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Large mammals occupancy in geothermal power plant activities

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Abstract. *Geothermal, as one of the renewable resources, serves as an alternative to address the ever-increasing electricity demand. Most of the sources are located in the forest ecosystem, in which ecological impact took place. PT Supreme Energi Rantau Dedap (SERD) constructs and runs a geothermal power plant project in the protection forest of Bukit Jambul Gunung Patah, South Sumatera. This research aims to investigate the large mammal's species richness and its occupancy through observing data from the SERD camera trap installed during the exploration and construction phases. Data were then analyzed with single-season occupancy modeling with habitat changes (distance), light, and elevation as the impact parameters. A total of 13 species from 14 large mammals were captured by the camera trap and one species was identified during a direct encounter. Most of the best occupancy model was with constants covariate. Hog badger* (Arctonyx hoevenii) *and Southern Red Muntjac* (Muntiacus muntjak) *are constantly apparent as high occupancy both in naïve occupancy and model results. Four species occupancies are affected by geothermal power plant activity, they are Sumatran Surili* (Presbytis melalophos), *Wild boar* (Sus scrofa), *Tapir* (Tapirus indicus), *and Sumatran hog badger* (Arctonyx hoevenii). *The result showed that during the development phase, large mammals still inhabited the powerplant area despite the fact that some species responded negatively to the impact. Meanwhile, during the construction phase, the species richness tends to be higher, but the detection level is lower with varying occupancy levels for each large mammal species.*

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INTRODUCTION

The national energy demand for development has been constantly increasing over the past few years. Currently, fossil fuels can only meet 86% of national energy demand. The government of Indonesia had committed to alternate 41% of its fossil fuel to geothermal as the energy resources. Indonesia is renowned as one of the largest geothermal producers worldwide by having 28.5 gigawatt electrical potential (DEN, 2019), consisting of 11 073 MW resources and 17 453 MW reserves. However, most of the geothermal sources are located in the forest area. Up until today, there are 41 sites in the conservation area, 46 sites in protected forests, and 37 sites in production forests (Sugiharta, 2016). Even though geothermal is renewable and holds economic premises, sourcing energy from a forest ecosystem is undeniably affecting the natural ecosystem.

In general, industrial activities, including geothermal powerplant, negatively impacted ecosystem and ecology (Budiharta *et al.*, 2018). Research showed that the geothermal activity brought negative impacts, despite in low level (Mardiastuti, 2018). Fragmentation, wildlife disturbance and distribution, poaching, and illegal logging are the common impacts apparent in forest areas where geothermal activity takes place (Sugiharta, 2016; Meijaard *et al.*, 2019). Access road establishment during the early phase of exploration and construction is the major cause of habitat change in forest area. Geothermal power plant in Indonesia has a higher ratio of forest cover change, compared to the other developing countries. For every 100MW produced electricity, the geothermal power plant needs a 10 to 5 km access road with 1 000 m impact distribution along with the riparian habitat (Meijaard *et al.*, 2019). Anthropogenic activities emit noise and lights that disturbs the habitat. Man-made light at night time negatively correlated with species emergence in its occupancy area. However, the negative impact of light pollution is decreasing along with open habitat expansion (Ciach and Frohlich, 2019).

Undeniably, geothermal activity affects wildlife in various manners. In one case, a decrease in bird diversity is apparent as a response to the impact (Kartika *et al.*, 2018). In the other case, larger mammals (i.e. Javan leopard or *Panthera pardus* melas) in Salak Mountain responded with adaptation (Ario, 2007). Carnivorous mammals also tend to keep their distance from the habitat edge and prefer the primary forest habitat (Brodie *et al.*, 2015). Moreover, the Muntjak group (*Muntiacus* sp) is reported to be able to adapt to disturbance and remaining habitat (Meijaard *et al.*, 2005; Duff *et al.*, 1984; Heydon, 1994).

