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Habitat suitability and assessment of corridors setup for Javan Gibbon conservation: A case study in Gunung Gede Pangrango National Park, Indonesia

Heri Suheri[1], Nobukazu Nakagoshi[1], Endan Suwandana[2,*]
[1]*Graduate School for International Development and Cooperation, Hiroshima University, Higashi-Hiroshima, 739-8529, Japan*
[2]*Education and Training Center of Banten Province, Jl. Lingkar Timur Km.4, Desa Pegadungan, Kec. Karang Tanjung, Pandeglang 42251, Indonesia*

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ABSTRACT

The habitat of Javan Gibbon, *Hylobates moloch,* in Gunung Gede Pangrango National Park has been fragmented due to habitat loss. Therefore, connectivity development among the fragmented habitats is crucial to conserve Javan Gibbon population. This study is conducted to identify habitat suitability and plan corridor setup for Javan Gibbon using Geographic Information Systems (GIS) technology. Principal component analysis and general linear model were used to statistically process the weight of each environmental variable for Javan Gibbon habitat. From the total area of 22,851 ha, the results showed that 17.15% (3,918 ha), 38.61% (8,823 ha) and 44.24% (10,110 ha) are classified to have high, moderate and low suitability for Javan Gibbon habitat, respectively. The application of least-cost path analysis in GIS produced seven corridors, which have the potential to connect several fragmented Javan Gibbon habitats in the park. It is expected that the implementation of these corridors would increase the threatened population of the Javan Gibbon in the park.

Key words: Connectivity, GIS, habitat fragmentation, habitat loss, threatened population

INTRODUCTION

Javan Gibbon, *Hylobates moloch*, is one of the endemic primates in Java Island, Indonesia (Gates and Baker, 2001). This species is categorized as an endangered species by the International Union for Conservation of Nature (IUCN) and included in the Appendix I of the Convention on International Trade in Endangered Species (CITES). The current population of Javan Gibbon faces several threats, including habitat fragmentation, small population processes, and illegal pet trade (Smith, 2011).

In Indonesia, one location where the habitat of Javan Gibbon is fragmented is Gunung Gede Pangrango National Park (GGPNP), West Java Province. The GGPNP is very important because it is the only remaining wildlife area close to the metropolitan area of Indonesia.

Various human activities, such as forest disturbances by local people (Amelgia *et al*., 2009) inside and in the surrounding area of GGPNP, have put significant pressure on the ecosystem. In several locations, the habitat of Javan Gibbon is fragmented due to habitat loss because of agriculture encroachment and illegal logging activities (Iskandar, 2008). Hence, connectivity development among the fragmented habitats is crucial to conserve Javan Gibbon population.

Establishing corridors is a challenge that can provide alternative habitats for the movement and dispersal of animals in their territories among the fragmented habitats (Kharel *et al*., 2002). Habitat suitability mapping including the identification of suitable habitat is needed to establish corridors (Guthlin *et al*., 2011; Manly *et al*., 2002) which offer space, food, water and protection for the targeted species (Luan *et al*., 2010). In this regards, many researchers use the Geographic Information Systems (GIS) to assess habitat suitability and for other ecological modeling studies (Boyce and Waller, 2003; Bristow *et al*., 2005).

The objectives of this study were to identify suitable habitats and corridor setup for Javan Gibbon using the GIS technology. This study can be a contribution to improve the conservation of wild life and general biodiversity in this park.

METHODOLOGY

Study area

This study was conducted in GGPNP, which has been designated by UNESCO as a core area of the Cibodas Biosphere Reserve in 1977. In March 1980, the area was declared as a national park and became one of the first five national parks established by the Indonesian government. The total area of the park is approximately 22,851 ha (GGPNP, 2010). Administratively, the park belongs to Cianjur, Sukabumi and Bogor districts (Figure 1). Two big mountains: Mt. Gede and Mt. Pangrango, which have the height of 2,958 m and 3,019 m above mean sea level (asl) are located in the park.

GGPNP lies between latitude 6°41′–6°51′S and longitude 106°51′–107°02′ E with the elevation

