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The Importance of Unprotected Areas as Habitat for The Leopard Cat (*Prionailurus bengalensis javanensis* Desmarest, 1816) on Java, Indonesia

Pentingnya Kawasan Non Lindung sebagai Habitat Kucing Hutan (*Prionailurus bengalensis javanensis* Desmarest, 1816) di Jawa, Indonesia

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ABSTRACT

Protected areas play important roles for protecting many endangered species in Indonesia. However, very limited information regarding roles of protected areas and non-protected areas for supporting the habitat of less-concerned carnivores in Java, leopard cat (Prionailurus bengalensis javanensis). We aim to assess the relative roles of non-protected areas for the habitat of this cat on the highly fragmented and populated island of Java. We develop species distribution modelling, using Maxent by integrating various sources of presence data of this species and environmental data. Our finding confirms that leopard cat can life in various habitat types but mainly patchy forest areas. While most of the protected areas are suitable for the habitat of this smallest cat on Java, the non-protected areas provide much larger areas for its habitat (66.8 %). Our findings highlighted the importance of maintaining connectivity among habitat patches in non-protected areas, habitat protection using current government policy on high conservation value forest and essential ecosystems areas.

INTISARI

Kawasan lindung memainkan peran penting dalam melindungi banyak spesies yang terancam punah di Indonesia. Walaupun demikian, informasi mengenai peran kawasan lindung dan kawasan non lindung untuk mendukung habitat karnivora yang kurang mendapat perhatian di Jawa, kucing hutan (Prionailurus bengalensis javanensis), sangat terbatas. Penelitian ini bertujuan untuk menilai peran kawasan non lindung sebagai habitat kucing hutan di Pulau Jawa, pulau yang sangat terfragmentasi dan padat penduduk. Kami mengembangkan pemodelan distribusi spesies, menggunakan Maxent dengan mengintegrasikan berbagai sumber data kehadiran spesies kucing hutan dan data lingkungan. Temuan kami menegaskan bahwa kucing hutan dapat hidup di berbagai jenis habitat tetapi habitat utamanya adalah kawasan hutan yang agak terbuka. Meskipun sebagian besar kawasan lindung sesuai untuk habitat kucing terkecil di Jawa ini, kawasan non lindung justru menyediakan area yang jauh lebih besar untuk habitat kucing hutan (66,8 %). Temuan kami juga menyoroti pentingnya menjaga konektivitas antar habitat di kawasan non lindung dan perlindungan habitat dengan menggunakan kebijakan pemerintah saat ini tentang hutan Bernilai Konservasi Tinggi dan Kawasan Ekosistem Esensial.

Introduction

Home to 60% of Indonesia's human population (ca 170 Millions), the island of Java is one of the most densely populated islands in the world. Despite high anthropogenic pressures leading to many environmental problems such as loss of forest cover up to 64% as long as 2001-2009 (Ferdaus et al. 2014), this island is also still home to many endangered and critically endangered species, including the javan rhino *Rhinoceros sondaicus* (Setiawan et al. 2018; Harjanto & Mentari 2019), javan banteng *Bos javanicus* '(Pudyatmoko et al. 2007; Purnomo & Pudyatmoko 2011; Imron et al. 2016; Qiptiyah et al. 2019), javan leopard *Panthera pardus melas* ''' –''(Rode-Margono et al. 2014; Wilting et al. 2016; Wibisono et al. 2018; Husodo et al. 2019), dhole *Cuon alpines* '''(Nurvianto et al. 2015; 2016), javan hawk-eagle *Spizaetus bartelsi* (Balen et al. 2001) and numerous other birds species (Balen 1999).

Deforestation in Java began early in the 18th century (Nijman 2013). The *cultuurstelsel* policy, as implemented between 1830-1870 by the East India Trading Co. in the Netherlanzds, led to the wholesale conversion of vast forest areas into monoculture plantations such as coffee and tea (Balen 1999). It is currently estimated that < 10% of Java's original native forests remain, most occurring as geographically isolated patches associated within protected areas (Nijman 2013). Although the establishment of protected areas have helped to protect and recover natural forests, most are small and scattered. For example, the protected areas network in Central Java includes a total number 38 areas, most of them (26 areas) only cover no more than 60 hectares, respectively (Sulistyari 2013). Given the high human density of course, continued pressures on Java's forests persist, which continue to threaten the survival of many endangered species and even cause the decline of formerly common species.

