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The Use of Habitat Suitability Index Map for Designing Population Monitoring of Banteng (*Bos javanicus*) in Alas Purwo National Park-East Java-Indonesia

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ABSTRACT

Despite banteng is assigned as conservation priority species and its population is expected to increase by 10% in the wild, systematic and accurate population estimation including in the Alas Purwo National Park has been hampered by incomplete estimation. We studied habitat suitability index (HSI) map model to predict the distribution of banteng in the park as the basis for selecting areas for population monitoring. The presence of banteng was collected from 2007-2012 based on ranger reports in the field, whereas pseudo-absence data were generated randomly. We tested 548 points for Binomial Multiple Logistic Regression analyses and evaluated four different scenarios of habitat factor for predicting the presence of banteng, and compared their Kappa Index of Agreement for validation analysis. The presence of banteng was explained by elevation, distance from the beach/ seashore, distance from water/ rivers and distance from roads. The results from the binomial multiple logistic regression then extrapolated to the whole park and resulted in 8441.93 hectares of high suitability area. For establishing a reliable population estimation of banteng in the park, surveys should focus on four blocks with the total area of 9846.69 hectares, which are combination highly suitable area and some suitable areas.

Keywords: Alas Purwo National Park, binomial multiple logistic regression, banteng conservation, habitat selection, population monitoring.

INTRODUCTION

Banteng (*Bos javanicus* d'Alton 1832) is the second remaining largest mammals after Javan rhino on the Java island, the most densely populated island in the world. Its population has been threatened by many factors, i.e. poaching, predators, habitat destruction and fragmentation in the last century (Pudyatmoko 2004; Timmins *et al*., 2015). The conservation status of this large mammal is Endangered under the current review of IUCN Red List of Threatened Species (Timmins *et al*., 2015) and has been assigned as protected species (Indonesia 1999) and as a high priority species for conservation by Indonesian government (Menteri Kehutanan 2008).

Indonesian government set a target for population increment at 10% for all species conservation priority, including banteng population (Menteri Kehutanan 2008). Thus, to provide an accurate measure of conservation programs, population estimation of banteng is a crucial step as a successful indicator. Recent estimates showed that Banteng populations were distributed in a few protected areas on Java Island, which unfortunately isolation among those protected areas are occurring (Pudyatmoko 2004). Despite many protected areas on Java island play important roles for the last remaining habitat for banteng, accurate information about banteng population and distribution in each protected area is rarely available. The Alas PurwoNational Park (APNP) is one of important habitat for banteng in the southeast corner of the Java island. Population estimation in this park showed a significant reduction from 300-400 individuals in 1993 to 80 individuals in 2002(Pudyatmoko 2004; Timmins *et al*., 2015). However, existing estimation only relied on a concentration count method which has been applied in a single feeding ground of Sadengan in the park, whereas, a large area of the APNP, particularly in the core area, never been surveyed, due to logistical and financial issues. Providing population estimation and monitoring for banteng in the APNP should fit into cost effectiveness consideration. Therefore, an approach for predicting the potential distribution of banteng in the APNP is needed for the basis of establishing population estimation under limited condition.

The closed relationship between the presence of species and habitat attributes have encouraged to use habitat to predict species distribution (Hirzel, Randin, and Guisan 2006; Hirzel and Lay 2008). Predicting the distribution of wildlife can be done using quality or suitability of certain species using habitat factors which affect the density of wildlife, commonly call habitat

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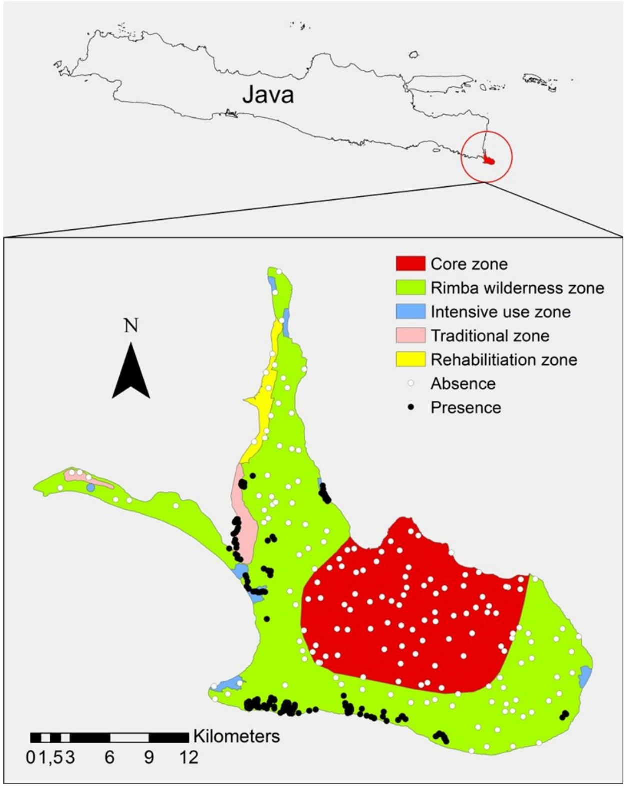

