Hamzah MS dan SA Yusuf. 1995. Pengamatan Beberapa Aspek Biologi Sotong Buluh *(Sepioteuthis lessoniana)* di Sekitar Perairan Pantai Wokam Bagian Barat, Kepulauan Aru, Maluku Tenggara. *Prosiding Seminar Nasional Biologi XI,* Ujung Pandang 20-21 Juli 1993. M Hasan, A Mattimu, JG Nelwan dan M Litaay (Penyunting), 769-777. Perhimpunan Biologi Indonesia.

iv. Makalah sebagai bagian dari buku

Leegood RC and DA Walker. 1993. Chloroplast and Protoplast. In: *Photosynthesis and Production in a Changing Environment.* DO Hall, JMO Scurlock, HR Bohlar Nordenkampf, RC Leegood and SP Long (Eds), 268-282. Champman and Hall. London.

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SPATIAL MODEL OF SUMATRAN TIGER (*Panthera tigris sumatrae*) POTENTIAL HABITAT SUITABILITY IN BUKIT BARISAN SELATAN NATIONAL PARK, INDONESIA*
[Model Spasial Kesesuaian Habitat Harimau Sumatra (*Panthera tigris sumatrae*) di Taman Nasional Bukit Barisan Selatan, Indonesia]

Suyadi[1,2✉ε] **, I Nengah Surati Jaya**[3]**, Antonius B Wijanarto**[4] **and Haryo Tabah Wibisono**[5]
[1]MSc in IT for NRM, Bogor Agricultural University; [2]UPT Balai Konservasi Biota Laut, Ambon, Indonesian Institute of Sciences (LIPI); [3]Laboratory of forest resources inventory, Bogor Agricultural University (IPB); [4]National Coordination Agency of Surveys and Mapping (BAKOSURTANAL); [5]Wildlife Conservation Society – Indonesia Program (WCS-IP). Alam Tirta Lestari, Jln Anthorium No 3, Ciomas, Bogor.
[ε]*e*-mail: yadi_pdt@yahoo.com; suya009@lipi.go.id

ABSTRAK
Studi ini menerangkan tentang model spasial kesesuaian habitat potensial harimau di Taman Nasional Bukit Barisan Selatan (TNBBS). Studi menghubungkan penginderaan jauh dengan survei harimau sumatra dan satwa mangsanya yang di kumpulkan menggunakan teknologi kamera-trap untuk mengidentifikasi faktor-faktor lingkungan dan faktor manusia yang berpengaruh secara nyata terhadap habitat potensial harimau dan untuk membangun sebuah model spasial kesesuaian habitat potensial harimau di TNBBS. Hasil studi menunjukan bahwa model spasial untuk memperkirakan kesesuaian habitat potensial harimau sumatra di TNBBS dapat dibangun menggunakan faktor-faktor lingkungan dan manusia. Faktor-faktor yang paling berpengaruh terhadap kesesuaian habitat harimau di TNBBS adalah faktor-faktor manusia seperti jarak dari jalan dan jarak dari tepian area deforestasi (hutan yang gundul) dan faktor lingkungan yakni jumlah satwa mangsa harimau. Hasil verifikasi model menunjukan bahwa model spasial ini dapat memperkirakan probabilitas kehadiran harimau dengan tingkat akurasi ± 78%. Hasil verifikasi model juga menunjukan bahwa data prediksi tidak berbeda nyata dengan data aktual dan memiliki sisaan rata-rata kurang dari 10%.

Kata kunci: Kesesuaian habitat potensial, harimau sumatra, pemodelan spasial, camera trap, Taman Nasional Bukit Barisan Selatan.

ABSTRACT
This study describes on development of habitat suitability for Sumatran tiger in Bukit Barisan Selatan National Park (BBSNP). In this study remotely-sensed data set were linked with tiger and it prey survey using camera trap to identify the environmental and human factors that influences the tiger's potential habitat, and to develop a spatial model as well as in BBSNP. All at once, the study showed that the potential model for estimating the tiger's potential habitat suitability could be developed using environmental and human factors. The most significant factors that influence the tiger habitat suitability in Bukit Barisan Selatan National Park are human factors such as distance to road and distance to forest edge and the environmental factor i.e. the number of tiger prey. The verification of the model shows that the model is capable to estimate the probability of the tiger presence having accuracy of approximately 78%. The model shows that there is no significant difference between the predicted data and actual data and having mean deviation less than 10%.

Key words: Potential habitat suitability, sumatran tiger, spatial modeling, camera trap, Bukit Barisan Selatan National Park.

INTRODUCTION

The sumatran tiger (*Panthera tigris sumatrae*) is the only one of three subspecies of tigers remaining in Indonesia. The other subspecies, the Javan subspecies (*P. t. sondaica*) and the Bali subspecies (*P. t. balica*) have gone extinct. The tiger is often considered a key species in Asian land-use plans aimed at conservation, restoration of degraded lands, and sustainable natural resource use and has also been used as a charismatic flagship species for protection of biodiversity. Today, Sumatran tigers have been classified as Critically Endangered on the IUCN 2006 Red List of Threatened Animals and as Appendix I under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. The Sumatran tiger is also protected under the Act No.5 of the Republic of Indonesia (1990) concerning the Conservation of Biological Resources and their Ecosystems (UU No. 5 Tahun 1990 Tentang Konservasi Sumberdaya Alam Hayati dan Ekosistemnya).