As a taxonomic group, mammalian carnivores generally occupy higher relative trophic positions in a given ecosystem, have relatively high metabolic rates, and are distributed across comparably low densities; they are therefore particularly vulnerable to extinction resulting from the effects of habitat loss, habitat fragmentation, and illegal hunting, inevitable consequences of the encroachment of agricultural and urban development (Lindenmayer & Fischer 2006). High market demand for mammalian carnivores as pets and for their parts (Oswell 2010) have caused the acceleration of an extinction vortex. Following the extinction of the Javan tiger *Panthera tigris sundaica*, the island is believed to still provide habitat for three felid species: the critically endangered javan leopard *Panthera pardus melas (Gunawan 2010)*, the javan leopard cat *Prionailurus bengalensis javanensis* ''(Shanida et al. 2018) and the fishing cat *Prionailurus viverrinus* (Melisch et al. 1996). Javan leopards are mostly confined to protected areas, such as large national park and nature reserves '''

(Wilting et al. 2016; Wibisono et al. 2018). Wherever leopards are absent, the smaller leopard cat by default becomes the largest felid predator, and is an important predator of agricultural pests (Silmi et al. 2013).

Different leopard cat subspecies have been intensively studied in and around many protected areas, including a wildlife reserve in Bangladesh (Khan 2004), tiger and biosphere reserves in India (Bashir et al. 2013; Selvan et al. 2014), various protected areas in Nepal –(Appel et al. 2013), China (Jinping 2010), South Korea '(Lee et al. 2015), Japan (Schmidt et al. 2009; Oh et al. 2010), Thailand (Grassman 2000; Austin et al. 2007), Malaysia (Rajaratnam et al. 2007; Brodie & Giordano 2010; Mohamed et al. 2013), Indonesian Borneo (Cheyne & Macdonald 2011; Silmi et al. 2013; Mohamed et al. 2016), and Sumatra (Subagyo et al. 2013; McCarthy et al. 2015).

Although leopard cats are known to be more tolerant of human-modified landscapes (Mohamed et al. 2016) and it is not globally threatened, leopard cats in Java have recently endured population declines as a result of habitat loss and fragmentation. Whilst the IUCN considers its status as 'Least Concern', local populations are still being hunted and traded, this despite legal protection from the Indonesian government. Still widely distributed across Java, traditional and online trade in the species (Nowell & Jackson 1996; Nijman et al. 2019) may have substantial negative impacts on local populations. And because most protected areas in Java emphasize only the leopard as a flagship species to further conservation agendas, there is much less concern and awareness about leopard cats.

In contrast to large cat species, which serve as symbols of beauty and strength for many cultures while also being feared and admired (Boomgaard 2001), meso-carnivores like small cats are frequently considered pests that threaten poultry, or other small livestock and pets (Jenks et al. 2014). However, island populations are vulnerable to local extinction, and need to be managed as a distinct management unit (Watanabe 2012). Several other island leopard cat subspecies and populations, including the Taiwanese leopard cat and Iriomote cat, are already endangered (Schmidt et al. 2009; Chen et al. 2016). A better understanding therefore of the distribution of the leopard cat across Java is theoretically important for the implementation of proactive conservation measures. Until now, verifiable information on leopard cat occurrences outside of protected areas has been extremely limited. Our study aims to investigate and map the probabilistic distribution of leopard cats on Java to constitute the basis of a conservation strategy for this still widespread but declining species.

Material and Methods

Data collection

We reviewed and documented the occurrence of leopard cats (*P.b. javanensis)* on Java from field surveys, grey literature (*eg*, data repository, unpublished reports), and communication with field researchers and biologists involved in previous and ongoing studies. This included data from the state-owned forestry company PERUM PERHUTANI, and all provincial natural resources conservation bodies (ie, Central Java Province, East Java Province, Yogyakarta Special Province, West Java Province, Banten Province and Jakarta Province), as well as national park and natural resources conservation staff in Java.

We then collected various environmental variables as predictors of the presence of leopard cats in potentially suitable habitat (Kalle et al. 2014; Mohamed et al. 2016). These consisted of abiotic and biotic variables relating to the physiological and ecological “tolerance” (ie, “presence”) of leopard cats (Mohamed et al. 2016), including bioclimatic factors, land cover types, topography, ecologically-relevant features or distances, vegetation indices, and anthropogenic variables (Table 1).

Table 1. Predictor variables tested for the species distribution model of leopard cat
Tabel 1. Variabel-variabel prediktor yang diuji untuk model distribusi spesies kucing hutan

Variable	Sources	Type	Format
Annual mean temperature (°C)	BioClime (http://worldclim.org/version2)	Continuous	Raster
Annual precipitation (mm)	BioClime (http://worldclim.org/version2)	Continuous	Raster
Altitude	Digital Eelevation Model (DEM) Shuttle Radar Topgraphy Mission (SRTM) (https://dwtkns.com/srtm30m/)	Continuous	Shapefile
Slope	Calculated from elevation DEM	Continuous	Raster
Land Cover	The national spatial planning agency (Baplan) of Ministry of Environment and Forestry	Categorical	Shapefile
Distance to the road	Generated from RBI map (https://portal.ina-sdi.or.id/downloadaoi/)	Continuous	Raster
Distance to the river	Generated from RBI map (https://portal.ina-sdi.or.id/downloadaoi/)	Continuous	Raster
Distance to the nearest settlement	Generated from RBI map (https://portal.ina-sdi.or.id/downloadaoi/)	Continuous	Raster
Normalized Difference Vegetation Index (NDVI)	Landsat 8 2018 (https://earthexplorer.usgs.gov/)	Continuous	Raster
Soil type	Ministry of Agriculture	Categorical	Shapefile