Figure 1. Situation Map of the Alas Purwo National Park in the south-east of Java island and the distribution of presence and pseudo-absence points. The park is home to banteng population. Dots represent presence and pseudo-absence from 70% of total samples. Red dots represent presence data, and white dots are pseudo-absence data.

suitability index (HSI) (M. L. Morrison, Marcot, and Mannan 2006). The HSI map is one of the important approaches to predict the distribution of various birds (Michael A Larson *et al*., 2004; Jacquin *et al*., 2005; Alamets and Pa 2005), lemur (Lahoz-Monfort *et al*. 2010), carnivores (Imam, Kushwaha, and Singh 2009; Xiaofeng *et al*., 2011; LaRue and Nielsen 2008; García-Rangel and Pettorelli 2013), designing landscapes for conservation of bear (Merrill *et al*., 1999), reintroduction of Eurasian lynx (Schadt, Revilla, et al. 2002), and capybara(Schivo *et al*., 2015).

The use of HSI for predicting species distribution is not free from critics due to the wildlife distribution hypothesis (Ray and Burgman 2006; M. L. Morrison, Marcot, and Mannan 2006). However, the limitation can be reduced by the use of empirical data(Singh *et al*., 2009) as well as the use presence-only data (Li, Guo, and Elkan 2011). The use of logistic regression of presence-absence data and presence-only data are commonly used for conservation planning and wildlife management as well as for population viability analysis (Li, Guo, and Elkan 2011; Pearce and Ferrier 2000; M. A. Larson *et al*. 2004). For example, HSI map was used to evaluate the effectiveness of protected areas for mammals in South-east Asia (Catullo *et al*., 2008), and reintroduction of lynx (Schadt, Revilla, *et al*., 2002; Schadt, Knauer, *et al*., 2002). The use of habitat models for developing a reliable plan for conservation measure such as population estimation, however, has rarely been done. The potential distribution of banteng will be useful information for developing a reliable and precise population monitoring. This present study is aiming to seek the best model for the development of habitat suitability index maps for predicting the banteng distribution in the APNP. Secondly, to provide a possible design for population monitoring of banteng in the park. These are expected to contribute to filling the gaps of distribution information of the banteng in the park and support conservation plan, particularly for population estimation and possible habitat management.

MATERIALS AND METHODS

Study sites

The Alas Purwo National Park (APNP) is situated in the southeast corner of Java island, between 8° 26' 45“ - 8° 47' 00“ South and 114° 20’ 16“ - 114° 36’ 00“ East. The total area of the APNP area is 43.420 Ha and divided into the core zone (17,150 ha), wilderness zone (24,207 ha), Rehabilitation zone (620 ha), Intensive use zone (660 ha) and traditional use zone (783 ha). The APNP is one of the important national parks in Java where banteng population has been fluctuating during the last century (Pudyatmoko 2004). Figure 1 shows the situation of the APNP in Southeast Java Island. The APNP has natural and anthropogenic borders, where on the east and south parts have Bali Strait and Indonesian ocean as the border. On the west part of the west and north parts are having a border with local villages and production forest. Ecosystem types of the APNP vary from beach, lowland tropical forest, Karst (limestone forest) with elevation from 0 – 322 m above sea level.

