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Identifying Important Areas for the Release of Five Endemic Species in a Mountainous Landscape: Inference from Spatial Modeling Techniques

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Abstract

Efforts to release animals resulting from evacuation and rehabilitation into their natural habitats are important practices in wildlife conservation. Before releasing the animals, it is important to assess the habitat suitability of the areas to support the existence of the animals in the long run. Yet, there is limited study of habitat suitability assessment on national parks as release locations for wild animals. This study aimed to assess the suitable habitat of five charismatic animal species, i.e., Panthera pardus melas, Hylobates moloch, Prinonailurus bengalensis, Nycticebus javanicus, and Nisaetus bartelsi, in Gunung Halimun Salak National Park using Maxent, and to determine potential locations for releasing animal's species. Models for the P. p. melas show 47,619 ha and 21,391 ha, respectively, suitable as habitat and potential release location, for H. moloch, each is 57,537 ha and 33,471 ha, for P. bengalensis, each is 25,460 ha and 17.189 ha, for N. javanicus, each is 29,848 ha and 15,578 ha, and for N. bartelsi, each is 44,426 ha and 25,660 ha. Our study shows that a suitable habitat can be critical in choosing a wildlife release site. Further consideration of conflict mitigation and practicalities is required to achieve the long-term existence of released species.

Keywords: *endangered species management; habitat use; Maxent; presence only model; reintroduction*

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Introduction

The high economic value of wild animals, either in terms of their whole body and body parts or traded alive as pets and dead as decorations to be consumed and used for medicinal purposes, has driven illegal trade (Nijman et al., 2022). Among the wild animals traded, fishes rank first as the most traded species, followed by birds in the second, and next by reptiles (e.g., snakes and monitor lizards), and primates (e.g., leaf monkeys and long-tailed macaque) (traffic.org). In Indonesia and globally, trade has shifted to online platforms, a trend that may have been amplified by the covid-19 pandemic and partial lockdowns (Nijman et al., 2021). Recently, the illegal trade of wild animals has become increasingly widespread and has capitalized on the utilization of various social media channels and websites (Nekaris, 2014; Nijman et al., 2021). Trade poses a substantial threat to Indonesian wildlife, and without enforcement, the sheer volume of trade may mean that species of least concern or near threat may rapidly decline. Endaged species protected in Indonesia.

Indonesia is a hyper-rich country in terms of biodiversity (Parikesit et al., 2012). To ensure the preservation and sustainable use of biodiversity, the Government of Indonesia has established initiatives for wild animal protection and utilization to support the well-being of Indonesian citizens. For example, regulations regarding the use of wild plants and animals through captivity and cultivation exist; however, the utilization of wild animals in Indonesia is yet to be professionally realized, which threatens the survival of wild animals themselves since their protection will indirectly affect people's well-being (Mardiastuti & Soehartono, 2003).

In recent years, several countries, including the Indonesian Government, have intensively enforced laws to protect wildlife by arresting perpetrators of illegal hunting and trade of wild animals. Despite this, it is difficult to effectively control and reduce hunting. While culprits are captured for legal processes, traded animals are left to several institutions, including animal rescue centers and other conservation institutions. The centers also rescue wild animals that conflict with humans. On many occasions, centers must accommodate large numbers of wild animals. This has placed wild animals in an improper and ideal situation. Thus, the process of rehabilitation and release of

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wild animals that are ready to be released into their natural habitat must be carried out immediately.

Information regarding natural and suitable habitats for release locations is still limited (Othman et al., 2023). Most studies have focused only on investigating potentially suitable habitats, but it is unclear where the precise release locations should be (Rahman, 2020; Rahman et al., 2020). Based on the IUCN Guidelines for Reintroductions and other Conservation Translocations (2013), there are at least three primary requirements that need to be considered in the process of releasing wild animals back into their natural habitats: a) habitat for releasing the wild animal species must be part of their natural habitat and range, b) the released wild animals must be healthy and have a high level of genetic diversity, and c) the last one that needs to be considered is the existence of the individuals of the species that are already present in the area.