Data analysis

We then followed Dormann et al. (2013) in testing for multicollinearity to identify autocorrelation among continuous and potentially redundant predictor variables. We did this in Program R by randomly selecting 1000 points from the background where each point contained a variable value that was previously extracted. Landcover and soil type variables of course were excluded from these tests, as these are categorical variables. Multicollinearity can be detected by the value of Variance Inflation Factor (VIF). The VIF is a measuring tool to calculate the influence of interaction/correlation among independent variables. If the VIF exhibited > 10, it indicates a correlation between independent variables, and should be removed from further model development.

To construct a niche distribution model for the leopard cat on Java, we used the maximum entropy algorithm in the MaxEnt program version 3.4.1 (Phillips et al. 2004; 2006; Phillips 2017) in QGIS. MaxEnt is an established approach for predicting the distribution of species (Baldwin 2009) and has been used to advance similar conservation planning objectives for leopard cats on nearby Borneo (Mohamed et al. 2016). In Java, distribution modelling has also been used for other threatened mammal and bird species (Voskamp et al. 2014; Winasis et al. 2018; Sodik et al. 2020).

We initially used 75% of our leopard cat occurrence data as a training data set, and the remaining 25% as testing data. We changed MaxEnt setting combinations prior to each run of the model and followed Phillips et al. (2006) in our reporting of logistic regression outputs. Modelling simulations consisted of 10 replicates with bootstrap resampling technique (Guisan & Zimmermann 2000); we used a10th percentile training threshold value to classify habitat and non-habitat area as suggested by Redon and Luque (2010). The Receiving Operating Curve (ROC) was used to evaluate model performance. AUC's are created from ROC plots to give a positioned approach for valuing discrepancy of species allocations for a model compared to a random dispersion (Baldwin 2009). Only AUC values of at least 0.7 - 0.9 were considered informative, whereas AUC values > 0.9 ensured the highest levels of model precision (Swets 1988). A Jackknife test was used to determine the contribution of each variable to the overall model (Elith et al. 2011). Habitat and non-habitat areas were classified according to pixel value; pixel below the 10-percentile training threshold value (ie, < 10%) were classified as "non-habitat" areas, whereas those exceeding the threshold value were classified as "habitat". We then overlaid our probabilistic distribution map for the leopard cat over a map of protected areas to identify the proportion of Java's protected (eg, national parks, nature reserve, wildlife reserve, nature recreational parks, and grand forest parks) and unprotected areas potentially occupied by this small cat.

Results and Discussion

Species occurrences records

We collected and mapped 101 new occurrence records (Figure 1) of the leopard cat between 2013 - 2019 to train and develop our predictive distributional model (Table 2) for the species on Java.

Parameter selection

Unsurprisingly, our first multicollinearity test resulted in a high correlation between annual mean temperature and altitude variables (VIF>10). Because small carnivores are sensitive to environmental factors at the scale of individual home-ranges, we eliminated

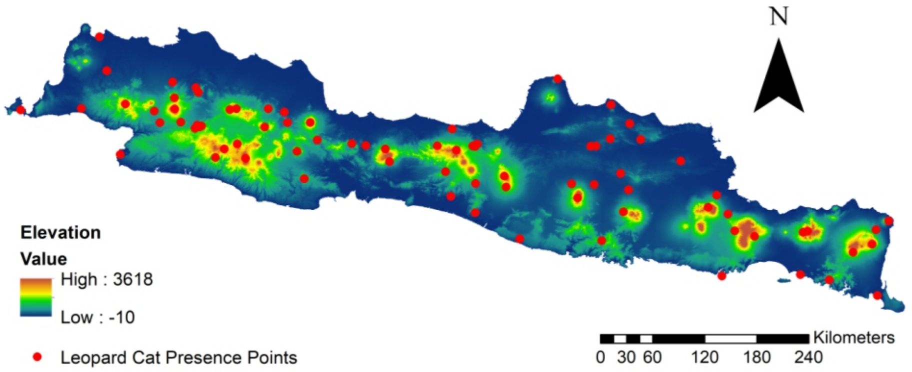

Figure 1. Distributional records of leopard cat (*P.b. javanensis*) on Java based on elevation as obtained from various surveys, grey literature reviews, and personal communication and data-sharing with rangers, forest staff, and other biologists, between 2013-2019.
Gambar 1. Sebaran kucing hutan (*P.b javanensis*) di Jawa berdasar ketinggian yang diperoleh dari berbagai survei, tinjauan pustaka abu-abu, komunikasi personal, dan berbagi data dengan praktisi dan staf kehutanan serta ahli biologi lain antara tahun 2013-2019.