*Corresponding Author's E-mail: endan2006@yahoo.com

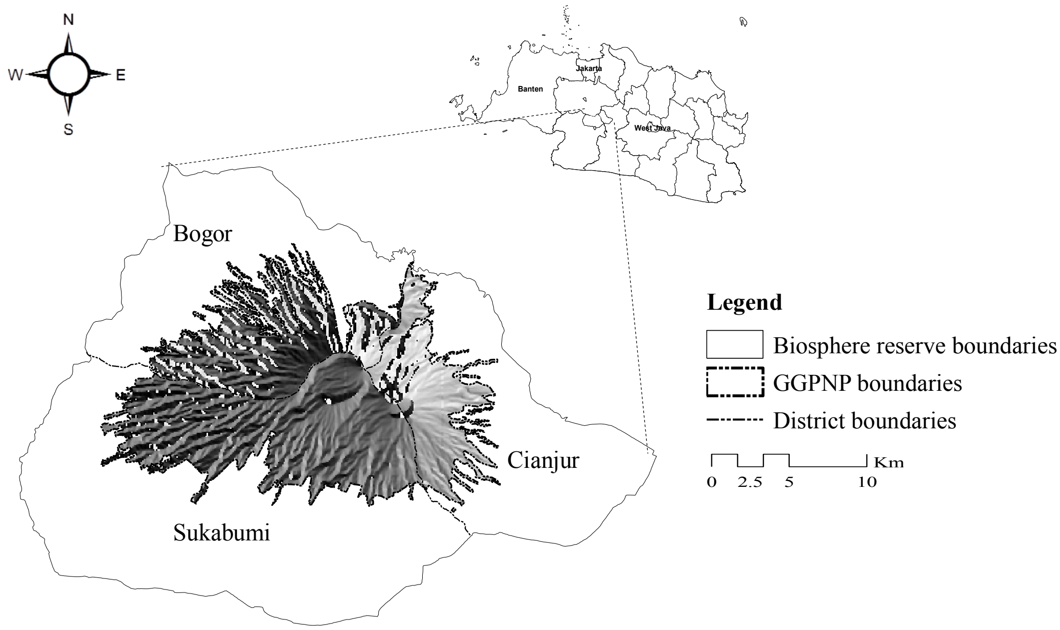

Figure 1. The location of Gunung Gede Pangrango National Park (GGPNP), West Java, Indonesia. Source: The GGPNP, 2010.

ranging from 700–3,000 m asl. The topography of GGPNP varies from flat plains to mountainous regions. The annual precipitation and mean temperature vary from 3,000–4,200 mm and from 5–18°C, respectively. The vegetation zones in GGPNP are sub-Montana (700–1,500 m asl), Montana (1,500–2,400 m asl) and above Montana (≥ 2,400 m asl) (GGPNP, 2010).

Cibodas Botanical Garden, Taman Safari Zoo, tea plantation and 66 human settlements (villages) are situated surrounding area of GGPNP. Human disturbance on natural resources in GGPNP is very common, particularly in supporting daily consumptions and livelihoods for the villagers. According to Amelgia *et al.* (2009), the villagers surrounding GGPNP strongly depend on several forest products collected in the park.

These forest ecosystem dependencies become one of primary causes of the current habitat fragmentation in the whole area of GGPNP. In 2009, the total human population in all neighboring villages of GGPNP was approximately 484,217 people (GGPNP, 2010).

Data collection

Habitat suitability analysis of Javan Gibbon was based on some data sources including several maps: the map of GGPNP administrative, topographic, NDVI and land use collected from GGPNP office and satellite imagery analysis, and the data of Javan Gibbon distribution obtained from previous research conducted by Iskandar (2008).

Javan Gibbon population is distributed in seven locations: Cibodas, Gunungputri, Selabintana, Situgunung, Cimungkat, Bodogol and Cisarua. In addition, vegetation survey was conducted from August to September 2011 for the purpose of habitat suitability mapping.

Habitat suitability mapping of Javan Gibbon

Habitat variables

Habitat suitability mapping of Javan Gibbon was created by classifying the matrix of suitability, including the selection of habitat variables. A GIS technique is used for mapping the habitat suitability of wildlife species (Rubert, 2007). In this study, ArcGIS 10 (Environmental Systems Research Institute, 2010) was employed to create the habitat suitability map of Javan Gibbon in GGPNP.

Ten important variables were determined for Javan Gibbon habitat suitability assessment, including elevation, slope, aspect, NDVI and some buffering-resulted maps such as distance to main roads, forest roads, rivers, human settlements, open areas and water bodies (Table 1).

Projection and habitat variable classification

The process of habitat suitability analysis generally is illustrated in Figure 2. After clipping by GGPNP boundaries, all of the maps of habitat variables were transformed into raster format at 30 m resolution and projected to the Universal Transverse Mercator (UTM) coordinate projection system. The next process is classifying three-suitability classes: low, moderate and high suitability habitat variables with the criteria following the range values listed in Table 1.

Weight of each habitat variable

Principal Component Analysis (PCA) was used to statistically process the weight of each environmental variable for Javan Gibbon habitat. It was determined by overlaying the current locations of Javan Gibbon distribution. Each location of Javan Gibbon distribution comprised values. The results were the PCA values as presented in Table 2.

Table 1. Matrix of suitability classification for Javan Gibbon habitat.

		Suitability classes		
Variables	**Unit**	**Low**	**Moderate**	**High**
Elevation	m.asl	>1,750	1,500–1,750	<1,500
Slope	%	0–8	8–25	>25
Aspects	-	240–360	120–240	0–120
NDVI value	-	-1–0.3	0.3–0.6	>0.6
Distance to main roads	m	<100	100–300	>300
Distance to forest roads	m	<100	100–300	>300
Distance to rivers	m	>400	200–400	<200
Distance to human settlements	m	<500	500–1,000	>1,000
Distance to open areas	m	<221	221–500	>500
Distance to water bodies	m	>400	200–400	<200

The table was adopted and modified from Ario *et al*. (2010), Berliana (2009), Dewi *et al*. (2007), Ikbal *et al*. (2008), Iskandar (2008) and Kadhafi (2011).