One of the national parks on Java Island, Gunung Halimun Salak National Park (GHSNP), is the largest in extent and the best habitat for several wild animals, such as javan gibbon (Supriatna, 2006; MoF, 2013) and javan leopards (Rahman et al., 2018; Wibisono et al., 2018). In the last two years, GHSNP has actively received rescued wild animals for release into the park, particularly wild animals, from the Natural Resources Conservation Agency (BKSDA) of DKI Jakarta and the Indonesian Nature Initiation Foundation for Rehabilitation (YIARI). Considering these facts, it is necessary to conduct a study on habitat suitability for released animal locations in the GHSNP area, particularly for traded wild animals. The study was carried out in the GHSNP, focusing on habitats for several endemic and protected wild animals that hold high conservation value and are commonly found in animal rescue centers. Moreover, wild animals are traded illegally and often conflict with humans. These species include javan leopards (*Panthera pardus melas*), javan gibbons (*Hylobates moloch*), leopard cats (*Prinolailurus bengalensis*), javan slow loris (*Nycticebus javanicus*), and javan hawk-eagle (*Nisaetus bartelsi*). Maximum entropy modeling (Maxent) has been widely used for species distribution modeling and prediction of suitable habitats for wildlife (Phillips et al., 2006; Elith et al., 2011; Rahman et al., 2020). Based on predictions of habitat suitability for five species by Maxent modeling, we aimed to a) identify the environmental variables that influence five endemic species site use in GHSNP, b) predict the site-use intensity across mountain areas and identify important areas for protection and released animal locations, and c) illustrate the accuracy of Maxent modeling results by validating habitat suitability results with actual conditions in the field in the Javan leopard population. We hypothesized that Maxent could be utilized for five species of conservation concern and is likely to be highly useful for other reintroduction programs, especially where the individuals being released are from an endangered species.

Methods

Study area The study was carried out in the area of GHSNP (S06°44'21"E106°31'53" and S06°44'47"E106°32'1"; Figure 1) that expands across two provinces (West Java and Banten Provinces) and three districts (Bogor, Sukabumi, and Lebak Districts) with a total area of 87,699 ha. The area is characterized by a landscape mosaic, dominated by the natural tropical rain forest ecosystem and classified as a 'Colline Primary Forest Zone', interspersed with several settlement areas (enclaves). The vegetation in this area is dominated by *Homalantus populneus*, *Nauclea lanceolata*, and *Macaranga* sp. The climate in the GHSNP is categorized as type A, with a mean temperature of 21–25 °C and a relative humidity of 72–89%. Located in a tropical area, the mean annual rainfall and temperature range between 3,200–6,000 mm and 16–30 °C, respectively.

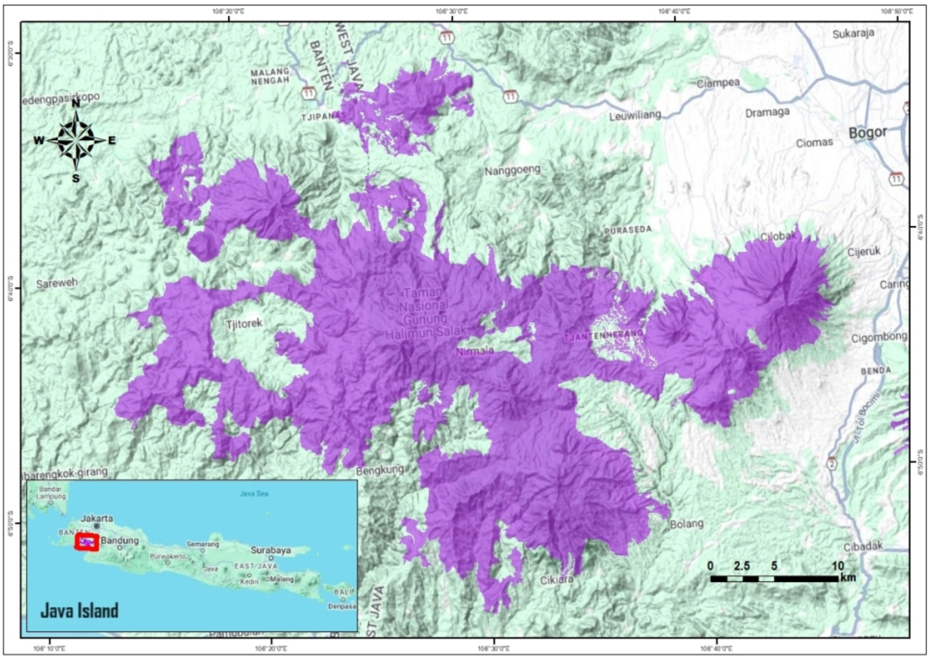

Figure 1 Map of study area in Gunung Halimun Salak National Park.