Table 2. Sources and number of leopard cat on Java island data collected from various sources
Tabel 2. Jumlah dan sumber data kucing hutan di Jawa yang dikumpulkan dari berbagai sumber

No	Types of data	Sources	No Records	Region
1	Field survey	Irawan (2019)	21	(indirect from tracks and feces and camera traps data) Temanggung District, Central Java Province
2	Grey Literature	University Online Repository	2	Petungkriono (Pemalang District) and Nusakambangan (Cilacap District) Central Java Province
		PERUM PERHUTANI	12	East Java Regional Division
			11	Central Java Regional Division
			12	West Java Regional Division
		Ministry of Environment and Forestry	10	National Parks
			21	Natural Resources Conservation Agency
		Social media	7	R Soeryo Grand Forest Park, Mekars ari Biodiversity Park, Sewu Karst Mt, Argopuro Mt, Penanggungan Mt, Walat Mt, Tampo mas Mt
		Communication with researcher	1	Cipaganti, Garut District, West Java Province
3	Research Article	Shanida et al (2018)	4	Cisokan, Cianjur District, West Java Province

the annual mean temperature for our subsequent test. This test resulted in no additional collinearity among included variables (VIF < 10), clearing the way for their use in model development (Table 3).

Importance of environmental variables

The contribution and importance of each environmental variable used as a predictor model is expressed as a percent (Table 3). The highest contribution from among our model variables was for landcover (26.6%). Our regularized training gain, test gain jackknife, and jackknife of AUC tests, also confirm that land cover was the factor most important in influencing the presence of the leopard cat on Java (Figure 2). Among land cover types, the gain value from AUC jackknife test showed that primary dryland forest, secondary dryland forest, primary mangrove forest, plantation forest, and shrubland, play an important role in contributing to habitat for the leopard cat (Table 4).

Table 3. VIF values for our first and second multicollinearity test of continuous variables, and their contribution to model development using all environmental predictors of leopard cat presence on Java
Tabel 3. Nilai VIF untuk uji multikolinearitas pertama dan kedua dari variabel-variabel lingkungan serta kontribusinya terhadap pengembangan model dengan menggunakan seluruh prediktor lingkungan keberadaan kucing hutan di Jawa

Environment variable	VIF		Contribution to model	
	First	Second	Percentage	Permutation importance
Annual mean precipitation	1,492	1,447	3.7	5.8
Annual mean temperature	33,124	Excluded	NA	NA
Distance from the river	1,106	1,106	0.7	0.9
Distance from the road	4,130	4,108	14.8	4.8
Distance from the settlement	5,713	5,697	8.1	8.8
Altitude	34,330	2,576	11.2	16.8
NDVI	1,184	1,163	2.4	3.9
Slope	2,437	2,365	8.7	11.8
Landcover	NA	NA	28.4	26.6
Soil	NA	NA	22	20.6