In addition, PCA requires a normal distribution data (Janzekovic and Novak, 2012) which is obtained from multicollinearity analysis. The tolerance and VIF (Variance Inflation Factor) values were required in this process. If the tolerance values less than 0.1 or the VIF values more than 10, the data indicated as multicollinearity problem (Shieh, 2011).

The results showed that three of ten variables (distance to main roads, forest roads and open areas) had the tolerance less than 0.1(0.025, 0.044 and 0.048) and VIF values more than 10 (40.376, 22.498 and 20.863), respectively. It indicated that the data were not normally distributed (Table 3). The values of the three variables had to be transformed into normal values using Kolmogorov-Smirnov test.

Habitat suitability model

The PCA values were used as the inputs for habitat suitability model of Javan Gibbon through the General Linear Model (GLM) method. It comes with the following formula which is similar to multi linear regression adopted from Soemartini (2008):

$$F = (\beta_1 \text{ x elevation}) + (\beta_2 \text{ x slope}) + (\beta_3 \text{ x aspects}) + (\beta_4 \text{ x NDVI}) + (\beta_5 \text{ x distance to main roads}) + (\beta_6 \text{ x distance to forest roads}) + (\beta_7 \text{ x distance to rivers}) + (\beta_8 \text{ x distance to human settlements}) + (\beta_9 \text{ x distance to open areas}) + (\beta_{10} \text{ x distance to water bodies}) \quad \textbf{(1)}$$

The F value can be expressed as:

$$F = ((-0.041 \text{ x Elevation}) + (0.365 \text{ x Slope}) - (0.251 \text{ x Aspect}) + (0.098 \text{ x NDVI}) + (0.136 \text{ x distance to main roads}) + (0.396 \text{ x distance to forest roads}) - (0.085 \text{ x distance to rivers}) + (0.164 \text{ x distance to human settlements}) + (0.211 \text{ x distance to open areas}) - (0.049 \text{ x distance to water bodies}))$$

The F value of equation 1 is an input data for the GLM as a similar way to the one of Singh *et al.* (2009) in the following formula:

$$Y = \beta_0 + \beta_i F + \varepsilon_i \quad \textbf{(2)}$$

Table 2. The PCA scores of each habitat variable.

Component scores coefficient matrix		
	Principal Component (PC)	
	PC1	**PC2**
Elevation	-0.041	-0.181
Slope	0.365	-0.067
Aspects	-0.251	0.462
NDVI value	0.098	0.101
Distance to main roads	0.136	0.050
Distance to forest roads	0.396	-0.251
Distance to rivers	-0.085	0.385
Distance to human settlements	0.164	-0.020
Distance to open areas	0.211	-0.033
Distance to water bodies	-0.049	0.221

Extraction method: Principal component analysis
Rotation method: Varimax with Kaiser Normalization.

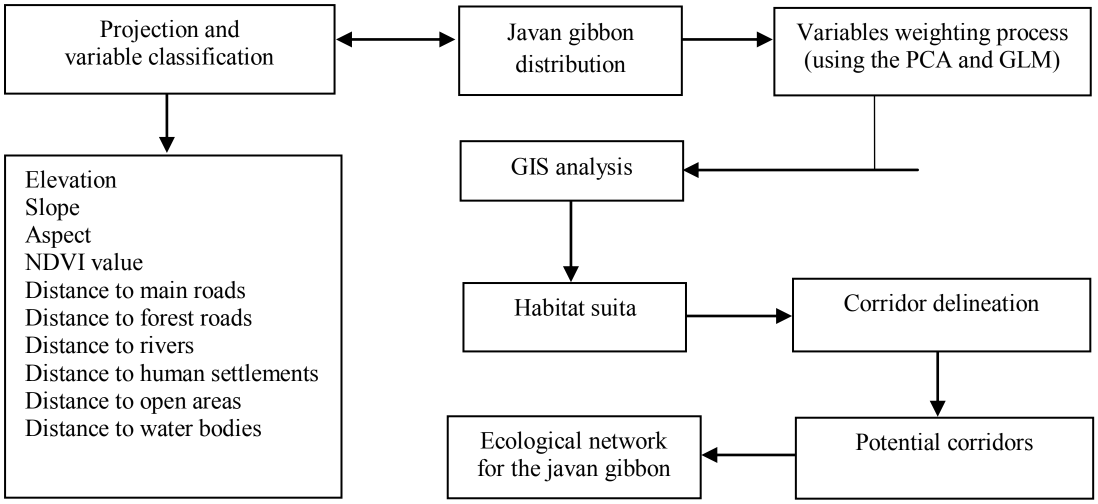

Figure 2. The process of habitat suitability analysis.