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Presence and environmental data The study utilized wild animal presence data for both direct and indirect encounters (e.g., footprints, feces, food remains, vocalization, and photos and videos derived from camera traps) from 2007 to 2019. The number of presence data records for each target animal was as follows: a) javan leopards = 1,027 points; b) javan gibbons = 710 points; c) javan slow loris = 216 points; d) leopard cats = 35 points; and e) javan hawk-eagle = 10 points. Animal presence data were processed using MS Excel, then converted into a comma-separated value (.csv) format (Young et al., 2011). Since the number of leopard cats, javan slow loris, and javan hawk-eagle was not sufficient, bias grid processing was conducted in advance to minimize the bias of the results (Wibisono et al., 2018; Ario et al., 2022).

The environmental variables of the habitat niche are different for each target animal. The variables were determined by studying animal behavior and animal ecology. The study used environmental variables that consisted of slope, elevation, land cover, distance to river, precipitation, density of food resources, normalized difference vegetation index (NDVI), distance to the nearest farm, distance to primary forest, distance to secondary forest, and distance to community settlement (Hijmans et al., 2005; Jiang et al., 2006; Franklin, 2009; Slater & Mixhael, 2012; Yang et al., 2013; McCarthy et al., 2015; Rahman et al., 2017; Rahman et al., 2018; Wibisono et al., 2018; Rahman et al., 2019; Sodik et al., 2019; Zhang et al., 2019; Arslan et al., 2020; Rahman, 2020; Rahman et al., 2020). Secondary data and literature studies on the behavioral patterns, ecology, and habitat characterization of each target animal determined the environmental variables for each target animal (Table 1).

The environmental variables in the form of vectors were changed into rasters. The files were then converted into ASCII (.asc) format (Phillips et al., 2006; Phillips & Dudik 2008; Young et al., 2011). These variables were overlaid with the area boundaries and delineated. Therefore, they had the same area and number of pixels with an area of 0.0069 ha. Eventually, the number of pixels in all variables comprised 7,583 columns and 5,360 rows. All data were processed using the same projection system, WGS 1984 UTM Zone 48S.

Next, Pearson's correlation test was performed to determine the level of correlation among environmental variables. Significantly correlated environmental variables were eliminated (Rahman et al., 2017; Rahman et al., 2022). Thus, every environmental variable was used independently (McCarthy et al., 2015).

Spatial model analysis Spatial modeling for habitat suitability was performed using Maxent version 3.4.1. The tool compares the environmental variables of animal presence data to environmental variables in other areas, and then models the similarity between the two environmental variables (Phillips et al., 2006; Phillips & Dudik, 2008). The software processes the animal presence and environmental variable data (Phillips et al., 2006; Phillips & Dudik, 2008; Young et al., 2011). Some of the settings applied in this study were: a) running the measurement of the jackknife level importance, and b) transforming the output format to logistic and output type to .asc, c) random percentage test = 25%, d) replication of as many as ten times, e) type of subsample replication, and e) maximum iterative process of 5,000 times. With regard to the target animals that have a minimal amount of animal presence data, bias grid processing was conducted in advance to minimize the bias of the results (Phillips & Dudik, 2008; Wibisono et al., 2018).

This study evaluated the model using discrimination metrics: the area under the curve (AUC). The receiver operating characteristic (ROC) curve was produced based on the analysis of omission/commission. The area under the ROC curve (AUC) indicated the performance of the running model. An AUC value of 0.5 suggests that the model is not great. An AUC value close to 1.0 insinuates that the model is superior (Young et al., 2011). However, the AUC value tends to be higher for species with limited data distribution. Therefore, a high AUC value does not always indicate a superior model. Instead, it is an artifact of AUC statistics (Phillips et al., 2006; Phillips et al., 2009).

Next, we conducted data validation through ground checks to evaluate the results of the spatial modeling. Data validation was carried out to discover the suitability between the computational results of spatial modeling and the field condition. Data validation was performed in 38 sample grids. The grids were distributed randomly in six blocks that represent the GHSNP area. The grid locations represented some characteristics of the modeling results, such as opened areas, forest areas, and areas that are considered suitable as release locations. The correlation between the spatial modeling results and field conditions was determined using logistic regression analysis. This method is the best model to

Table 1 Environmental variables for each target animal

Environmental variable	Javan leopard	Javan gibbon	Javan slow loris	Leopard cat	Javan hawk-eagle
Elevation	√	√	√	√	√
Slope	√	√	√	√	√
Precipitation	√	√	-	√	-
Distance to the river	-	√	√	√	√
Food	√	-	-	-	-
NDVI	√	√	√	√	√
Land cover	√	√	√	√	√
Distance to farm areas	√	√	-	-	
Distance to primary forest	√	√	-	-	√
Distance to secondary forests	√	√	√	√	√
Distance to community settlements	√	√	√	√	√

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illustrate the relationship between responsive variables (Hosmer & Lemeshow, 2004). The formula used is shown in Equation *[1]*.

$$Logit\ P(Y) = ln\left(\frac{P(Y)}{1-P(Y)}\right) \leftarrow \hat{Y}_i = b_0 + b_1X_1 \quad [1]$$

Note: Logit $P(Y)$ is the logistic regression, b_0 is a constant, and b_1X_1 is the variable coefficient.