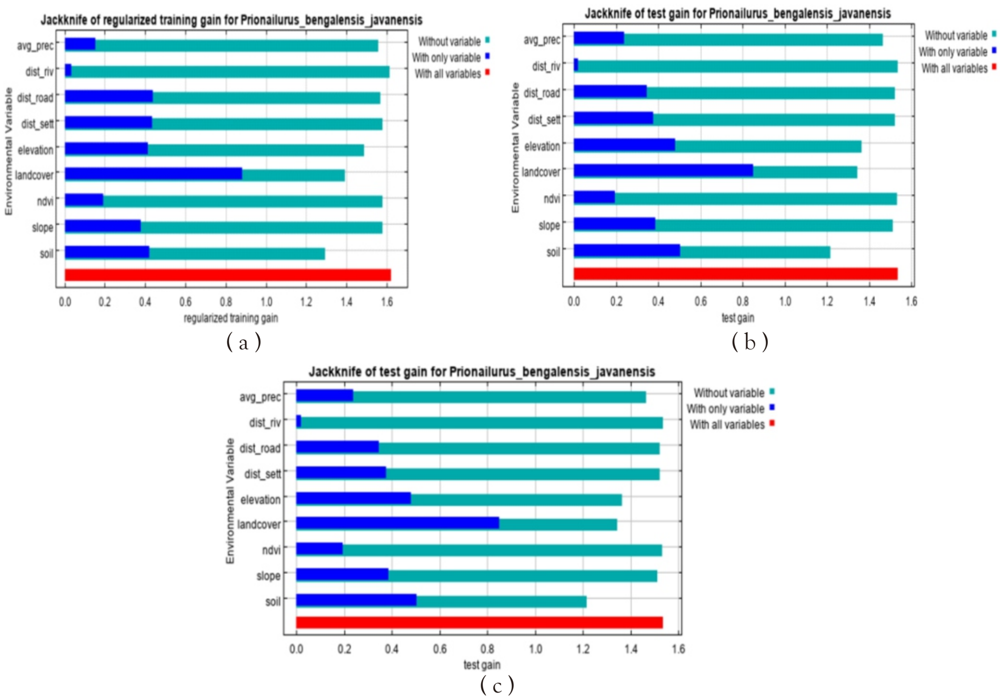

Figure 2. (a) jackknife of regularized training gain, (b) jackknife of test gain and (c) jackknife of AUC.
Gambar 2. (a) uji jackknife *regularized training gain* (b) uji jackknife *test gain* dan (c) uji jackknife AUC

Table 4. *Gain* value in each land cover class using the AUC jackknife
Tabel 4. Nilai *Gain* pada setiap kelas penutupan lahan dengan menggunakan uji jackknife AUC

Land cover types	*Gain* Value
Primary Dryland Forest	0.7192
Secondary Dryland Forest	0.6632
Primary Mangrove Forests	0.7224
Plantation Forest	0.5289
Shrubland	0.5323
Plantation	0.1813
Settlement	0.0683
Open Land	0.0683
Savanna / Meadow	0.0683
Water body	0.0683
Secondary Mangrove Forests	0.0683
Dryland farming	0.0683
Mixed Dry Land Agriculture	0.1259
Dry Land Farming	0.0953
Pond	0.0437
Airport / Port	0.0683
Mining	0.0683
Swamp	0.0683

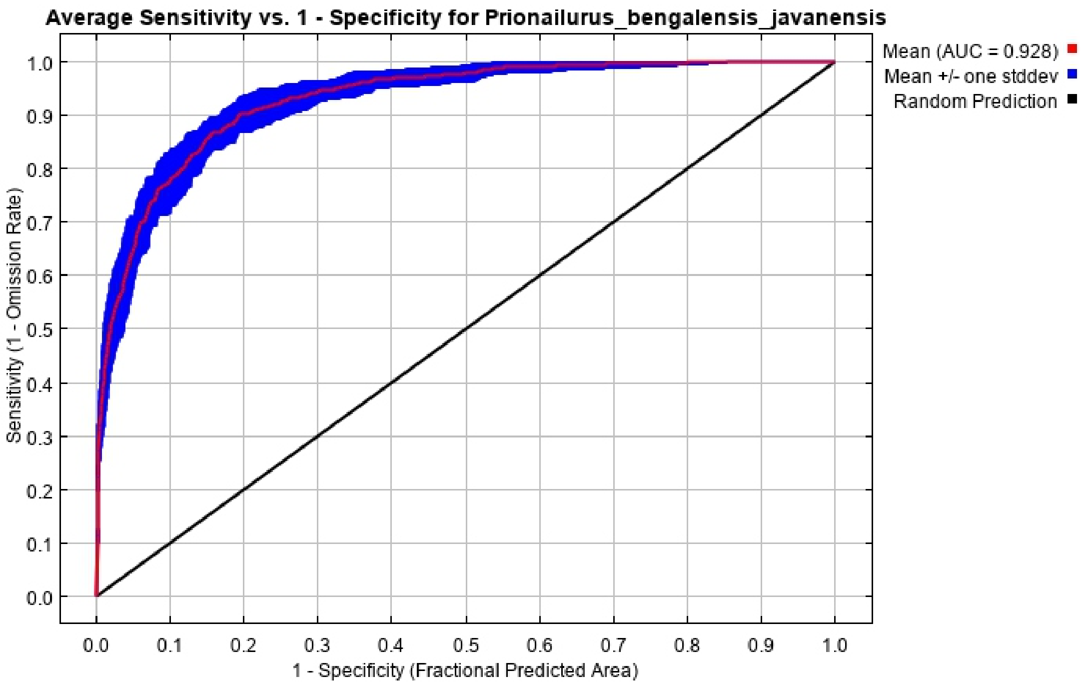

Figure 3. ROC curve graph of the model AUC value using Fractional Predicted Area and Sensitivity for *P.b. javanensis*
Gambar 3. Grafik kurva ROC dari nilai model AUC menggunakan *Fractional Predicted Area* dan sensitifitas untuk *P.b javanensis*

Spatial distribution model

We achieved a high AUC value for our model (0.928), indicating that it had relatively high accuracy. This can be further visualized by the ROC curve, which clearly indicates high model performance for predicting the presence of leopard cat (Figure 3).