Map preparation

We used six maps for predicting the presence of banteng i.e. slope, elevation, the normalized difference vegetation index (NDVI), distance from the beach (DistBch), distance from roads (DistRoad) and distance from the river (DistRiv). The terrain and elevation map were developed by contour map with 1: 25,000 scale extracted from the terrain map of Indonesia (Peta Rupa Bumi Indonesia) from Badan Informasi Geospasial using Triangulated Irregular Network (TIN) analysis under Arc GIS 10.1 software. We used Landsat 8 Images (downloaded from *http://landsat.usgs.gov*) Path 116 Row 66 on 5 May 2014 (wet season) 12 October 2014 (dry season) to develop the NDVI map. The band 4 and band 5 of the Landsat images were combined with ENVI 4.5 using Band Math with the formula: (float(b5)-float(b4))/(float(b5)+float (b4)). Where b4 is band 4 and b5 is band 5 of the Landsat images. Then the NDVI map was generated using simple formula

$$\frac{band\ 5 - band\ 4}{band\ 5 + band\ 4}$$

The DistRoad, DistRiv and DistBch were extracted from road networks map, rivers and border from the sea respectively. All those maps were originated from the RBI map and then converted into raster and with a resolution of 30m x 30m and used to generate data in each presence and pseudo-absence data.

Presence and Pseudo-absence data collection

The presences of banteng in the field were from reports of rangers during 2008-2012. Since rangers only collected presence data, we did not use the same method for absence data, but pseudo-absence data. Pseudo-absence points were generated randomly within the park area. In total 619 points of both presence and pseudo-absence data were collected. If a pseudo-absence point was too close to a presence data, then the point was excluded for analysis. Finally, we only used 548 points for the HSI map development.

Habitat Suitability Map Development and Validation

For the habitat suitability model development, we used 70% of total points (385 points) for binary logistic regression analysis with the distribution of 212 presence points and 173 pseudo-absence points. All data extracted from raster maps then used as predictors for the presence of banteng. IBM-SPPSS 19 was used to conduct binomial multiple logistic regression (BMLR) using presence and absence data for the response variables. The model from BMLRT is shown as follows.

$$P = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}}$$

P : Binomial proportion

β_2 : second explanatory variable constant

β_0 : model constant

X_n : explanatory variable number n

X_1 : first explanatory variable

β_n : explanatory variable constant number -n

β_1 : first explanatory variable constant

X_2 : second explanatory variable

Since we did not know which NDVI map (either wet or dry season) provide good predictor, we compared the results of the analysis on both dry and wet season data. The spatial model then developed from the results of the best predictor model and extrapolated through all areas in the APNP using Arc GIS 10.1. The model validation used 30% of the total data (162 points) with 79 presence points and 83 absence points. The points then used to calculate the Kappa Index of Agreement – (KIA) for selecting the best model. The best model then used to develop a habitat suitability map of banteng using the Raster Calculator for the whole area of the Alas Purwo National Park. Finally, the results of the map were used to delineate blocks for population monitoring in the park.

RESULTS

Distribution of Presence Points of banteng

Presence points of banteng from 2008-2012 data tended to clump into certain characteristics of the habitat. The distribution of banteng is mostly clumped into the lower area of the APNP, particularly lower than 75 meters above sea level (m-ASL) whereas it avoided the area with higher than 225 m-ASL of elevation. Banteng also sidestepped extreme steep area (> 45% slope) but it possible to occupy from gentle (0-8%) to very strong slope (25-45%). Table 1 shows the distribution of presence of banteng in different predictor variables.

Banteng occupancy showed a clear indication that banteng tended to be near rivers and the sea but did not display clearly to avoid the presence humans (roads).

Table 1. Number of presence points from each predictor variables of banteng in the Alas Purwo National Park from 2008-2012 data.

Predictor Variables	Num. of presence points	Predictor Variables	Num. of presence points
Elevation classes (m-asl)		***Distance from roads (m)***	
< 75	192	0 - 5.000	58
75< - 150	17	5.000 - 10.000	15
150< - 225	3	10.000 - 15.000	112
225< - 300	0	15.000 - 20.000	13
> 300	0	20.000 - 25.000	11
		> 25.000	3
Slope classes (%)		***Distance from sea (m)***	
0 - 8	169	0 - 1500	173
8< - 15	12	1500 - 3000	20
15< - 25	22	3000 - 4500	6
25< - 45	9	4500 - 6000	13
> 45	0	> 6000	0
Distance from River (m)		***NDVI***	
0 - 1000	205	(-0,194) - (-0,0366)	0
1000 - 2000	7	(-0,037) - (0,120)	6
2000 - 3000	0	(0,120) - (0,277)	25
3000 - 4000	0	(0,277) - (0,434)	150
> 4000	0	(0,434) - (0,591)	31