The study designated the javan leopard as one of the target animals to analyze the compatibility between the spatial modeling results and field conditions. This designation is based on the fact that the javan leopard is the top predator in balancing the food web in the ecosystem. Moreover, the javan leopard is an opportunistic animal belonging to the big cat family (Rahman et al., 2017). It is not a fastidious animal, and it exerts all the opportunity to catch its prey. Thus, the existence of a javan leopard is an indicator of the existence of other animals or prey. Therefore, this study expects that the data validation of spatial modeling results of javan leopard habitat suitability could illustrate the accuracy of the spatial modeling results and how the model validation process must be carried out before it can be considered as a potential release location.

Prediction of release location In addition to strictly complying with the three main requirements set out by the IUCN Guidelines for Reintroductions and other Conservation Translocations (2013), results from the spatial modeling process would be the basis for determining the location for animal release. After determining the habitat suitability for each target animal, elimination was conducted to designate the area for the released location. The criteria consisted of the distance to the community settlement being more than 500 m (>0.5 km) and the maximum distance to the road (translocation endpoint) being less than 2 km.

The first criterion was to ensure that the release location was not too close to the community settlements. Moreover, it also prevented the released animals from moving from their habitat and entering community settlements. The second criterion was to ease transportation and logistical support when carrying the animals to the release location (with a note that, typically, animal release activities include land transportation and are carried out on foot).

Results and Discussion

Environmental variables and habitat suitability The analysis used animal presence data that was mainly in the GHSNP database. From 2007 to 2019, there were 13,000 records of animal encounter points consisting of various species. However, this study had some limitations. The presence data varied for each target animal because some animals are naturally secretive, cryptic, nimble, and live in remote areas. For example, for the javan hawk-eagle, we utilized the point records of the encountered active nests with the assumption that the existence of the nests indicates the presence of the species. The javan slow loris data were derived from the post-release monitoring conducted by YIARI, which employed radio telemetry data and data on wild javan slow loris inventory with relatively less data occurrence. Generalization was needed to minimize bias in the analysis results (Wibisono et al., 2018). The data were studied and filtered to acquire five animals targeted in this study. The modeling results for all target animals in this study were adequate, with AUC values of 0.886–0.916 and a standard deviation of 0.005–0.027 (SD<0.05). The number of animal encounter points used varied according to the availability of animal data (Table 2).

The effects of environmental variables varied for each target animal. For the javan leopard, the three most contributing variables to the Maxent model result (>10%) were food distribution (31.3%), slope (26.7%), and elevation (21.5%). For javan leopards, food distribution had a prominent influence on the modeling results because their distribution patterns tend to follow the movement of their prey (Lamichhane et al., 2021; Ario et al., 2022). While the slope and elevation did not limit the movement of javan leopards, these variables became the factors that restricted prey. The environmental variables that significantly contributed to the suitability of the javan gibbon habitat were slope (25%), distance to secondary forest (19.4%), distance to community settlement (12.6%), elevation (12.8%), and distance to primary forest (11.9%). The slope contributes the most to the model results because the movement of the javan gibbon is not limited by this variable as long as a canopy is available to keep it moving (Hamard et al., 2010; Cheyne et al., 2016). On the other hand, the javan gibbon is found much further away from secondary forests and settlements as a self-defense mechanism and to avoid disturbance.

For the javan slow loris model, the results were primarily affected by the distance to secondary forest (36%), elevation (27.6%), and distance to community settlement (25.5%). According to the response curve of Maxent's modeling, the habitat suitability of javan slow loris tends to be higher closer to the secondary forest. Moreover, bamboo woods and agricultural lands, such as coffee and rubber plantations (Cabana et al., 2017; Nekaris et al., 2017; Sari et al., 2020; Sodik et al., 2020), are frequent habitats for Javan slow loris (Voskamp et al., 2014; Nekaris et al., 2017). Owing to the large amount of feed in agricultural areas, the habitat of the javan slow loris has a very wide niche (Pliosungnoen et al., 2010). Javan slow loris feeds on a variety of sources, including insects, *Calliandra* spp., gum, and nectar (Cabana et al., 2017; Fransson, 2018).