We found the leopard cat to be widely distributed across Java from the west coast, including Ujung Kulon National Park, to the island's easternmost region in Alas Purwo National Park. Our results suggest that the central or middle part of Java is surprisingly important to the distribution of the leopard cat on Java (Figure 4). This is interesting because there are no large protected areas in this region. The highest probabilities of their occurrence appeared to be associated with relatively high altitudes (Figure 4). In using the 10th percentile training threshold to determine habitat potential for leopard cats (, we obtained a threshold value of 0.1955 for the model.

We classified 1,986,462.5 hectares, or approximately 15.78% of the total terrestrial area of Java, as leopard cat habitat. Although leopard cat habitat is distributed widely across the island from east to west and north to south, the highest quality and density habitat appeared to be associated with relatively high altitudes and mountainous areas in eastern Java. Classified habitat in central and western Java was less dense and more scattered or interspersed with non-habitat.

Our classification of different land cover types indicated that plantation forests and secondary dryland forests provide significant habitat for leopard cats, comprising 53.90% and 22.44% of the total habitat expanse for the species on Java (Table 5). Interestingly when evaluating land protection status, most of the area classified as leopard cat habitat occurs outside of those areas with some conservation protection status (66.8 %) on Java (ie, most leopard cat habitat is "unprotected" land according to our model); economic production forest in particular is an important habitat for leopard cats (Table 6). In contrast, protected areas only represented approximately one-third of the total habitat for leopard cats by area. Among those protected areas most important to leopard cats, the relatively small wildlife reserves, totalling 32,493.75 hectares in area, appear to play a very important role (93.04% based on function).

(a)

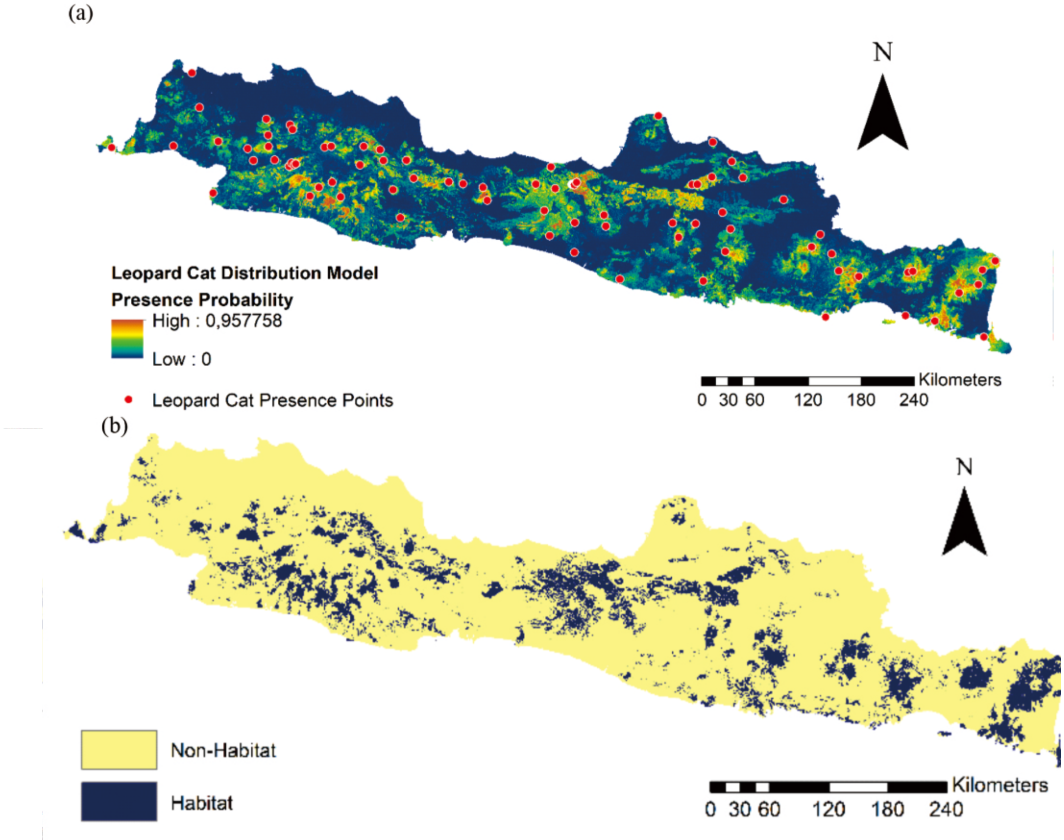

Figure 4. (a) Map of leopard cat distribution for Java based on our model; (b) Habitat and non-habitat classification map of the leopard cat

Gambar 4. (a) Peta sebaran kucing hutan di Jawa; (b) Peta klasifikasi habitat dan non habitat kucing hutan