Where; Y = Habitat suitability model.
β_0 = Constant.
β_i = Coefficient.
F = non multicollinearity variables.
ε_i = Standard error.
i = Number of variable (1–10).

The Y value can be obtained from the regression coefficient analysis (Table 4) and is expressed as below:

$$Y = -0.062 + (0.005 \times ((-0.041 \times \text{Elevation}) + (0.365 \times \text{Slope}) - (0.251 \times \text{aspects}) + (0.098 \times \text{NDVI value}) + (0.136 \times \text{distance to main roads}) + (0.396 \times \text{distance to forest roads}) - (0.085 \times \text{distance to rivers}) + (0.164 \times \text{distance to human settlements}) + (0.211 \times \text{distance to open areas}) - (0.049 \times \text{distance to water bodies}))$$

The equation 2 was also used to determine habitat suitability map of Javan Gibbon by the ArcGIS 10.

The assessment of corridor setup

Development of corridors is necessary to connect the fragmented habitats. It was created in five stages: (1) defining the features classes, (2) reclassifying the features classes, (3) calculating the features classes, (4) identifying the corridors, and (5) buffering the corridors, similar to the procedures suggested by Hepcan and Ozkan (2011).

The connectivity of the corridors was measured by estimating cost distance which similar to suitable habitat criteria. Combination of estimates travels cost of sources and destination is applied to generate a least-cost corridor. It was identified as the best available corridor between the suitable habitats (Cypher *et al*., 2007).

RESULTS

Habitat suitability map of Javan Gibbon

Habitat suitability map of Javan Gibbon classified GGPNP area into three of suitability: low, moderate and high suitable habitat (Figure 3).

Table 3. The tolerance and VIF value of each habitat variable.

Model	**Coefficients[a] Collinearity Statistics**	
	Tolerance	**VIF**
Elevation	0.309	3.233
Slope	0.260	3.842
Aspects	0.210	4.771
NDVI value	0.511	1.958
Distance to main roads	**0.025**	**40.376**
Distance to forest roads	**0.044**	**22.498**
Distance to rivers	0.322	3.110
Distance to settlements	0.160	6.262
Distance to open areas	**0.048**	**20.863**
Distance to water bodies	0.195	5.116

a. Dependent variable: species

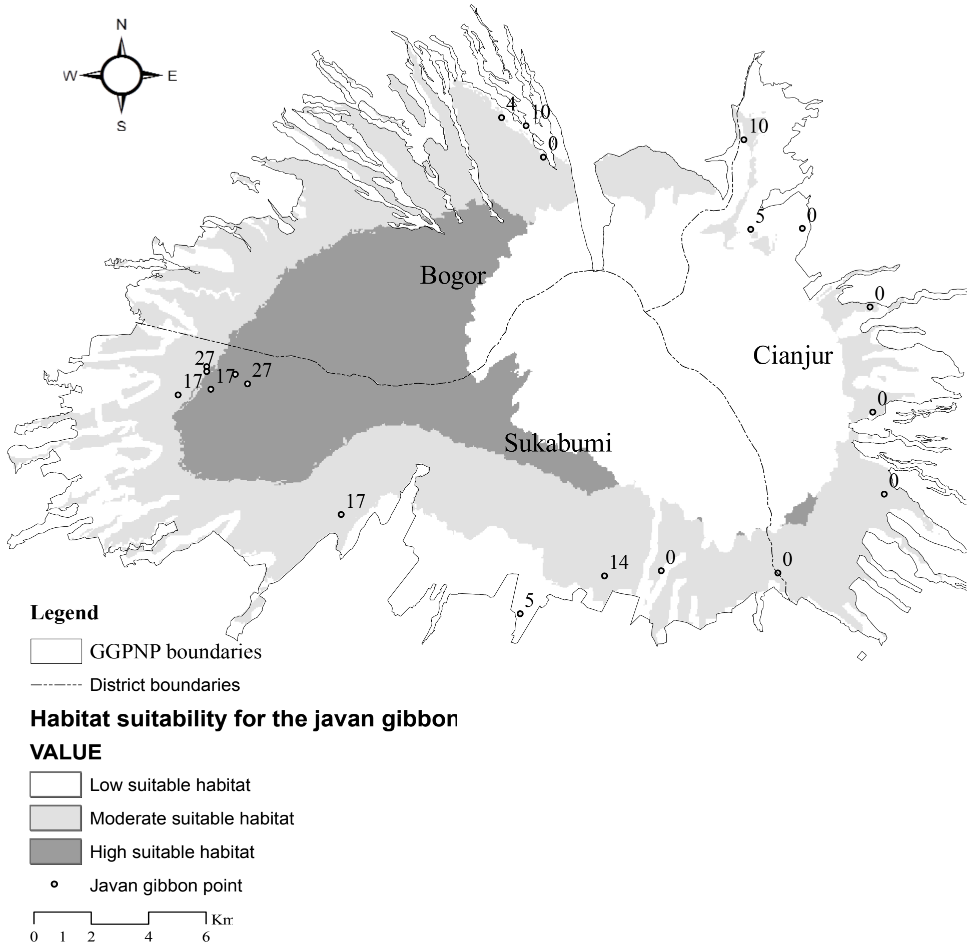

Figure 3. Habitat suitability map of Javan Gibbon. Numbers are showing the heads of Javan Gibbons in each point, and 0 means null.