Table 2. Results of the binary logistic analysis of different combination of predictor variables and Kappa Index of Agreement (KIA)

No	Variable	Hosmer and Lemeshow Test	Negelk-erke R Square	Classifica-tion Table	KIA
1	Altitude, distance from beach, NDVI (wet season), distance from river, distance from roads (including path roads)	0,124	0,702	87,0	0,692
2	Altitude, distance from beach, NDVI (wet season), distance from river, distance from roads (only main roads)	0,203	0,704	87,3	0,692
3	Altitude, distance from beach, NDVI (dry season), distance from beach , dist from rivers, distance from roads (+ path roads)	0,097	0,708	88,3	0,717
4	Altitude, dist from beach, NDVI (dry season), dist from beach, dist from rivers, dist from roads (only main roads)	0,061	0,711	89,1	0,729

Banteng preferred to avoid an area with too far distance from the river (> 2 km) and from mineral/salt sources (> 6 km). Although banteng did not show clear evidence of the presence of humans, banteng seems to feel comfortable at a distance 10-15 km of roads. We also found that banteng can be in proximity with human within 5 km (Table 1). Banteng occurrences also indicate that this large mammal on Java could tolerate various dense of vegetation (NDVI) from relatively open to dense vegetation. However, it seems that banteng avoids too dense and too open area (Table 1).

Predictors for the presence of banteng

During the binomial multiple logistic regression analysis, we developed four scenarios to select the best predictor variables. Characteristic of roads and NDVI are the main consideration for the development of scenarios (see the difference in Table 2). All predictor variables have a significant contribution to predicting the presence of banteng in the APNP, except slope. All scenarios have significantly explained the binomial proportion of the presence of banteng (Hosmer and Lemeshow value > 0.05). However, among all scenarios we selected the only model with the highest value of the Negelkerke R square, Classification table and Kappa Index of Agreement (Table 2). Thus, altitude, distance from the beach, NDVI (dry season), distance from the river and distance from the main roads are contributing significantly to the presence of banteng,

The final model from the binomial multi-logistic regression analysis as follow:

$$\frac{1}{1+e^{-(-0{,}045669*altitude)+(0{,}000695*DistBch)+(9{,}856239*NDVI)+(-0{,}001602*DistRiv)+(-0{,}000074*DistRoad)}}$$

Suitability area for banteng

Based on the binomial multi-logistic regression model, we extrapolated the model for the whole area of the APNP. The largest proportion of area with not suitable for banteng was found in the park, and less than half of the size were suitable and highly suitable for banteng (Table 3).). Figure 2 shows the distribution of each class for the best predictor parameters, i.e. elevation, NDVI, distance from the river, distance from roads, distance from the beach and the results of a habitat suitability model for banteng with presence and pseudo-absence validation points. The highly suitable area for the presence of banteng are mainly distributed in the west part of the park (close to the border), and also in the south and southeast area of the park. Only a small portion of the north area and north coast are suitable for banteng (Figure 2).

Table 3. Size and proportion of each suitability class in the Alas Purwo National Park

Suitability Classification	Size (ha)	Proportion (%)
Highly suitable	8441.93	19
Suitable	5347.30	12.03
Not suitable	30646.68	68.97

Population monitoring design

There are four possible different blocks in the park with a high suitability index for the population monitoring (**Figure 3**). In total, we could have less than 10.000 ha for the focus of monitoring of banteng population. The smallest size of the block is 967.74 ha which is situated along the south coast of the APNP. Next, the Sadengan area also has a high suitable area with a total area of population monitoring of 1280.81 hectares, followed by the block on the southeast coast of the park with 2,786.95 hectares. The largest area of population monitoring is distributed from the north to the north-west area in the park with the size of 4811.19 hectares (Table 4).

DISCUSSION

This present study demonstrated the use of available information from the field and secondary data particularly from available maps for the development of habitat suitability map for banteng in the Alas Purwo National Park.