Populations of Sumatran tigers have declined throughout their range from about 1,000 in 1978 (Borner, 1978) to 400-500 total individuals in 1992 (Tilson *et al*., 1994). A study conducted by the Wildlife Conservation Society (WCS) between 1998

*Diterima: 19 September 2011 - Disetujui: 10 Januari 2012

and 1999 estimated that the tiger density in BBSNP was 1.7 individuals/100 km^2. The population of tigers in BBSNP declined from 68 in 1992 (Tilson *et al*., 1994) to 40~43 animals in 1999 (O'Brien *et al*., 2003). The most recent estimate of tiger population size in BBSNP is 12~30 individuals (Wibisono, 2006). An investigation of the illegal killing of tigers in BBSNP and its vicinity revealed that 8~12 tigers were killed annually from 1997–2000 (O'Brien *et al*., 2003). Currently, Sumatran tigers persist in isolated population throughout Sumatra including BBSNP.

Bukit Barisan Selatan National Park is an important area for supporting populations of Sumatran tigers and has been identified by the WCS and the World Wildlife Fund (WWF) as a high-priority tiger conservation area (TCU I = Tiger Conservation Unit I) for tropical moist evergreen forest in Southeast Asia (Wikramanayake *et al*., 1998). In addition, the park has been declared a World Heritage site (decision 28COM 14B.5) by UNESCO. The greatest threats for Sumatran tigers in BBSNP are hunting pressure, habitat loss caused by deforestation and fragmentation caused by road development. Forest cover of BBSNP has declined dramatically and deforestation has become one of the greatest threats to the preservation of Sumatran tiger habitat. Nearly half (344,409 ha) of BBSNP's forest was cleared from 1972 to 2002 (Gaveau *et al*., 2007). Kinnaird *et al*. (2003) predicted that in 2010, 70% of BBSNP would be agricultural lands or village enclaves and that in 2036 all lowland forest in BBSNP will have disappeared. One of the implications of deforestation in BBSNP is the increase in peripheral forest along the forest edge; this is problematic because tigers tend avoid peripheral forest (Kinnaird *et al*., 2003).

The UNFCCC (2007) declared that the international community faces the urgent task of reducing tropical deforestation as one of a suite of strategies to maintain biological diversity. Recently, deforestation in Sumatra (including in BBSNP) has attracted global attention because BBSNP contains extensive biodiversity-rich lowland forests. The combination of tiger poaching, over-hunting of tiger prey, habitat destruction, and habitat fragmentation has increased the threats to the survival of tigers in BBSNP. Much international attention is being paid to the threats of tiger poaching to over-hunting of tiger prey and to the Sumatran tiger. On other hand, habitat destruction and availability of suitable habitat is paid less attention (especially in BBSNP) but may actually have a greater effect on the viability of tiger populations. Conservation biologists believe that habitat loss in BBSNP constitutes one of the greatest threats to the population of Sumatran tigers. The original cause of the decline of Sumatran tigers was the accelerated destruction of their natural habitat (Dinerstein *et al*., 1997). Schneider (2001) explains that total habitat area and degree of fragmentation are often good predictors of wildlife abundance. However, the suitability of potential tiger habitat in BBSNP has not been adequately assessed.

Actually, conservation biologists have begun to respond to the threat of habitat loss by developing an array of tools for measuring and monitoring habitat loss, many of which use remotely-sensed data. However, many factors related to habitat loss cannot be measured using satellite sensor (Turner *et al*., 2001). For example, we need to link remote sensing analyses with wildlife survey analyses in order to assess the suitability of potential tiger habitat.

Here, remotely-sensed were linked with wildlife surveys (carried out using camera traps) to identify the ecological variables which influence to the tiger potential habitat significantly and to develop a spatial model of the suitability of potential tiger habitat. The results of the study provide important information that will allow BBSNP authorities to better manage tiger habitat and to promote conservation of BBSNP.

METHODOLOGY

Bukit Barisan Selatan National Park, the third-largest protected area (3,568 km^2) in Sumatra, Indonesia. A part of BBSNP belongs to the Provinces of Lampung and Bengkulu. The park extends

150 km along the Bukit Barisan Mountain, and contains diverse topography that ranges from coastline in the south to mountainous forest in the north. The park is narrow in shape, with a perimeter longer than 700 km in length, and is bordered by villages and agriculture. Poaching and encroachment for logging and agriculture are rife. Despite these problems, BBSNP remains an important refuge for Sumatran tigers.

The study was performed using long-term camera trap surveys of large mammals from the Wildlife Conservation Society. Five periods of large mammal surveys were conducted from September 1998 to July 2006 in BBSNP using passive infrared camera traps (Camtrakers South Inc., Watkinsville, GA 30677). Cameras were placed within 2.0 km x 10 km sampling blocks. There were ten camera sampling blocks: 1) Way Belambangan, 2) Way Paya, 3) Way Pemerihan, 4) Sukaraja, 5) Way Ngaras, 6) Way Marang, 7) Liwa, 8) Rata Agung, 9) Tanjung Iman, and 10) Pulau Beringin.

Models were developed to determine the suitable potential tiger's habitat in BBSNP. Data used in the model are tiger presence (y_1) and tiger density (y_2) from the camera traps and tiger track survey. The models were developed following several steps. First step identified dependent variables i.e. tiger presence and tiger density, second step created environmental and human factors, third step identified the relationship between dependent variables (y) and independent variables (x) and among independent variables, fourth step was multiple regression analyses and model development, and the final step was model verification.