Distance to community settlement (27%), elevation (22.9%), land cover (17.6%), and distance to secondary forest

Table 2 The information inputted into Maxent and the results of area under the curve (AUC)

Species	Number of points/dots	AUC values	SD
Javan leopards	1,027	0.886	0.005
Javan gibbons	710	0.804	0.006
Leopard cats	35	0.891	0.027
Javan slow loris	216	0.916	0.010
Javan hawk-eagle	11	0.897	0.059

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(11.6%) were the environmental variables that mostly contributed to the suitability of leopard cat habitat. The variables that contributed the most to the model results for the javan hawk-eagle were land cover (40.4%), distance to secondary forest (19.5%), and slope (17.9%). Nests of the javan hawk-eagle are generally found in areas with high-density land cover and mountainous terrain, according to field observations. To avoid disturbances and predators, this is a form of self-defense. Elevation and distance from the secondary forest were the two most influential variables in the analysis results. Except for the javan hawk-eagle, elevation had an influence on the model results. The distance from the settlement affects all animals other than the javan leopard. Distance to agricultural area, distance to river, precipitation, and NDVI are other variables that do not significantly affect the model results. This demonstrates that these variables have little impact on animal distribution.

Based on logistic regression analysis, the javan leopard was found in 26 of the 38 grids. The analysis showed that when the Maxent logistic value increased, the probability of detecting a javan leopard increased significantly ($\beta = 12.067 \pm 4.95$, $z = 2.44$, p-value <0.05). This exhibited a strong positive correlation between the presence of javan leopards and habitat suitability prediction based on Maxent analysis (Figure 2). The logistic regression analysis results depict the probability of javan leopard encounters, in which the higher the value of spatial modeling for habitat suitability, the greater the possibility of encountering the indicators of javan leopard presence rises significantly. According to field observations, the percentage of compatibility between the results of habitat suitability modeling and the actual condition in the field reached 92%. Furthermore, the javan leopard appeared in 35 of the 38 grids that had suitable land cover. Therefore, employing the results of spatial modeling using Maxent software for further use in determining habitat suitability and predicting release locations is acceptable.

Designation of release location Many studies on habitat suitability and distribution modeling focus on how various algorithmic models on paper are used only to theoretically assess and predict potential habitats for wildlife. Unfortunately, this modeling has not been widely applied for species conservation purposes, especially in efforts to repatriate species to their natural distribution habitats. Habitat suitability assessments are necessary to identify potential locations to release rehabilitated wild animals. Our study demonstrated that this can be achieved with the utilization of spatial modeling using Maxent software, validation of Maxent results through a ground check, and field correction. Thus, a suitable habitat and the prediction of release locations for each target animal can be identified. In general, the spatial modeling results were consistent with the ground verifications and actual conditions in the field. In highly suitable habitats of the target animals modeled using Maxent, the encounter with the indicators of animal presence was adequately high. Conversely, in less suitable habitats (low pixel values), the actual condition in the field included non-forest areas, such as pastures, rice fields, and community settlements. Other information recorded during data validation included potential locations for releasing the target animals, as well as potential threats in the predicted areas for releasing the animals.

Using the habitat suitability map (Figure 3), the designation of animal release locations was based on two additional criteria: the location was not too close to community settlements and not too far to facilitate the manual translocation process (carrying boxes containing released animals by hand). In this process, the identified suitable habitat predicted using Maxent was clipped based on these two criteria. The approximate total area for animal release locations was 15,578–33,471 ha (Table 3; Figure 4). In Indonesia, national parks are managed using a zoning system. Based on this notion, this study also estimated the total area of suitable habitat in each management zone. The analysis showed that suitable habitats and predicted release locations were identified in all types of management zones,