Table 4. The coefficient of each habitat variable resulted from the GLM.

Coefficients[a]							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-0.062	2.691		-0.023	0.982		
F	0.005	0.001	0.688	4.024	0.001	1.000	1.000

a. Dependent variable: species

Table 5. The district-based area of habitat suitability classes of Javan Gibbon in

Location	Suitability classes (ha)			Total area (ha)
	Low	Moderate	High	
Cianjur	3,096	1,137	785	5,018
Sukabumi	4,733	4,446	1,283	10,462
Bogor	2,281	3,240	1,850	7,371
Total area (ha)	10,110	8,823	3,918	22,851

The areas with high and moderate suitable habitat were located mostly in the west part of GGPNP, where the areas administratively belong to Sukabumi and Bogor districts. In total area of GGPNP (22,851 ha), there were 17.15% (3,918 ha) identified as high, 38.61% (8,823 ha) as moderate and 44.24 % (10,110 ha) as low suitable habitat for Javan Gibbon.

The map shows that most of the area in Cianjur is located within the elevation above 1,750 m asl, which is not suitable for Javan Gibbon. Here, the tourism and agricultural activities of the villagers were the primary causes that could reduce the suitable habitat for Javan Gibbon (Iskandar, 2008). Because of the limited suitable habitat found in Cianjur, it is very important to improve the habitat suitability of the least suitable area to reach the minimum size that the Javan Gibbon can survive. Based on Ario *et al.* (2010), the optimal size of Javan Gibbon habitat for each family group requires nearly 260 ha.

Table 5 shows the habitat suitability class of Javan Gibbon in GGPNP displayed in district base, from which the management planning of GGPNP including the strategy to improve the quality of habitats can be considered.

This study considered only the high and moderate suitable habitats (which are shown in Figure 3 by dark gray and gray color, respectively) by combining both classes into one suitable class. Seven locations were identified as suitable habitats (Figure 4) and considered as the core habitats for Javan Gibbon. The detail locations and size of the core habitats are presented in Table 6.

Potential corridors for Javan Gibbon habitat

The potential corridors for Javan Gibbon habitat in GGPNP described in Figure 5. The information regarding the length, size and location of the corridors are given in Table 7.

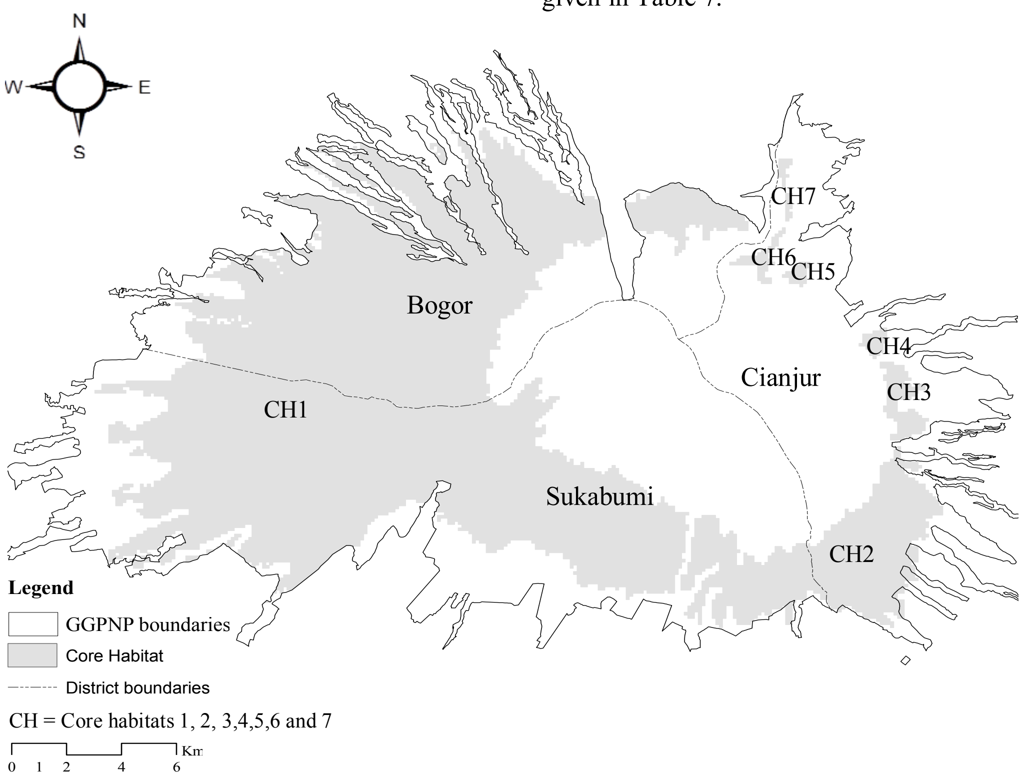

Figure 4. Core habitat map of Javan Gibbon in GGPNP.