Sumatra Island is home to threatened species of charismatic and iconic mammals (Mossbrucker, 2020). Mammals is a bio-indicator of an ecosystem (Larsen, 2016; Meijaard *et al.* 2005). Mammals play important roles in the ecosystem, including the seed distribution of several tree species (Terborgh, 1992). However, human and mammals' conflicts are frequently appearing on the island because both share a large portion of the terrestrial area for a living (Meijaard *et al.*, 2005). Nevertheless, humans also gain benefits from mammals, like protein sources and even economic benefits (Redford, 1992; Peres, 2000).

This research aims to identify large mammal species, including its occupancy, that is apparent in the area of PT Supreme Energy Rantau Dedap (SERD) geothermal power plant. The study analyzes impact parameter of geothermal power plant activity and the habitat type as occupancy covariate, of which habitat variation and night light.

METHOD

Site Description and Time of Research

The research took place in SERD geothermal plant in the protection forest of Bukit Jambul Gunung Patah which occupy 26 064 ha of Forestry Management Unit VIII Semendo. Administratively, the SERD is located in Rantau Dedap Sub District of Muara Enim Regency of South Sumatera Province. The research site is depicted clearly in Figure 1. However, the research is only limited to the edge habitat located around the geothermal power plant. Then again, it can be delineated as 2 000 meters off the edge (Lynam *et al.*, 2012)

This research used the data from 2018 to 2021 to capture the geothermal power plant activity during the exploration and construction phases. We used camera trap data from October 2014 to January 2015 and July-November 2016 to capture the exploration phase. Meanwhile, data from May 2018 to March 2021 were used to capture the construction phase.

The study area is located in a mountain-forest ecosystem with elevation ranges from 1 000 to 2 600 m above sea level. The area has type A Schmidt and Ferguson climate system, or in other words, the climate is very wet. The comparison of the average number of dry months with the average number of wet months (Q) is 0.1. The highest precipitation is 3 603 mm/year, and the lowest is 1 685 mm/year. The Wettest month is November, with average rainfall reaching 355 mm/month and the driest month is June-July, with 127 mm/month average rainfall (PT SERD, 2017).