This study used Program CAPTURE (PWCR Software archive) to identify tiger presence and estimate the density of tigers. The tiger's body have unique body stripe pattern that can be used to identify them using capture-recapture methods (Nichols dan Karranth, 2002). In capture-recapture models, abundance estimation requires that the population be closed (Otis *et al.*, 1978) meaning that there is no recruitment (birth or immigration), or loses (death or emigration) during the sampling period.

The environmental and human factors were used in the model did not include all of the ecological variables that affect tigers, as these are complex. Therefore, the variables that were used in the model depended on the data availability that the variables used actually influence tiger habitat suitability. The predicted variables for environmental and human factors are shown in Table 1.

Variable data of elevation and slope are created from the SRTM ASTER Digital Elevation Model (DEM) 30 m. The SRTM ASTER DEM was obtained from the BBSNP office. The BBSNP boundary was obtained from BBSNP office, and corrected in the field with a GPS, by a team from the BBSNP Office, the WCS and the WWF. The other vector data, such as road networks, rivers, rainfall, human-tiger conflict locations, and settlements or villages were assembled from the WCS, Yayasan Badak Indonesia (YABI), and the BBSNP Office.

This study used LANDSAT images to generate maps of land use and land cover. Land use was categorized into four classes: forest, mixed gardens, coffee plantations, and shrubs. Land cover was categorized into forest and non-forest. The variables distance to roads, distance to the BBSNP boundary, distance to rivers, distance to villages, distance to deforested edges, and distance to conflict locations were created by spatial analyses using Euclidean-distance buffering techniques. The total number of all prey and each prey such as argus pheasants (*Argusianus argus*), mouse deer (*Tragulus javanicus* and *Tragulus napu*), muntjacs (*Muntjiacus muntjak*), wild pigs (*Sus sp*), macaques (*Macaca nemestrina*), sambars (*Cervus uniclor*), tapirs (*Tapirius indicus*) were collected from the camera trap and were analyzed using capture-recapture methods.

The habitat suitability model was developed used many independent variables (x) which described in Table 1, as there are may be more than one independent variables that significantly correlates with tiger presence (y_1) and tiger density (y_2). Tiger presence (y_1) is binary data type, i.e., 1 for tiger pres-

Table 1. Environmental and human factors used as independent variables

No.	Variables	Representation
Environmental Factors		
1.	(x_1) Argus pheasant	Prey availability
2.	(x_2) Mouse deer	Prey availability
3.	(x_3) Muntjac	Prey availability
4.	(x_4) Wild pig	Prey availability
5.	(x_5) Macaque	Prey availability
6.	(x_6) Sambar	Prey availability
7.	(x_7) Tapir	Prey availability
8.	(x_8) Total all prey	Prey availability
9.	(x_9) Rainfalls	Environmental component
10.	(x_{10}) Elevation	Environmental component
11.	(x_{11}) Slope	Environmental component
12.	(x_{12}) Landcover	Territory and hunting area
Human Factors		
1.	(x_{13}) Landuse	Territory and hunting area
2.	(x_{14}) Distance to road	Disturbance
3.	(x_{15}) Distance to Park boundary	Protection contribution
4.	(x_{16}) Distance to river	Water supply
5.	(x_{17}) Distance to settlements	Disturbance
6.	(x_{18}) Distance to deforested edge	Disturbance
7.	(x_{19}) Distance to tiger conflicts	Threatening

ence and 0 for tiger absence. The estimation of tiger density (y_2) was determined by the estimated number of tigers divide by the area of the park.

To identify the correlations, either between the dependent variables (y_1 and y_2) and independent variables (x) or among independent variables itself (Table 1), the analysis was done using a correlation test. The purposes of the correlation analysis are to identify the independent variables (x) that have close relationship with tiger presence (y_1) and tiger density (y_2), and to identify the relationship among independent variables (x). The closed relationship ($r > 0.5$) of independent variables (x) with tiger presence (y_1) and tiger density (y_2) selected as predicted variables to predict tiger potential habitat.

The second step in the model development was standardizing the data of selected independent variables (x) which have various units to the independent variables (z) which have normal distribution and more uniform. Standardizing is a dimensionless quantity derived by subtracting the population mean from an individual raw score and then dividing the difference by the standard deviation. The purpose of the standardizing is to less the dimension of the data and it allows comparison of observations from different normal distributions, which is done frequently in research.

The next step is the study using a multiple regression analyses method to predict tiger potential habitat using the standardized selected predicted variables (z). This method was chosen because there are only two possibilities for the dependent variable (y), i.e., 1 for tiger presence and 0 for tiger absence. This analysis does not require a Gauss-Markov assumption to assume that the variables are normally distributed and of homogenous diversity (*homoscedasticity*), as is needed in the multiple regression analyses. In addition, the analysis is valid not only for predictive variables in an interval or ratio scale, but also can be applied to nominal and ordinal scale variables.

The predicted value of the multiple regressions (y_1 and y_2) is a probability value (that varies between 0 and 1); thus the results indicate the probability that an area will be suitable for tiger habitat based on the predicted value. The mathematical form of the model is as follows:

$$y_{1i} = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + ... + \beta_n\chi_n$$

where:

y_{1i} = the probability of suitable tiger habitat at observation point $_{i,}$ based on tiger presence,

β_0 = intercept,

β_n = binary logistic regression coefficient from the predictive variable *n*, and

χ_n = the number of predictive variables *n*.