Table 5. Size and proportion of leopard cat habitat under different land cover types
Tabel 5. Proporsi dan ukuran habitat kucing hutan pada tipe penutupan lahan yang berbeda

Land cover class	Size (ha)	Habitat (ha)	Non-Habitat (ha)	Proportion (%) habitat from	
				land cover classes	Total habitat
Plantation forest	2,312,881.25	1,414,118.75	898,762.50	61.14	53.9
Secondary Dryland Forest	658,500.00	588,612.50	69,887.50	89.39	22.44
Dryland Farming Mixed	2,123,756.25	155,056.25	1,968,700.00	7.3	5.91
Shrubland	116,462.50	91,337.50	25,125.00	78.43	3.48
Primary Dryland Forest	58,962.50	55,818.75	3,143.75	94.67	2.13
Rice fields	3,598,493.75	79,987.50	3,518,506.25	2.22	3.05
Plantation	386,925.00	72,443.75	314,481.25	18.72	2.76
Dryland farming	1,595,387.50	122,437.50	1,472,950.00	7.67	4.67
Settlement	1,481,593.75	16,843.75	1,464,750.00	1.14	0.64
Open Land	44,043.75	11,706.25	32,337.50	26.58	0.45
Savanna / Meadow	11,443.75	9,025.00	2,418.75	78.86	0.34
Water body	69,181.25	4,362.50	64,818.75	6.31	0.17
Primary Mangrove Forests	662.5	587.5	75	88.68	0.02
Secondary Mangrove Forests	6,618.75	525	6,093.75	7.93	0.02
Mining	4,862.50	256.25	4,606.25	5.27	0.01
Pond	102,000.00	237.5	101,762.50	0.23	0.01
Swamp	1,768.75	50	1,718.75	2.83	0
Port/Air port	6,318.75	56.25	6,262.50	0.89	0
Swamp shrub	718.75	93.75	625	13.04	0
Total	12,580,581.25	2,623,556.25	9,957,025.00		100

Table 6. Size and proportion of leopard cat habitat under different land use functions. Habitat proportions are reported as a percentage of habitat size in each function out of the total area for each land use function
Tabel 6. Proporsi dan ukuran habitat kucing hutan pada fungsi penggunaan lahan yang berbeda. Proporsi habitat dilaporkan sebagai persentase ukuran habitat pada setiap fungsi kawasan terhadap total kawasan untuk setiap fungsi penggunaan lahan

Land use Function	Size (ha) (a)	Habitat (ha) (b)	Non-Habitat (ha)	Habitat Proportion (%)	
				Based on function	Total habitat
NON-PROTECTED AREA					
Other uses	9,637,687.50	896,056.25	8,741,631.25	9.3	34.01
Production forest	1,410,068.75	650,381.25	759,687.50	46.12	24.68
Limited Production Forest	398,187.50	215,850.00	182,337.50	54.21	8.19
Total NON PROTECTED AREA	11,445,943.75	1,762,287.50	9,683,656.25	66.8	15.39
PROTECTED AREA					
Protected Forest	646,400.00	491,606.25	154,793.75	76.05	18.66
National Park	352,525.00	262,943.75	89,581.25	74.59	9.98
Nature Reserve	56,781.25	47,381.25	9,400.00	83.45	1.8
Wildlife Reserve	32,493.75	30,231.25	2,262.50	93.04	1.15
Grand Forest Park	31,062.50	28,350.00	2,712.50	91.27	1.08
Hunting Park	12,525.00	9,012.50	3,512.50	71.96	0.34
Nature Tourism Park	3,918.75	3,031.25	887.5	77.35	0.12
Total PROTECTED AREA	1,135,706.25	872,556.25	263,150.00	33.11	33.12
TOTAL	12,581,650	2,634,843.75	9,946,806.25		

Discussion

This maximum entropy (MaxENT) distribution model we present here is the first for the leopard cat on the world's most populous island. This approach has previously been used effectively to model the distribution of a diversity of species in Indonesia, including numerous birds (Winasis et al. 2018) and mammals, such as the javan slow loris *Nycticebus javanicus* (Voskamp et al. 2014; Sodik et al. 2020) and proboscis monkey *Nasalis larvatus* (Wardatutthoyyibah et al. 2019). For some of these species as with the leopard cat here, data was limited and restricted to presence only, constraints for which this approach is best-suited "(Merow et al. 2013). Alternatively, Bashir et al. (2014) used a binary logistic function to model the distribution of the leopard cat. This approach however requires the integration of both presence and absence data, often difficult to obtain from grey literature or acquire through secondary sources. Despite that leopard cats are widespread and “relatively common” across Java, confirmed occurrence records for and studies of the species are still relatively lacking.