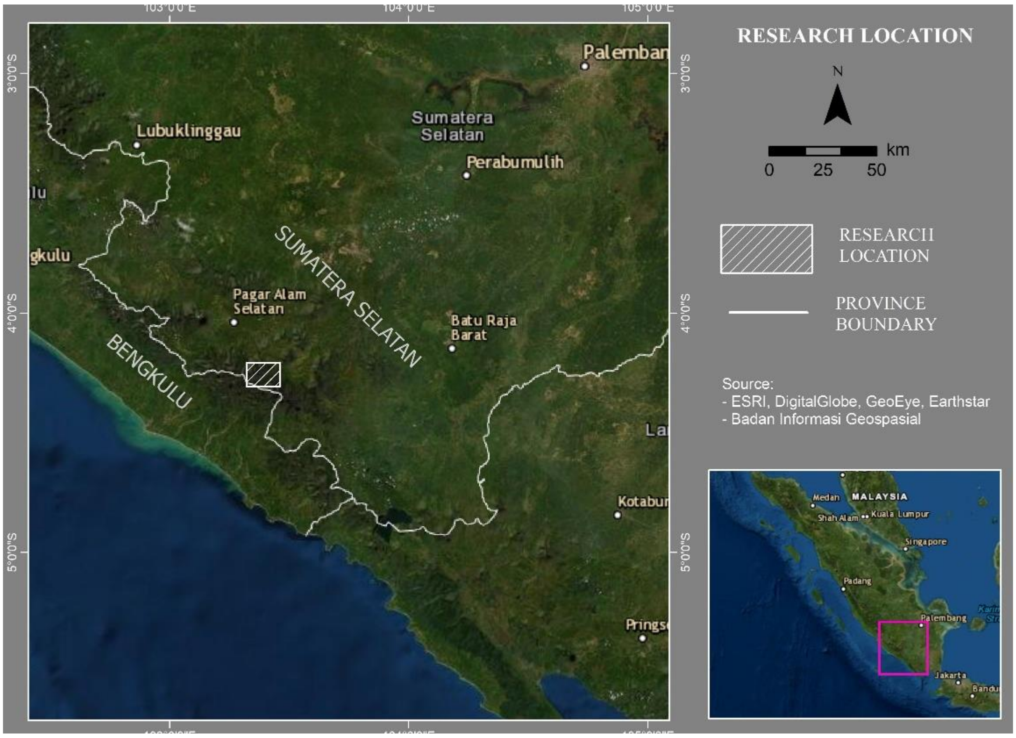

Figure 1 Research location

Data Collection

Species Richness

The study installed Bushnell models camera trap 119537C and 119437C during the exploration and construction phases. Camera traps during the exploration phase were installed with a grid approach of 2x2 meters and set on the habitat edge. Meanwhile, on the construction phase, the cameras were installed within a 1 km range of the geothermal power plant activities. With reference to the previous study, we identified independent pictures with a photo species approach with a 30-minute time-lapse (Sunarto *et al.*, 2014). Table 1 describes the camera traps data from the exploration and construction phases.

Table 1 Summary of camera trap data

Stages	Location	Number of Photos	Independence Photo	Total Day Effort
Exploration	17	35	35	1 204
Construction	12	595	195	5 847

The camera traps were installed in the most appropriate way to best record the species. It was set for 30-100 cm off the ground and adjusted to the topography of the animal route. Animal appearance marks or the information from local people are the basis for route identification. The camera trap setting varied between the exploration and construction phase. A 3-times photo was the common setting for the exploration phase, while the combination of a 3-times photo and 15-second video was the common setting for the construction phase.

The Effect of Geothermal Power Plant on Habitat

In this study, we identified the effect of the geothermal power plant as habitat changes and artificial light pollution. Variations or changes in wildlife habitat are the primary impacts of geothermal power plant activity on the natural ecosystem (Meijaard *et al.*, 2019; Sugiharta, 2016). We applied the remote sensing method to analyze the habitat changes. Sentinel-2 satellite image of Copernicus Hub with 10 m/pixel resolution delivered data for habitat changes analysis. Time series data from 2013, 2016, and 2020 depict changes before and after geothermal power plant activity. Forest, bushes, farmland, open area, and geothermal power plant area are the habitat classification used in this study.

Light pollution is another impact of geothermal power plant activity (Meijaard, 2019). Humans included light in every aspect of its activity, not to mention the construction sites. We identified the light radiance value by analyzing VIIRS-DNB (Visible Infra Imaging Radiometer Suite Day-Night Band) satellite image as in NOAA website provides the cloud-free image from the satellite, from which we were able to extract data on monthly average radiance (Ciach and Frohlich, 2019).

Data Analyses

Species Richness

We identified mammals as a large mammal if the weight was approximately more than 5 kg (Suyanto and Semiadi, 2004). As for the species identification, we analyzed the species morphology captured in camera trap photos. Sumatran Mammals Field Guide (Mossbrucker, 2020) and Protected Mammal Species Identification Guideline (KLHK, 2019) served as the references for the identification process.

The study explores the camera trap photo to identify relative species abundance as well (Jenks *et al.*, 2011). We uphold the hypothesis that an independent photo detection rate indicates animal abundance. Moreover, the Relative Abundance Index (RAI) is computed as the number of events divided by sampling effort and multiplied by 100 (i.e. events per 100 days of camera trapping) (Rovero *et al.*, 2014).

Changes in Habitat and Night Light Disturbance

To identify the habitat variation, we used ArcGIS 10.4 to run the spatial examination, and Sentinel 2 act as the data (Figure 2). An object-based classification approach was applied instead of pixel-based classification to aim for high accuracy in the analysis processes (Amalisana *et al.*, 2017; Baba, 2015). Spatial overlay of habitat map in each phase plays an important role in estimating the value of forest cover change or habitat modification resulting from powerplant activity.