This model was developed using binary data as mentioned above.

The model for y_2 (tiger density) is mathematically drawn as follows:

$$y_{2i} = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + ... + \beta_n\chi_n$$

where:

y_{2i} = the probability of suitable tiger habitat at observation point $_{i,}$ based on tiger density,

β_0 = intercept,

β_n = binary logistic regression coefficient from the predictive variable *n*, and

χ_n = the number of predictive variables *n*.

The tiger potential habitat suitability model was extrapolated to the study area of BBSNP. The result of the model extrapolation is the probability map of tiger potential habitat and the map of tiger potential habitat suitability in BBSNP based on tiger presence and based on the tiger density. The resolution of the grid for the extrapolated areas is 100 meters x 100 meters.

The model verification is just simply comparing its output variables against measured data. The verification sample plots were chosen randomly using the other survey data of tiger track recorded simultaneously during the study. The number of observation coordinate that used in validation is 50 for location of tiger presence and 50 of tiger absence location. On the basis of the selected model, then verification was performed. The predicted value using the model equation was compared to the actual value that had been collected during ground survey. Observation data is 2 binary data type, i.e., 1 for tiger presence and 0 for tiger absence. The predicted value ranging from 0 to 0.49 was rounded down to 0, while the other was rounded up to 1.m. The verification accuracy was evaluated using simple overall accuracy, χ^2 test and mean deviation (MD). The overall accuracy is commonly acceptable when the accuracy is more than 60%, while the tabulated χ^2 at 95% confident level should be less than $H_0\,\chi^2$ calculation (null hypothesis is accepted). For the mean deviation should be less than 10%.

The hypotheses of the model verification are:

H_0 = the actual and the estimated values are not significant different.

H_1 = the actual and the estimated values are significant different.

The decision rules are as follow:

If $\chi^2 \leq \chi^2_{cal}$. then H_0 is accepted

If $\chi^2 > \chi^2_{cal}$. then H_0 is rejected

where:

$$\chi^2 cal. = \frac{\sum \left(Ti_{(m)} - Ti_{(a)}\right)^2}{Ti_{(a)}}$$

$$MD = \frac{\sum \left(Ti_{(m)} - Ti_{(a)}\right)}{n} x100\%$$

where: *m* = actual, and

i = estimate

RESULTS

The Relationships of Environmental and Human Factors with Tiger

Of the 12 environmental analyzed, the correlation analyses indicates that only several environmental factors that closely correlated with the tiger presence (y_1), namely total number of all prey (r = 0.79, $p < 0.04$), the number of wild pigs (r = 0.79, $p < 0.42$), muntjacs (r = 0.69, $p < 0.01$), tapir (r = 0.66, $p < 0.37$), sambars (r = 0.66, $p < 0.61$), argus pheasants (r = 0.54, $p < 0.97$), mouse deer (r = 0.52, $p < 0.01$), and macaques (r = 0.51, $p < 0.51$). The considered environmental factors that are not significantly correlated with the tiger presence are landcover (r = 0.008, $p < 0.80$), distance to rivers (r = 0.040, $p < 0.23$), rainfall (r = 0.016, p < 0.92), elevation (r = 0.051, $p < 0.06$), and slope (0.046, $p < 0.35$).

The density of tigers (y_2) was positively correlated with the total number of all prey (r = 0.71, $p < 0.03$), the number of wild pigs (r = 0.51, $p < 0.10$), muntjacs (r = 0.60, $p < 0.05$), tapir (r = 0.44, $p < 0.16$), sambars (r = 0.47, $p < 0.14$), argus pheasants (r = 0.30, $p < 0.35$), mouse deer (r = 0.21, $p < 0.01$), and macaques (r = 0.22, $p < 0.48$). The other environmental variables i.e. landcover (r = 0.011, p = 0.72), distance to rivers (r = 0.039, $p < 0.22$), rainfall (r = 0.005, $p < 0.87$), elevation (r = 0.054, $p < 0.13$) and slope (r = 0.002, $p < 0.96$) were not correlated.

From the seven human factors analyzed, the correlation analyses indicates that only distance to roads and distance to deforested edges that closely correlated with the tiger presence having r = 0.77, $p < 0.041$ and r = 0.72, $p < 0.009$ respectively. The distance to roads and distance to deforested edges also closely correlated with tiger density having r of 0.71 ($p < 0.470$) and r of 0.65 ($p < 0.023$). In short, from 19 environmental and human factors were analyzed, there are only distance to roads, distance to deforested edges, and prey availability i.e. the total number of all prey are closely correlated with tiger presence and tiger density.

The total number of all prey was correlated with the number of each prey species: argus pheasants (r = 0.66, $p < 0.03$), mouse deer (r = 0.73, $p < 0.01$), muntjacs (r = 0.74, $p < 0.02$), wild pigs (r = 0.76, $p < 0.01$), macaques (r = 0.77, $p < 0.01$), sambars (r = 0.76, $p < 0.01$), and tapirs (r = 0.52, $p < 0.01$). Since there are close correlation between the total number of all prey and the number of each prey species considered thus the analyses used only the total number of all prey to develop spatial model of tiger habitat suitability.

Spatial Model of Tiger Habitat Suitability

From the correlation analyses described previously, this study found that there are only three environmental and human factors that significantly correlated with tiger presence and tiger density i.e. distance to roads, distance to deforested edges, and the total number of all prey. Thus, the study eliminates insignificant variables and used only these three significant variables as a predictor to establish a spatial model of tiger potential habitat suitability.