Table 6. Core habitats for Javan Gibbon in GGPNP.

Core habitats	Location	Total area (ha)
1	Both Bogor and Sukabumi district	10,125
2	Both Sukabumi and Cianjur district	1,532
3	Sarongge	924
4	Sarongge	60
5	Gunungputri	35
6	Cibodas	54
7	Cibodas	11

Table 7. Potential corridors for Javan Gibbon habitat in GGPNP.

Corridors	Location	Corridor length (m)	Total area (ha)	Total buffer (ha)
1	Selabintana	61	3	178
2	Gedeh	308	15	184
3	Sarongge	127	6	183
4	Gunungputri	2,101	105	375
5	Cibodas	270	14	193
6	Cibodas	180	9	186
7	Cibodas	180	9	195
Total		**3,227**	**161**	**1,494**

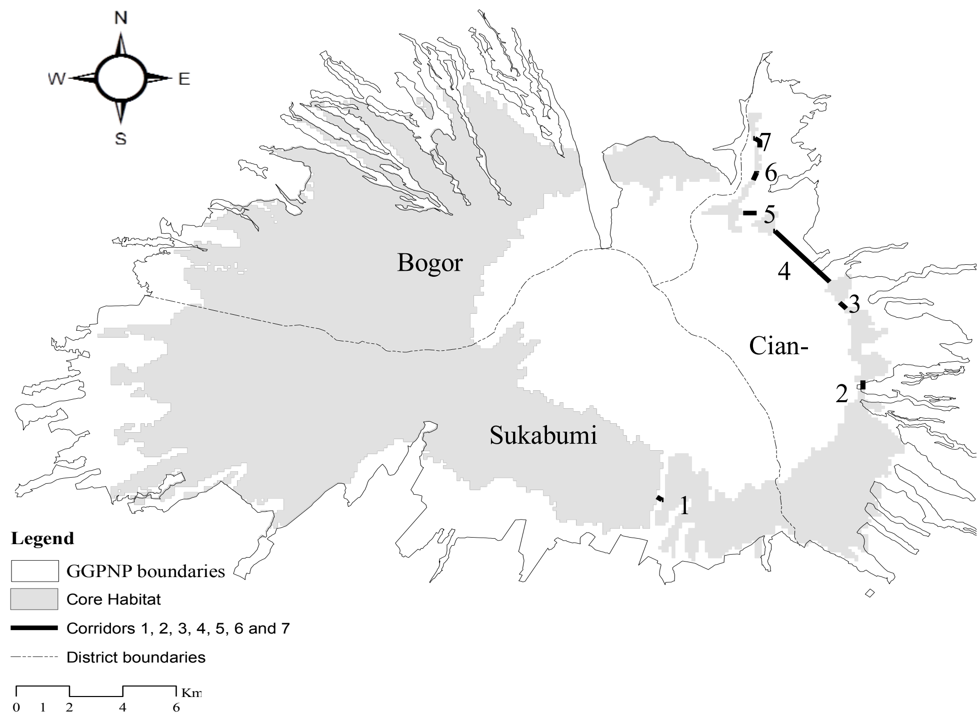

Figure 5. Potential corridors for Javan Gibbon habitat in GGPNP.

DISCUSSION

The identification of habitat suitability in GGPNP is crucial aspects for the conservation management in the park, not only for Javan Gibbon but also for other species, particularly the endangered species. Since Javan Gibbon is a key species for biodiversity conservation, many studies regarding Javan Gibbon population and conservation have been conducted in GGPNP. Unfortunately, most of the studies have focused only on the behavioral aspect of Javan Gibbon and mostly limited to the western part of GGPNP. Meanwhile, the habitat suitability and connectivity of the fragmented Javan Gibbon habitats have not been assessed. Therefore, this study can be a contribution to improve the conservation of wild life and general biodiversity in this park.

The habitat suitability results showed that 17.15% (3,918 ha), 38.61% (8,823 ha) and 44.24% (10,110 ha) of total area are categorized to have high, moderate and low suitability for Javan Gibbon habitat, respectively. In this perspective, the suitability habitat of GGPNP was very poor for Javan Gibbon.

In Cianjur, most of the areas were low suitability, so that it was a critical area for Javan Gibbon. From the suitable habitat area (1,922 ha), it consist of 1,137 ha and 785 ha as moderate and high, respectively. Figure 5 shows that Cianjur was mostly above 1,750 m asl, wherein most of food vegetation for Javan Gibbon is not able to grow. Sugardjito *et al*. (1997) said that the Javan Gibbon prefers to stay on the location less than 1,750 m asl. Besides that, the moss on the tree is obstacle factors for Javan Gibbon brachiating (Ario *et al*., 2010). It explains that why population of Javan Gibbon in Cianjur was the lowest. According to Zhang *et al*. (2010), an obvious aspect of habitat quality is food. The intensive tourism and agricultural activities are two other factors that inhibit the population grow of Javan Gibbon in Cianjur. The Javan Gibbon is very sensitive species related to habitat changing (Pranasai *et al*., 2010). Human pressure is believed to be obstacles of Javan Gibbon movement and dispersal. Some researchers describe that habitat destruction was an important cause of declining in the populations of primates, including the species of gibbons (Ganzhorn, 2003; Setchell and Curtis, 2003).