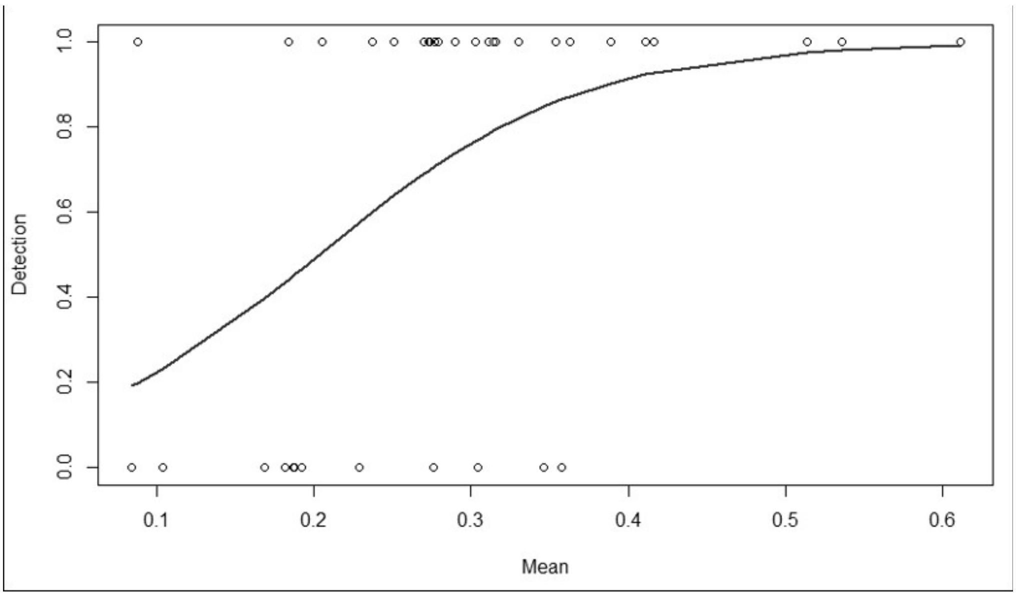

Figure 2 The relation between pixel means value and the possibility of the detection of javan leopard.