The multiple regression analyses indicate that the variables that significantly influence in the tiger habitat suitability based on the tiger presence are distance to roads with coefficient value of 0.006167 and *P-value* of 0.002 (< 0.5%) and distance to deforested edges with coefficient value of 0.010304 and *P -value* of 0.042 (< 0.5%) (Table 2). This finding means that the human activity along the road and forest edge is significant on establishing the model of

Table 2. Regression analyses between total number of all pray, distance to road, and distance to deforested edges with the tiger presence

Variables	**Coefficient**	**SE Coefficient**	**P - value**
Constant	0.02979	0.01474	0.044
Total number of all pray	0.001957	0.001103	0.076
Distance to roads	0.006167	0.001975	0.002
Deforested edges	0.010304	0.005056	0.042

tiger habitat suitability.

The statistically test (Tabel 2) showed that only constant; distance to roads, and distance to deforested edges are significant to predict tiger potential habitat suitability. Although total number of all prey is not significant to predict tiger presence (coefficient value of 0.001957 and *P-value* of 0.042 (> 0.5%)) this predictor variable is still included in the model development because the correlation analyses showed there are close correlation to tiger presence and tiger density. This means that the total number of all prey has also important contribution to predict the tiger potential habitat suitability. This is also in line with Pindyck dan Rubinfeld (1991) that prey availability is important to predict tiger preference. This analysis produces a mathematical form of the tiger potential habitat suitability model:

Model 1:

$$y_1 = 0.0298 + 0.00196x_8 + 0.00617x_{14} + 0.0103x_{18}$$

where: y_1 is tiger presence,

x_8 is the total number of all prey (individual),

x_{14} is the distance to roads (km), and

x_{18} is the distance to deforested edge (km).

The multiple regression analyses indicate that human factors i.e. distance to roads and distance to deforested edge are not only significant to predict tiger presence, but also significantly correlated with tiger density (Table 3) having coefficient value of 0.007431 with *P-value* of 0.007 (< 0.5%) and coefficient of value 0.003931 with *P-value* of 0.010 (< 0.5%) respectively.

This analysis produces a mathematical form of the tiger potential habitat suitability model:

Model 2:

$$y_2 = 0.0474 + 0.0101x_8 + 0.0074x_{14} + 0.0039x_{18}$$

where: y_2 is tiger density,

x_8 is the total number of all prey (individual),

x_{14} is the distance to roads (km), and

x_{18} is the distance to deforested edge (km).

Suitable Habitat for Tiger in Bukit Barisan Selatan National Park

The probability of tiger potential habitat suitability was extrapolated to cover the entire study area (BBSNP). The study produced a map showing the probability of tiger potential habitat suitability based on the tiger presence. There are three class of the probability of tiger potential habitat suitability based on the tiger presence: 1) highly suitable habitat having probability more than or equal to 0.6, 2) suitable habitat having probability ranging from 0.3 to less than 0.6, 3) not suitable habitat having probability less than 0.3 (Figure 1). For simplification, the study reclassifies the probability map (Figure 1) and then produces a map of tiger potential habitat suitability based on the tiger presence (Figure 2). The tiger potential habitat suitability based on tiger pres-

Table 3. Regression Analyses between total number of all pray, distance to road, and distance to deforested edges with tiger density

Variables	Coefficient	SE Coefficient	P - value
Constant	0.02474	0.02040	0.226
Total number of all prey	0.010109	0.006997	0.149
Distance to roads	0.007431	0.002733	0.007
Distance to deforested edges	0.003931	0.001527	0.010