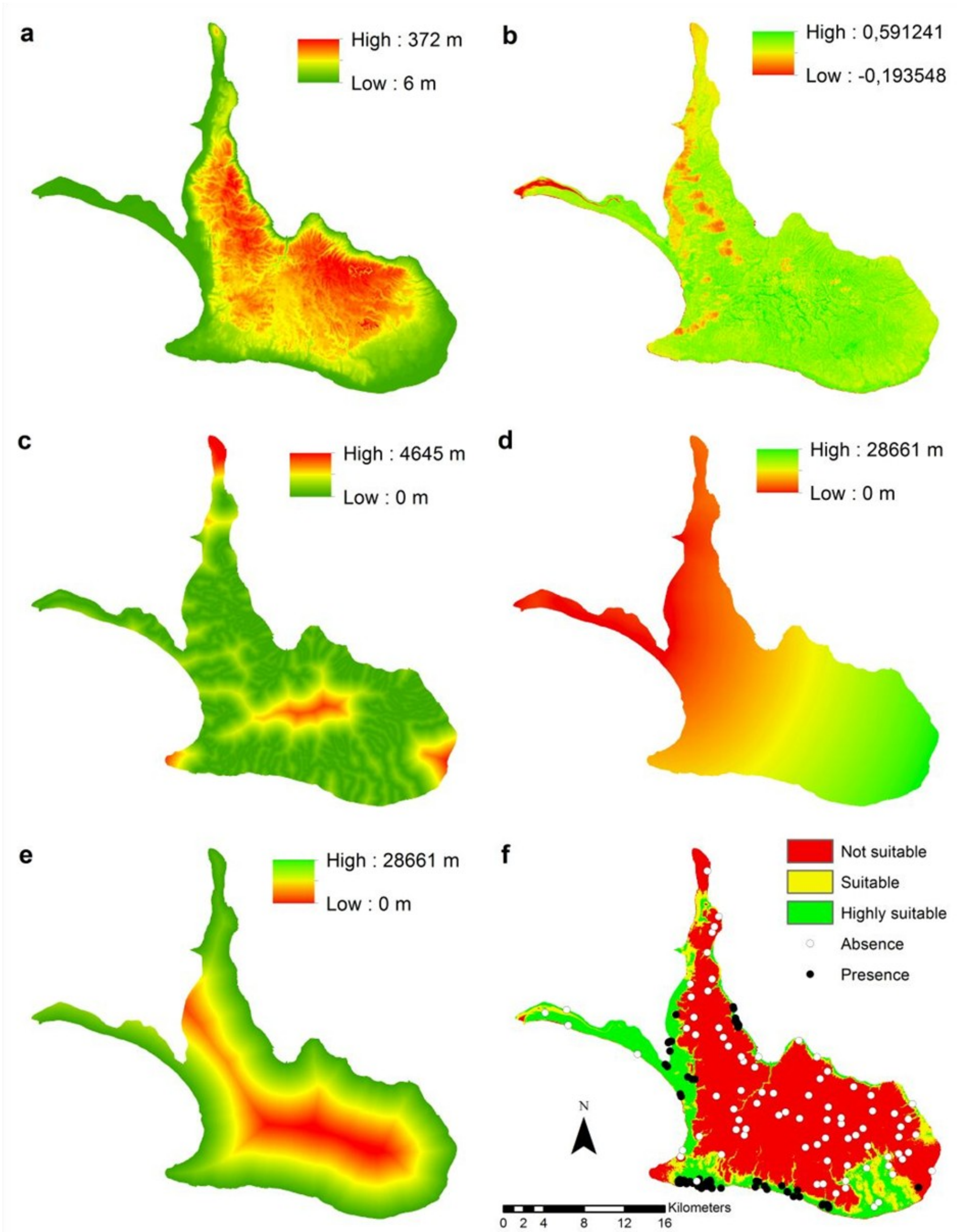

Figure 2. Maps of the distribution of each suitability classes for different predictor parameters i.e elevation (a), NDVI (b), distance from river (c) distance from roads (d), distance from beach (e) and the results of habitat suitability model for banteng with presence and pseudo-absence validation points (f). Each map shows the gradient from lowest to highest values of each parameter.

This approach is an important step toward providing reliable population estimation by reducing the larger area in the park and separated into smaller potential areas for establishing baseline area for population estimation of banteng in the Alas Purwo National Park. We discussed here the trade-off using the previous approach in the park and our results for the improvement of population estimation.

Predictors of Presence of Banteng

Understanding ecology of banteng is the central issue for the development habitat suitability model. Information from maps are important for the development of the model, however since habitat component is species specific(M. L. Morrison, Marcot, and Mannan 2006), to predict the presence of banteng using habitat suitability model should relate the ecological information from the map about the presence of banteng.