The total suitable habitat in Sukabumi site was 5,729 ha, it consist of 4,446 ha and 1,283 ha as moderate and high suitable, respectively. In Bogor was 5,090 ha, it consist of 3,240 ha and 1,850 ha as moderate and highly suitab, respectively.

To improve the suitability habitat of Javan Gibbon, vegetation restoration should be implemented in all areas, especially in Cianjur. Chen *et al*. (2008) explained that to change unsuitable habitat into suitable and to improve the connectivity of the landscape, could be done by the vegetation restoration. The vegetation restoration should include the vegetation which can provide food and shelter, because Javan Gibbon is categorized as an arboreal species and classified as frugivorous species. They prefer to live in the high tree at heights of 20–25 m (Nijman, 2002), diameter 27–130 cm and density more than 100 trees per ha (Kadhafi, 2011).

This study determined seven locations of potential corridors for Javan Gibbon movement among the fragmented habitats. Determining corridors, setting buffers and expanding the core habitat become important efforts to improve the habitat connectivity (Chen *et al*., 2008; Li, 1997). Among the seven potential corridors, some of the longest corridors were found in Cianjur site, ranging between 61–2,101 m. Therefore, Cianjur area is suggested to be the highest priority for conservation management to improve Javan Gibbon habitat in GGPNP. This study was used ten variables. To obtain the good results can use more than ten variables.

CONCLUSIONS

Identification of habitat suitability is crucial aspect of conservation management. This study attempts to develop habitat suitability and corridor setup for Javan Gibbon in GGPNP, based on some identified environmental variables in the fieldwork area.

In total area of 22,851 ha, it showed that 17.15% (3,918 ha), 38.61% (8,823 ha) and 44.24% (10,110 ha) are classified to have high, moderate and low suitability for Javan Gibbon habitat, respectively. Then, from the high and moderate suitable habitat, seven locations were measured as the core habitats for Javan Gibbon, which are fragmented.

Totally, seven corridors locations were setup, they are potential to connect several fragmented habitats of Javan Gibbon in the area of Selabintana, Gedeh, Sarongge, Gunungputri and Cibodas. This study suggests that a restoration program should be implemented immediately in GGPNP, in order to improve suitable habitat for Javan Gibbon.

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REFERENCES

Amelgia, R., Wicaksono, K. P. and Nakagoshi, N. 2009. Forest product dependency excluded timber in Gede Pangrango National Park in West Java. *Hikobia* 15, 331–338.

Ario, A., Supriatna, J. and Andayani, N. 2010. The Javan Gibbon in the Gunung Gede Pangrango National Park. Conservation International Indonesia, Jakarta. (in Indonesian).

Berliana, K., 2009. Mapping of Javan Gibbon habitat suitability (*Hylobates moloch* Audebert, 1798) in Gunung Tilu protected area, Kabupaten Bandung with geographical information systems application. Bogor Agricultural University, Bogor. (in Indonesian).

Boyce, M. S. and Waller, J. S. 2003. Grizzly bears for bitterroot: Predicting potential abundance and distribution. *Wildlife Society Bulletin* 31, 670–683.

Bristow, K. D., Boe, S. R. and Ockenfels, R. A. 2005. Predicting habitat suitability for wildlife in Southeastern Arizona using geographic information systems: Scaled quail, a case study. USDA Forest Service Proceedings RMRS–P–36. Arizona Game and Fish Department, Phoenix.

Chen, L. D., Liu, X. H., Fu B. J., Lu, Y. H. and Qiu, J. 2008. Identification of the potential habitat for giant panda in the Wolong Nature Reserve by using landscape ecology methodology. National Key Lab of Systems Ecology, Research Center for Eco–Environmental Sciences, Chinese Academy of Sciences, Beijing.

Cypher, B. L., Phillips S. E. and Kelly, P. A. 2007. Habitat suitability and potential corridors for San Joaquin Kit Fox in the San Luis Unit. California State University, Stanislaus.

Dewi, H., Prasetyo, L. B. and Rinaldi, D. 2007. Habitat suitability mapping of silvery gibbon (*Hylobates moloch* Audebert, 1797) in Gunung Halimun–Salak National Park. Bogor Agricultural University, Bogor. (in Indonesian).

ESRI, 2010. Designing wildlife corridors helps species survive. ArcNews online. Redlands, California.