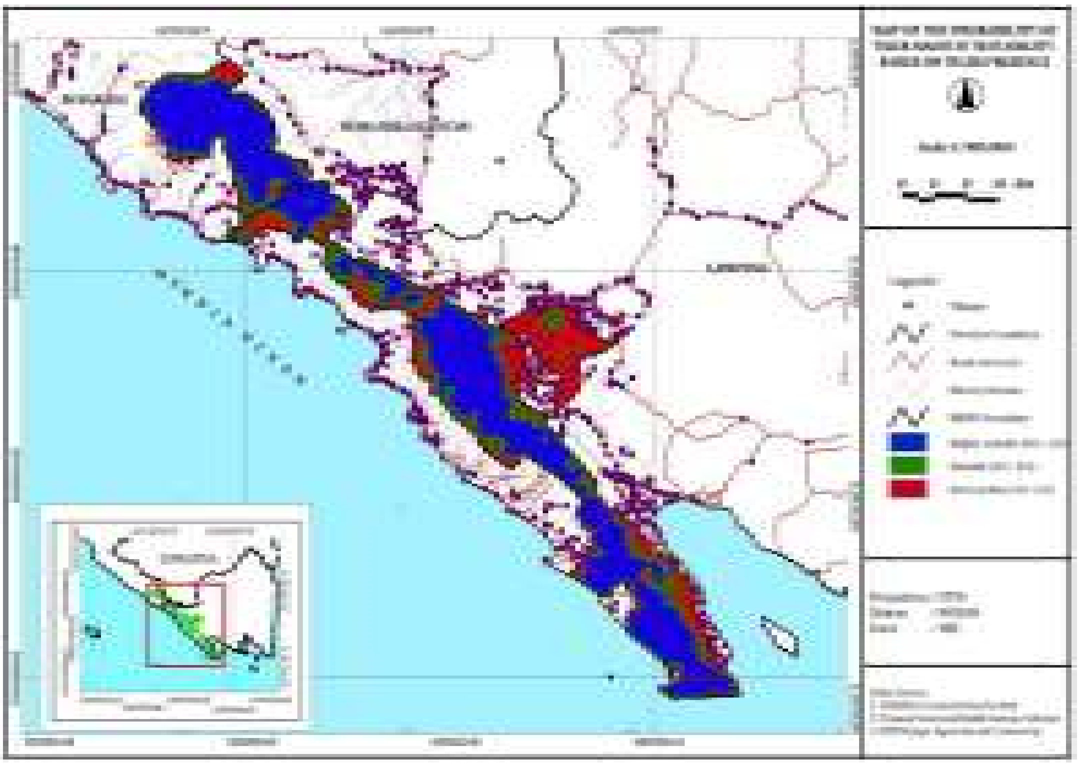

Figure 1. Map of the probability of tiger potential habitat suitability based on tiger presence

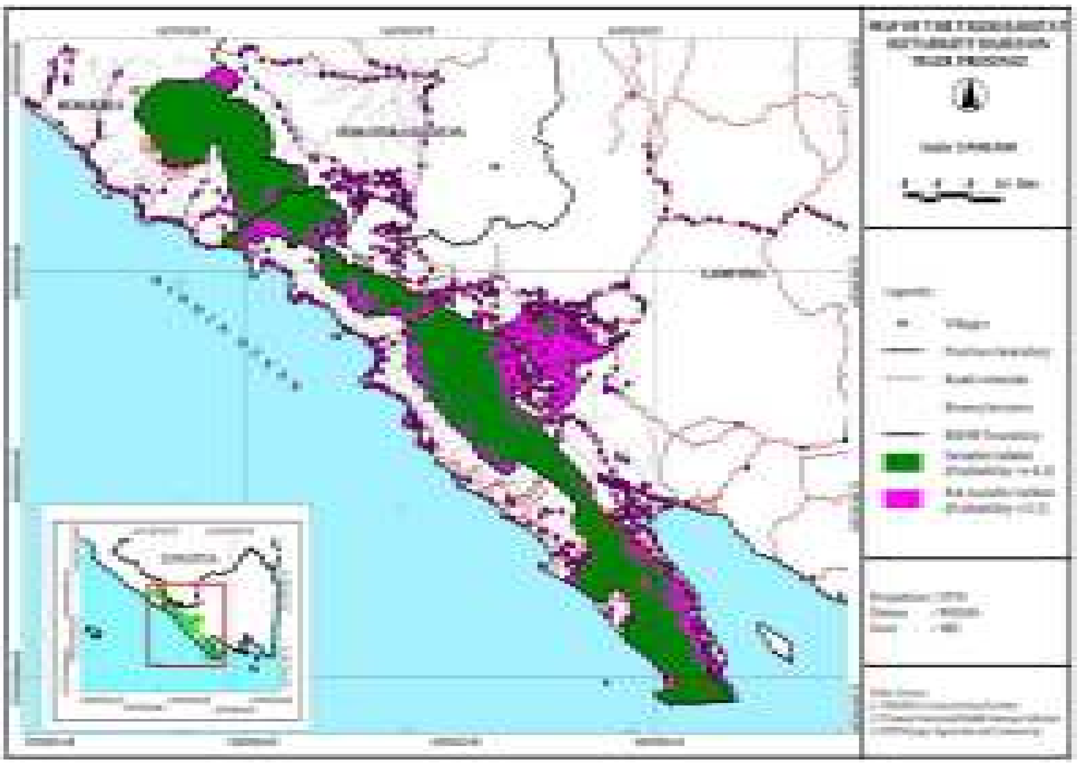

Figure 2. Map of tiger potential habitat suitability based on tiger presence

ence divided into suitable habitat (probability ≥ 0.3) and not suitable area for tiger habitat (probability < 0.3) (Figure 2). The area of suitable tiger habitat is 2467. 78 km^2, represent 76.05% of BBSNP area (3245.07 km^2), and the area of not suitable tiger habitat is 777.29 km^2 represent 23.95%.

For more detail, the study also produced a map showing the probability of tiger potential habitat suitability based on the tiger density (Figure 3). The map of tiger potential habitat based on tiger density reclassified into 3 classes, i.e. (1) highly preferred habitat having tiger density more than or equal 1 individu/100km^2 (10 individu/100,000ha), (2) preferred habitat having tiger density ranging from 0.5 individu/100km^2 (5 individu/100,000ha) to less than 1 individu/100km^2 (10 individu/100,000ha), and (3) less preferred habitat having tiger density less than 0.5 indvidu/100km^2 (5 individu/100,000ha) (Figure 4). Based on the spatial analysis the study found that the highly preferred area covering the area of approximately 1487.07 km^2 represent 45.8% of BBSNP, while the preferred area covering the area about 980.71km^2 (30.2%), and the less preferred area covering the area about 777.29 km^2 represent 23.95% of the Park.

The verification accuracy showed that overall accuracy of the model output is 78% for model 1 (based on tiger presence) and 72% for model 2 (based on tiger density). This means that 78% of the model output is match with verification data. The x^2 test of the model 1 and model 2 is not significantly different ($\chi^2 = 0.046$) and $x^2 = 0.063$, or $\chi^2_{cal.} < \chi^2_{df}$, 1 and 5.6 for model 2 less than <10%. This means that the model is good enough in tiger habitat prediction.