Table 4. Size of each block for the banteng population monitoring design

Block	Size (Ha)
1	4811.19
2	1280.81
3	967.74
4	2786.95
Total	9846.69

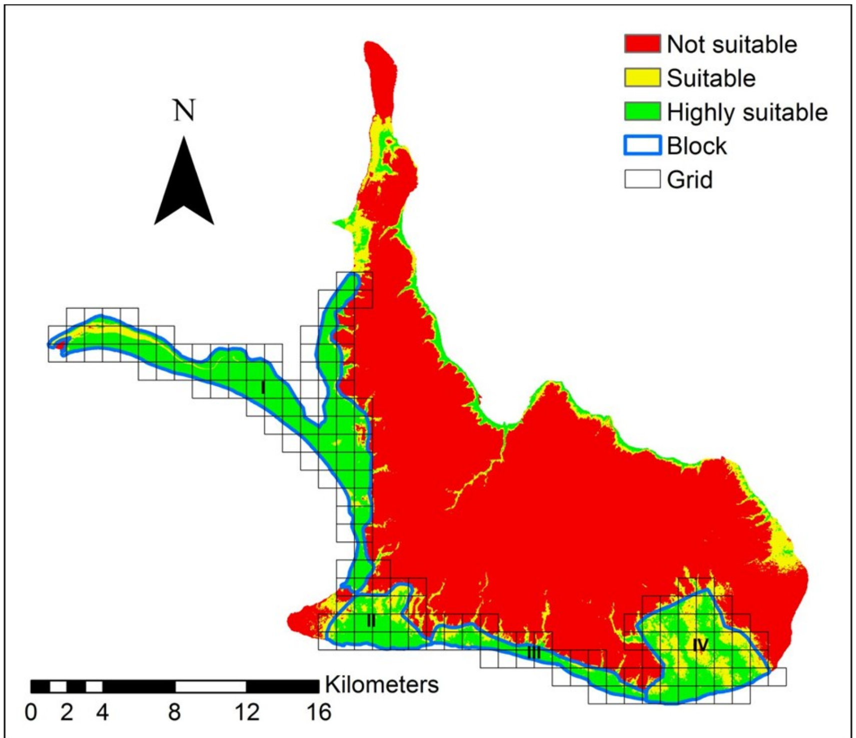

Figure 3. Map of the blocks of the area with high suitability index for banteng in the Alas Purwo National Park. The population monitoring of banteng can be established on the west (Blok I) and South (Block II and III) also south-east (Block IV) area of the park. Line transect with systematic or random layout can be prepared for monitoring purpose in each block.

This current study includes all important information which represented in maps. However, not all habitat factors can be illicitly modeled using a map such as density of grass and shrubs covers which might be important for herbivore such as banteng. This current study has applied a current approach to the use of satellite images for predicting species presence (Lahoz-Monfort *et al*., 2010).

Our model is able to predict the probability of the banteng distribution using presence and pseudo-absence data. Five predictors play important roles in determining the presence of banteng i.e. elevation, NDVI (dry season), distance from the beach, distance from river and distance from main roads. Elevation up to 2,100 m ASL has been recognized to support the occurrence of banteng in the wild (Pudyatmoko 2004; Timmins *et al*. 2015), however, our study finds that banteng tends to avoid elevation higher than 225 mASL and commonly occurs below 75 mASL. The spatial patterns might be in relation to other factors such as mineral and water seeking behavior.

Water and food source are important components of habitat for many species (M. L. Morrison, Marcot, and Mannan 2006) particularly for banteng (Pudyatmoko 2004; Timmins *et al*., 2015) and were well presented by a map of distance from the rivers and distance from beach or sea in our model. Banteng populations in Java is mainly distributed in protected areas [1] which have beach/shoreline in their areas. The presence of beach or shoreline contributes significantly in our model which indicates that banteng uses the beach for consuming minerals. Also, as a large herbivore, banteng requires a large quantity of water for their survival (Pudyatmoko 2004; Timmins *et al*. 2015), thus, distance from water or river is a crucial information for predicting the occurrence of banteng in the Alas Purwo National Park. Other study using field measurement (Pudyatmoko 2004) and literature study (Timmins et al. 2015) confirmed our results that banteng could tolerate various vegetation conditions from relatively open to dense vegetation and avoid too dense or too open area. Our findings imply that the use of secondary data such as NDVI map is useful for predicting species presence as suggested by Lahoz-Monfort (Lahoz-Monfort et al. 2010).