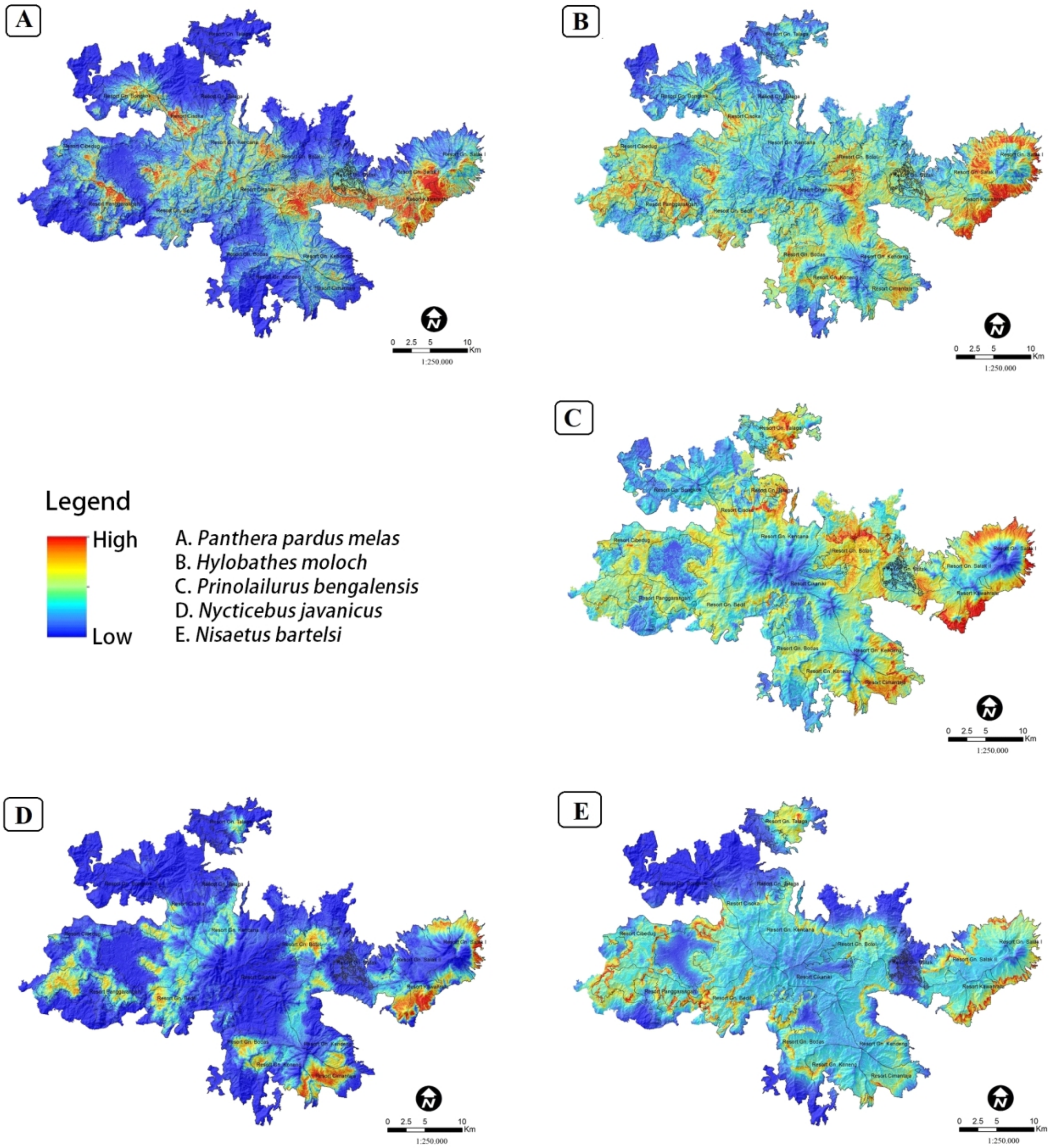

Figure 3 The result of animal habitat suitability modeling in Gunung Halimun Salak National Park.

Table 3 Total area of suitable habitat predicted using Maxent and potential release locations in Gunung Halimun Salak National Park

Species	Suitable habitat (ha)	Release location (ha)
Javan leopards	47,619	21,391
Javan gibbons	57,537	33,471
Leopard cats	25,460	17,189
Javan slow loris	29,848	15,578
Javan hawk-eagle	44,426	25,660

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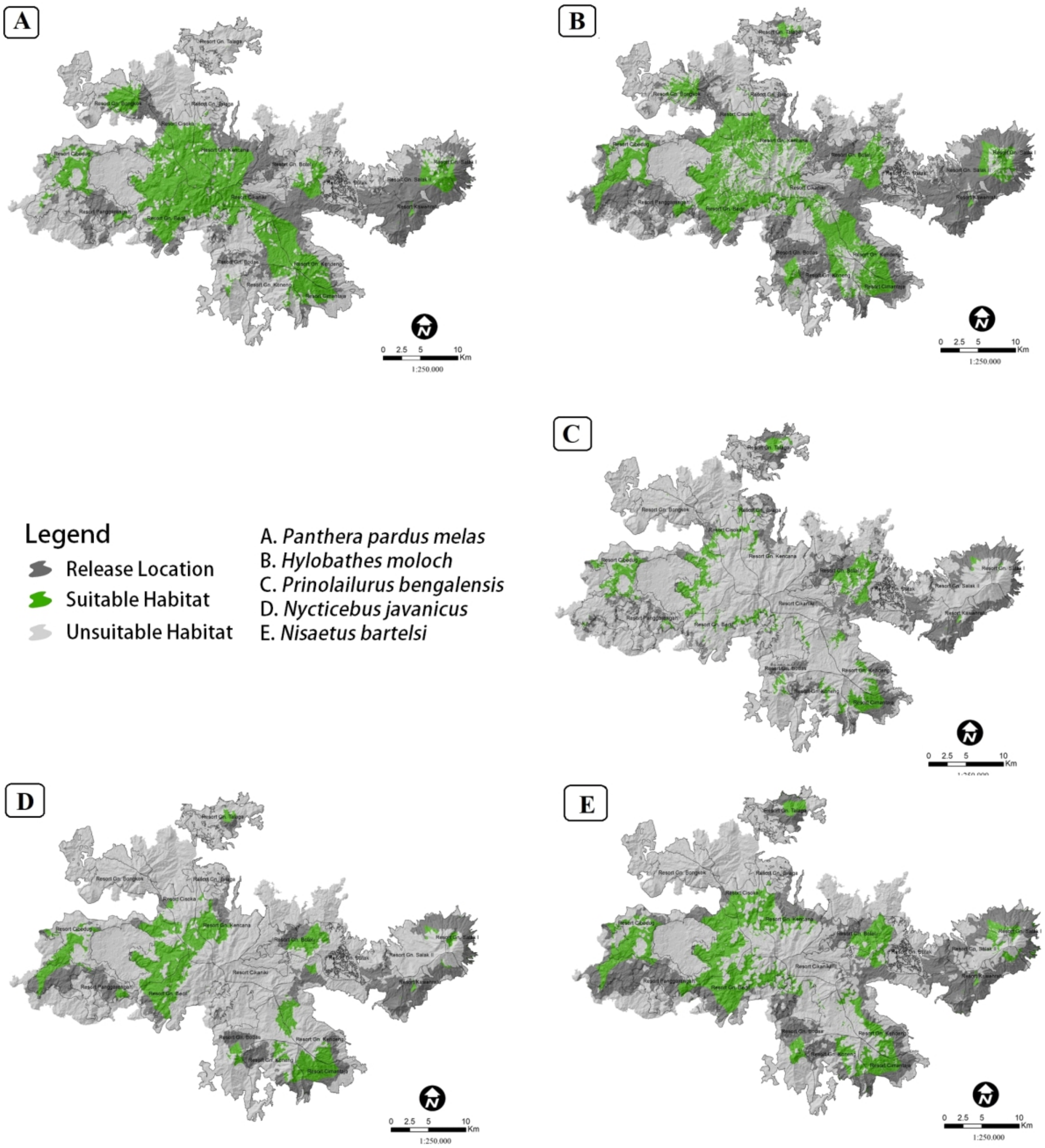