The only one environmental factor that correlated with tiger presence and tiger density is the number of prey included the number of all prey and the number of each prey species: muntjacs, tapir, argus pheasants, mouse deer, and macaques. On other hand, Wibisono (2006) who noted that the only the number of sambars ($r = 0.35$, $p < 0.03$) and the number of wild pigs ($r = 0.30$, $p < 0.060$ were positively correlated with tiger presence. There are many environmental factors do not influent on tiger existence in BBSNP because tigers are considered to be habitat generalist. Schaller (1967) explain that tigers are capable of living in a wide range of environments. Wibisono (2006) explain that although elevation is correlated with tiger presence this relationship may be as a result of deforestation pressure in low elevations, rather than selection of high elevation habitats.

The study showed that distance to roads and distance to deforested edges are significantly correlated with tiger presence and tiger density. This result means that more distance from the road and deforested edge more suitable for tiger habitat. This finding also indicates that tigers prefer use interior forest area as their habitat. Tigers preferentially use interior forest area as avoidance of human activities that reduce forest cover along the forest edge. Kinnaird *et al*. (2003) found that large mammals included tiger in BBSNP tend avoid forest edge to keep away conflict with human.

The spatial model based on the three significance variables (distance to road having coefficient value of 0.007431 with *P-value* of 0.007, distance to deforested edges having coefficient of value 0.003931 with *P-value* of 0.010, and the number of all prey having coefficient of value 0.006997 with *P-value* of 0.226) showed that tigers tend avoid habitat along the deforested edges and roads, but they are capable to survive in its habitats as long as prey is available. This finding is in line with Karanth dan Stith (1999) report where tigers are capable to live in the deforested area such as secondary forest, shrub area, and agricultural area as long as water and their prey are available. Seidensticker *et al*. (1999) also explain that tigers able to live in the habitat of forest and agricultural area as long as sufficient prey is available.

Tiger Habitat Suitability

Regarding to the bio-ecological of tiger, the model describes that the further distance from roads and deforested edges with the higher number of prey

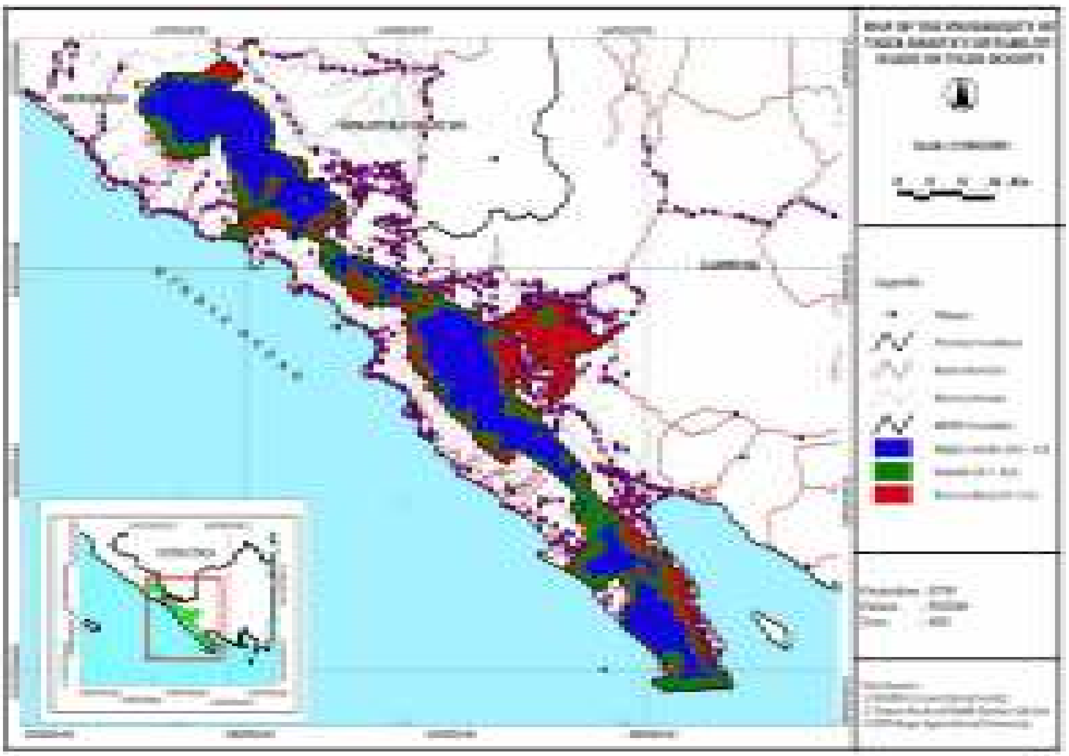

Figure 3. Map of the probability of tiger potential habitat suitability based on tiger density