The use of Habitat Modelling for designing population monitoring

The binary multiple-logistic regression is a common approach for predicting the presence of species, and the function of the regression can be extrapolated into the wider areas (Schadt, Revilla, et al. 2002). This present study provides valuable insight for predicting the presence of banteng in one of important remaining protected areas in Java. This study provided the best model to predict suitable areas for banteng within the Alas Purwo National Park, following our understanding of the ecology of the banteng and field observation.

Our model predicted that suitable area for banteng was not randomly distributed in the Alas Purwo National Park. The population estimation design for banteng should rely on the spatial distribution of suitable areas. Existing estimation which only used a single location for monitoring population in Sadengan might resulting over or underestimation (M. L. Morrison, Marcot, and Mannan 2006; M L Morrison 2001; Seber 1982). Also, it is rarely found that spatial model such as habitat suitability model being employed for population monitoring. Many studies have focusing on the use of spatial model for population viability analysis and conservation planning including corridor design (García-Rangel and Pettorelli 2013; LaRue and Nielsen 2008; Schadt, Revilla, et al. 2002; Torres et al. 2010; Xiaofeng et al. 2011; Nikolakaki and Dunnett 2005; M. A. Larson et al. 2004). Existed studies using occupancy methods only focusing on detecting species presence(Linkie et al. 2015; Hirzel, Randin, and Guisan 2006; García-Rangel and Pettorelli 2013; Schadt, Revilla, et al. 2002; Hewson et al. 2011) but missed on the use of these approach for population monitoring. Thus, this present study provides new insight to use existing spatial-ecological knowledge to design population monitoring.

Among population estimation design, the transect line design is a promising approach for the condition in Alas Purwo National Park. The line transect technique has been proven powerful for population estimation of various species which also useful for understanding the ecology of studied species (Burnham, Anderson, and Laake 1980; Biswas and Sankar 2002; Shrestha 2004; Karanth et al. 2004; M L Morrison 2001).Therefore, using the results from our study will improve the accuracy and reliability population estimation of banteng in the Alas Purwo National Park. Field surveys should focus on four blocks with a total area of 9846.69 hectares, which are combination highly suitable and smaller part of the suitable area. Also, when resources are available, population estimation can employ non-invasive approach particularly using molecular study which was successfully applied to the Sumatran elephant and other large mammal species (Moßbrucker et al. 2015; Dixon et al. 2007; Brodie and Giordano 2012; Kawanishi 2002; Mondol et al. 2009).

Conservation implication

This present study demonstrated the use of important habitat components that are available in map information for the development of habitat suitability index map for banteng population in the Alas Purwo National Park-East Java – Indonesia and use it to design population survey. Java island, the most densely populated island in Indonesia, has potential threats for the conservation of banteng from development process where many natural areas are converted into human-induced areas. Protected areas for banteng in Java island are widely separated due to fragmentation (Pudyatmoko 2004). Despite the limited application in this study for the Alas Purwo National Park, a similar approach can be applied to larger areas such as in The East part of Java where three national parks (Baluran National Park, Alas Purwo National Parks and MeruBetiri National Park) exist. The future of banteng population in Java will depend on the effectiveness of landscape to provide protected areas, increasing suitable habitat and connecting protected areas by corridor (Palomares et al. 2001; Pudyatmoko 2004; Schadt, Revilla, et al. 2002; Torres et al. 2010; LaRue and Nielsen 2008; Imron, Herzog, and Berger 2011). The use of HSI for predicting corridor between protected areas has been successfully implemented for a cougar (LaRue and Nielsen 2008). Thus implementing HSI map in our results for further detection of the corridor between parks will be useful information for banteng conservation.

Banteng is a the second largest herbivore in Java and plays roles as important prey species for predators such as dhole (Pudyatmoko 2004). Spatial models have been useful for conservation of some predator species (García-Rangel and Pettorelli 2013; Imam, Kushwaha, and Singh 2009; LaRue and Nielsen 2008; Merrill et al. 1999; Schadt, Revilla, et al. 2002; Xiaofeng et al. 2011; Singh et al. 2009). Thus, the further application of the habitat suitability model development for the predator of banteng will also be important for the management of higher level of trophic and providing support for conservation of umbrella species such as dhole or Javan leopard.

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