Figure 4 The map of suitable habitat predicted using Maxent and potential release locations in Gunung Halimun Salak National Park

in which 70% to 80% of the suitable habitat was located in the core and forest zones (Table 4). Based on their function, the core and forest zones serve as primary locations for wild animal habitats and populations. Hence, the actual conditions were consistent with the assessment of habitat suitability.

Implications and conservation strategy The results of this study are applicable for implementation in the GHSNP area. The management of GHSNP could respond directly and rapidly each time if there is an appeal for a release location but still with the precautionary principle, especially for territorial animals such as the javan leopard, javan gibbon, javan slow loris, and javan hawk-eagle. For example, choosing a location with unhealthy population conditions in an area or when the population is likely much lower than the carrying capacity of its habitat. For territorial wild animals, it is crucial to consider the population density in the candidate release locations to perceive the valid population status and animal distribution. Furthermore, it is also necessary to conduct further studies on the socio-economic aspects of nearby communities. Both studies are essential to minimize the conflict between humans and territorial animals. Consequently, the primary considerations in determining release locations are relatively far from the community settlements (to mitigate new conflicts), relatively safe from hunting activities or threats, and with adequate food

Table 4 Suitable habitat for each target animal on each zone in Gunung Halimun Salak National Park (hectares)

Zones	Javan leopard	Javan gibbon	Leopard cat	Javan slow loris	Javan hawk-eagle
Core	27,437.56	25,519.25	8,249.79	16,781.80	19,303.52
Forest	10,805.47	14,171.50	7,606.17	7,897.11	12,098.82
Utilization	4,897.45	5,603.26	3,035.26	2,151.00	3,631.49
Rehabilitation	2,394.69	6,014.18	4,298.51	1,664.99	5,055.05
Specific	747.31	1,246.09	577.94	439.44	944.44
Traditional	138.99	229.45	214.96	190.54	220.19
Culture	1.33	5.02	4.55	4.51	4.55
Outer NP	1,197.19	4,749.25	1,473.25	718.72	3,168.95
Total	47,619.98	57,538.00	25,460.44	29,848.10	44,427.00

availability. This notion is encouraged by many experts, who argue that further studies that focus on territorial animals, such as javan leopard (Wibisono et al., 2021) and javan gibbon (Kim et al., 2011; Bartlet et al., 2016; Ario et al., 2018), are required.

This research is expected to provide an answer for determining the release location, particularly for five species of animals in the GHSNP area. The findings of this study have been used to determine the release sites for javan slow loris and leopard cat species over the last two years. Finally, it is hoped that this process can be replicated in other conservation areas, allowing animals currently housed in rehabilitation and rescue facilities to return to their natural habitat.

Conclusion

We identified 21,391 ha, 33,471 ha, 17.189 ha, 15,578 ha, and 25,660 ha of potential release locations for five charismatic animal species in GHSNP, successively for *P. p. melas*, *H. moloch*, *P. bengalensis*, *N. javanicus*, and *N. bartelsi*. Based on the analysis results, elevation and distance from the secondary forest were the two most influential variables. The model results were influenced by elevation, except for the javan hawk-eagle. However, the distance from the settlement affects all animals, except the javan leopard. Other variables such as NDVI, distance to agricultural areas, distance to rivers, and precipitation did not significantly affect the model results. The Maxent modeling framework presented here provided excellent results with notably high and stable AUC values. Furthermore, concerning the validation of five endemic species maps chosen to demonstrate the model's strength, we have shown that the model has good performance, where the percentage of compatibility between the results of habitat suitability modeling and the actual condition in the field reached 92% for the example of one of the charismatic species in the GHSNP. Moreover, the results of this study provide valuable baseline information on the habitat use of five endemic species of the GHSNP that would help managers of the park to detect changes that might occur in this aspect to make effective conservation decisions and measures. This study provides important ecological information on five endangered endemic species and demonstrates an imitative method for examining the distribution of wildlife in Indonesia.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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