Ganzhorn, J. U., 2003. Habitat Description and Phenology. In: Setchell, J. M. and Curtis, D. J. (Eds.) Field and laboratory methods in primatology, pp. 40–56. Cambridge University Press, Cambridge.

Gates, D. and Baker, C., 2001. Javan Gibbon rescue and rehabilitation center: A project report, pp. 1–7. Perth Zoo, Perth.

Gunung Gede Pangrango National Park. 2010. Profile of Gunung Gede Pangrango National Park Book. Gunung Gede Pangrango National Park, Cianjur. (in Indonesian).

Guthlin, D., Knauer, F., Kneib, T., Kuchenhoff, H., Kaczensky, P., Rauer, G., Jonozovic, M., Mustoni, A., and Jerina, K., 2011. Estimating habitat suitability and potential population size for brown bears in the Eastern Alps. *Conservation Biology* 144, 1733–1741.

Hepcan, C. C. and Ozkan, M. B. 2011. Establishing ecological network for habitat conservation in the case of Cesme-Urla Peninsula, Turkey. *Environmental Monitoring Assessment* 174, 157–170.

Ikbal, W., Prasetyo, L. B. and Risdiyanto, I. 2008. Habitat suitability of Javan Gibbon in Gunung Salak, West Java. Scientific articles JMHT Vol. XIV. 1, 1–8.

Iskandar, F., 2008. Habitat and Population of the Javan Gibbon (*Hylobathes moloch* Audebert, 1797) in Gunung Gede Pangrango National Park, West Java. Bogor Agricultural University, Bogor. (in Indonesian).

Janzekovic, F. and Novak, T., 2012. PCA – A powerful method for analyze ecological niches. University of Maribor, Maribor.

Kadhafi, A. M., 2011. Characteristics preferential studies of Javan Gibbons habitat at Gunung Tilu nature reserve, West Java. Bogor Agricultural University, Bogor.

Kharel, S., Chhetri, R. B., Khanal, S. N., Jnawali, S. R. and Pathak, S. R., 2002. Wildlife corridor mapping between Royal Bardiya National Park, Nepal and Katarniyaghat Wildlife Resereve, India by using GIS. Kathmandu University, Kathmandu.

Li, C. B., 1997. A Study of staple food bamboo for the giant panda. Sichuan publishing house of science and technology. Guizhou Science and Technology Press, Guiyang pp. 83–221.

Luan, X., Qu, Y., Li, D., Liu, S., Wang, X., Wu, B., Zhu, C., 2010. Habitat evaluation of wild amur tiger (*Panthera tigris altaica*) and conservation priority setting in Northeastern China. *Environmental Management* 92, 31–42.

Manly, B. F. J., McDonald, L. L., Thomas, D. L., McDonald, T. L. and Erickson, W. P., 2002. Resource selection by animals: Statistical design and analysis for field studies. Kluwer Academic Publisher, Dordrecht.

Nijman, V., 2002. Forest (and) Primates. Conservation and ecology of the endemic primates of Java and Borneo. The *Troponbos-Kalimantan*, Series 5, 232. Drukkerij Ponsen en Looijen B. V., Wageningen.

Pranasai, K., Priyanto, Etty and Jumilawaty, E., 2010. Rehabilitation of Javan Gibbon habitat in the corridor Halimun–Salak mountain. Bogor Agricultural University, Bogor.

Rubert, L., 2007. Identifying habitat suitability and potential linkages for Swamp Rabbit conservation in Southern Illinois. Department of Zoology in the Graduate School, University Carbondale, Southern Illinoi.

Setchell, J. M. and Curtis, D. J., 2003. Field and laboratory methods in primatology. 372 p. Cambridge University Press, Cambridge.

Shieh, G., 2011. Clarifying the role of mean centring in multicollinearity of interaction effects. *Mathematics and Statistical Psychics* 64, 462–477.

Singh, R., Joshi, P. K., Kumar, M., Dash, P. P. and Joshi, B. D., 2009. Development of tiger habitat suitability model using geospatial tools–a case study in Achankmar Wildlife Sanctuary (AMWLS), Chhattisgarh India. *Environmental Monitoring and Assessment* 155, 555–567.

Smith, J. H., 2011. Reintroducing Javan Gibbons (*Hylobathes moloch*): an assessment of behavioral preparedness. San Diego State University, San Diego.

Soemartini, 2008. Principal component analysis is one of method to solved multicolienarity problem. Faculty of mathematic and natural science. Padjadjaran Univeristy, Bandung. (in Indonesian).

Sugardjito, J., Sinaga, M. H. and Yoneda, M., 1997. Survey of the distribution and density of primates in Gunung Halimun National Park West Java, Indonesia. *Research and Conservation Biodiversity* 2, 56–62.

Zhang, M., Fellowes, J. R., Jiang, X., Wang, W., Chan, B. P. L., Ren, G. and Zhu, J., 2010. Degradation of tropical forest in Hainan, China, 1991-2008: Conservation implication for Hainan Gibbon (*Nomascus hainanus*). *Conservation Biology* 143,1397–1404.