Our study demonstrates that whereas many other species have experienced substantial declines and local disappearances due to habitat fragmentation and conversion for agriculture and development, leopard cats still persist in many habitat types across Java. This suggests that our estimate of leopard cat habitat as perhaps only constituting approximately 15% of Java's total area is probably an underestimate. This is further supported by our model suggesting that almost two-thirds of this habitat occurs in unprotected lands. We note the resilience of leopard cats in these areas, and the role of managed habitats to their continued widespread distribution. Our findings underscore the particular importance for example of production and partial production forests under the management of the state-owned timber company (PERUM PERHUTANI) and local governments, as well as privately-managed forests, to leopard cats on Java today. It is possible that their small home ranges in agricultural areas that have been highly impacted by humans, including palm oil and other plantations as demonstrated for other regions (Lorica & Heaney 2013; Silmi et al. 2013; Hood et al. 2019), are a key ecological attribute to their persistence and adaptation. In fact leopard cats are extremely adaptable across their distribution, ranging from shoreline habitats to very high altitudes at > 3000 m asl (Appel et al. 2012; Ross et al. 2015).

As the leopard cat is relatively small and thus would be expected to have a smaller home range than the Javan leopard, relatively fewer resources are of course needed to ensure the persistence of local populations of the former. In addition, the adaptability of leopard cats to agricultural habitat matrices enhances the conservation value of secondary habitats along protected area perimeters and edges. This is in contrast to the Sumatran tiger for example, Indonesia's largest felid, for which viable populations depend on more sustainable land use “buffers” in those human-impacted landscapes surrounding protected areas (Imron et al. 2011; Poor et al. 2019).

Java's production forests are also important to other species, including some that are threatened, endangered, or declining. They provide habitat for javan surili *Presbytis fredericae* (Setiawan et al. 2007; 2010), javan gibbon *Hylobates moloch* (Nijman 2004), javan slow loris *Nycticebus javanicus* (Lehtinen et al. 2013; Nekaris et al. 2017a; Sari et al. 2020), and entire avian communities (Imron et al. 2018). In fact, many of these forests, though traditionally thought long-depleted and degraded on Java, are actually of high conservation value (HCV) (Sulistyowati & Hadi 2018). Initiatives by Indonesia's Ministry of Environment and Forestry to establish Essential Ecosystem Areas

(*Kawasan Ekosistem Esensial*) that permit and encourage active community and private sector conservation measures (Kementerian Lingkungan Hidup dan Kehutanan 2015), are additional contributions to the habitat of leopard cats and more threatened species.

Based on the evidences of morphological, genetic and biogeographical, the IUCN Cat Specialist Group recently distinguished 2 species of leopard cats: Mainland leopard cat *Prionailurus bengalensis* (Kerr 1792) and Sunda leopard cat *Prionailurus javanensis* (Desmarest, 1816) '(Kitchener et al. 2017). We believe that especially compared to other regions, more research is needed on the "javanese" leopard cat, or the javan populations of the sunda leopard cat. Field investigations of populations, including in both protected and agricultural areas (Bashir et al. 2013; Littlewood et al. 2014; Chen et al. 2016; Park et al. 2017; Lee et al. 2019), assessments of leopard cat diet (Grassman 2000; Lorica & Heaney 2013; Lovari et al. 2013; Naing 2019; Hisano & Newman 2020), and genetic investigations of population connectivity aand structure (Suzuki et al. 1994; Tamada et al. 2008; Lee et al. 2013), will all further our ecological understanding of the population dynamics, habitat preferences, and local conservation needs, of leopard cats amidst this large and fragmented island landscape. In addition, as our model suggests that most leopard cat populations are isolated among habitat patches, perhaps more attention might be directed to landscape configurations and tools that effectively facilitate dispersal across a non-habitat matrix, such as has been received for Javan primates (Nasi et al. 2008; Birot et al. 2019).

Finally, despite the leopard cat's adaptations to relatively to human-modified habitats, small anthropogenic and degraded habitat patches and their associated edge effects can lead to greater to conflict with humans (Inskip & Zimmermann 2009), competition with invasive species like feral domestics (Tschanz et al. 2011), and more illegal hunting of leopard cats (Nijman et al. 2019). To mitigate these potential negative impacts, we suggest that educational models promoting greater multi-cultural conservation awareness (Nekaris et al. 2017b; Brown et al. 2019) should be a strategy that accompanies habitat protection, particularly in rural parts of the island.

Conclusion

Our study highlights the roles of land cover as the most influential environmental factors for the presence of leopard cats. This modeling study also emphasizes the roles of unprotected areas on Java island as the habitat of leopard cats (66.8%). We also underline existing initiatives through high-value conservation forest policies and essential ecosystem areas to support the protection of leopard cats in unprotected areas in Java.

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