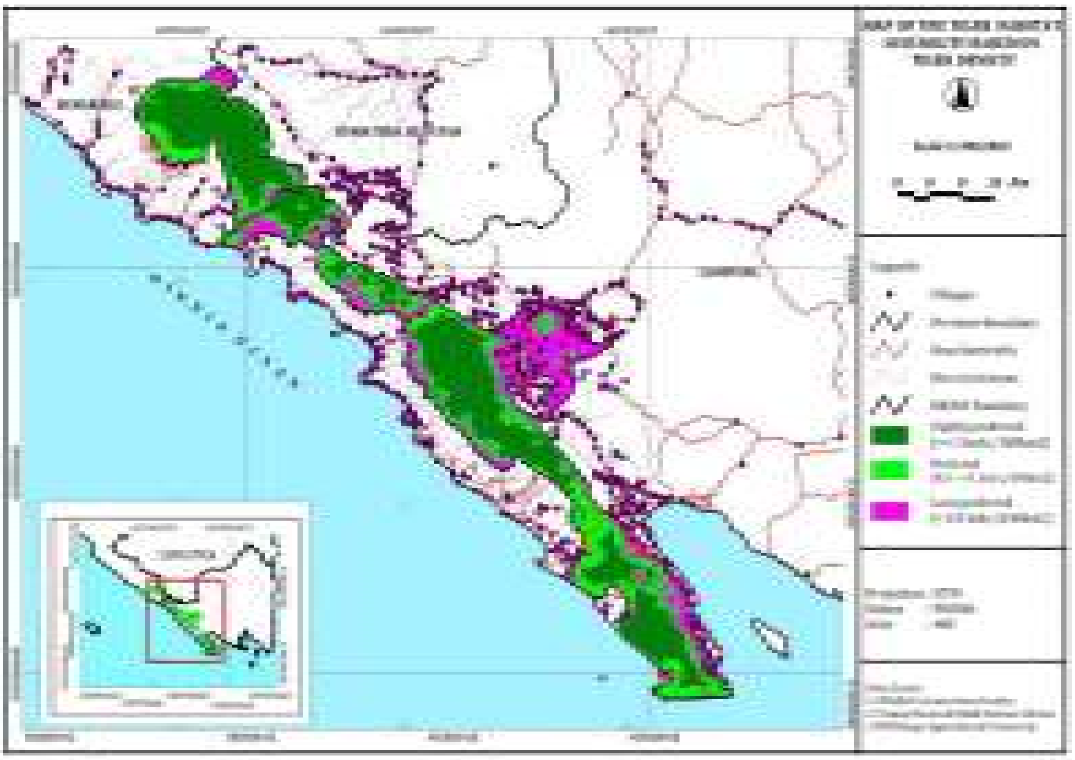

Figure 4. Map of the tiger potential habitat suitability based on tiger density

then the more suitable for tiger potential habitat. Kinnaird *et al*. (2003) found that tiger tend to avoid deforested edge and prefer interior forest. Tiger is sensitive carnivore to habitat disturbance, but they are able continue to survive in the wide range of habitat (Karanth dan Stith, 1999). On the other hand, Wibisono (2006) found tiger also survive in the deforested area outside BBSNP.

The suitable tiger habitat covers all forest types (lowland forest, hill forest, and montane forest), elevation, rainfall, and slopes across BBSNP. This finding is in line with Schaller (1967) and Karanth dan Stith (1999) that tigers are capable of living in a wide range of environments from mangrove forest to montane forest. Tiger recorded able to live in highland of Himalaya (> 4000 m asl), able to survive in the wet area (>10,000mm/year), and dry area (< 500 mm/year) (Karanth dan Stith, 1999).

The suitable habitat covers interior forest area and peripheral forest, but not covers active deforested area. In contrast, the area of not suitable tiger habitat covers active deforested area (Gaveau *et al.*, 2009). For instance, tigers were not presence in the active deforested area of Suoh which in this area deforestation activity is very high, people intensively living in the area and they had expanded in size of their land farming, clear more forest. Seidensticker *et al*. (1999) explain tiger used interior forest as their territory and use peripheral forest as a hunting area, which the number of tiger prey usually high in the peripheral forest.

The verification of the model shows that the model is capable to estimate the probability of the tiger presence having accuracy of approximately 78% and the probability of the tiger density having accuracy of approximately 72%. The model shows that there is no significant difference between the predicted data and actual data and having mean deviation less than 10%.

CONCLUSION

From the foregoing discussion, the following conclusions are derived: The most significant factors that influence the tiger habitat suitability in Bukit Barisan Selatan National Park are human factors such as distance to road and distance to deforested edge and the number of tiger prey. The spatial model for estimating the tiger's potential habitat suitability could be developed using environmental and human factors. The selected model for estimating tiger potential habitat is $y_1 = 0.0298 + 0.00196x_8 + 0.00617x_{14} + 0.0103x_{18}$, while the best model for estimating tiger preference to the tiger potential habitat is $y_2=0.0474+0.0101x_8+0.0074+0.0039x_{18}$.

RECOMMENDATIONS

The BBSNP manager should be considering to covering the entire tiger potential habitat as a core zone of BBSNP. Tiger potential habitat is reasonable to consider as a core zone of the Park because remaining tiger habitat is the last home for tiger in BBSNP and habitat disturbance proven one of the greatest threat of Sumatran tiger.

Tiger habitat management should be focus on the strategic approach such as conserving the remaining tiger potential habitat by focusing on environmental and human factors that influence to the tiger potential habitat suitability.

ACKNOWLEDGEMENTS

This study was supported by the Ford Foundation-International Fellowships Program, the WWF -Russell E Train Education for Nature Program, the Wildlife Conservation Society, the Royal Geographical Society, and Idea Wild. Thank you very much for Dr. Ir. Yanto Santosa DEA, for suggestion and comment. Thanks for Dr. Marion Adeney for English review, Uus Saepul Mukarom, Dr. Augy Syahailatua, Dr. Margaret F. Kinnaird, Dr. Timothy O'Brien and Dr. Noviar Andayani for their significant support.

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