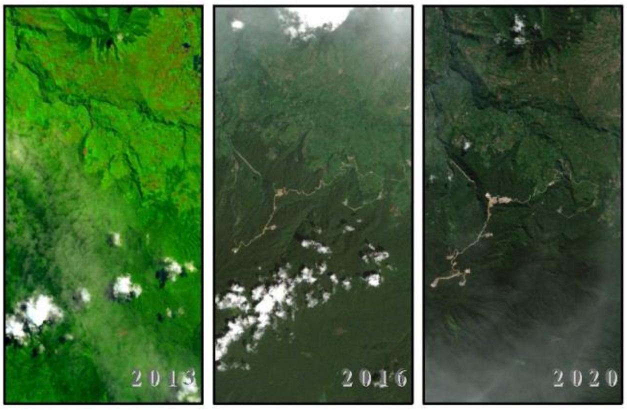

Figure 2 Historical of Sentinel 2 Satellite Imagery of sampling location

We also applied a spatial approach to identify night light disturbance. Monthly average VIIRS DNB radiance value data proceeded with overlay provided the data for average light radiance by months and by each phase (Ciach and Frohlich, 2019). Data from 2014-2016 represents the exploration phase, while 2018-2020 data represents the construction phase.

Large Mammal Occupancy Analysis

The results of species identification were used for large mammal occupancy (ψ) studies. The study of occupancy of large mammals used statistical methods using R software with Unmarked and Mass packages. Camera traps were used as stations with active camera days as replication. Photos as camera trap detection information for large mammals are used for the presence-absence information of each species which is then used as the input. The presence of large mammals were grouped into 5 days of active camera trapping. The number of days was obtained based on data exploration so that a fit model was obtained because of the high non-detection rate of species (Jenning *et al.*, 2015). At the exploration stage, data processing was divided into two stages, namely, data collection from October 2014 to January 2015 and July-November 2016. If the location is assumed to be independent, thus every observed location could have a probability model assembled from the collection date and maximize its function to attain parameter maximum probability. However, the occurrence and detection probability must be constant throughout the observation location.

$$L(\psi, p) = \left[\psi^{n.} \prod_{t=1}^{T}(1-p_t)^{n.-n_t}\right] \times \left[\psi \prod_{t=1}^{T}(1-p_t) + (1-\psi)\right]^{N-n}$$

Animal occupancy patterns are not only influenced by habitat characteristics but also by anthropogenic disturbance factors in natural habitats (Brodie *et al.*, 2015; Yaap *et al.*, 2016; Beier, 2006). Data analysis used three covariates, namely distance, night light interference (Light), and altitude (Elevation). Altitude covariates describe the type of forest ecosystem based on differences in altitude (Laumonier *et al.*, 2010). Distance and Light are covariates of the impact of habitat change caused by geothermal power plant activities. Next, the covariate value was standardized to a Z value (Jenning *et al.*, 2015). Occupancy (ψ) and detection (p) probabilities were analyzed using a single seasons model approach (Mackenzie *et al.*, 2006). Some of the data tests include the convergence test and the level of model fit (Fiske and Chandler, 2011). Mackenzie *et al.* (2002) mentioned that the model does not fit, one of which is caused by the discrepancy of the data with the parameters.

The evaluation of the best model utilized the Akaike Information of Criterion (AIC) value. The AIC value was used to compare the efficiency between models. AIC assesses the loss of information from the use of the model and describes certain variables or patterns. The best model was described by the lowest AIC value (Mazerolle, 2006). Occupancy probability and detection probability values were derived from the best model results. The value of the best model was checked for model fit (fitness model) with the chi-square test with the preboot function with 100 replications. If the value of Pr (t_B>t0) is above 0.05, then the model is fit (Fiske and Chandler, 2011).

RESULTS AND DISCUSSION

Large Mammals Species Richness

The process of collecting data on animal sightings using camera traps produces an overview of the species richness that exists in each SERD geothermal power plant working area. The camera trap photo identification process found 14 large mammals from 24 mammal species in the exploration and construction phase period (Table 2). The monitoring period at the construction stage recorded a larger number of large mammals than at the exploration stage. A total of 13 species were recorded in the construction stage and 9 species were recorded at the exploration stage. The order Carnivores and Cetartiodactyla are the most common orders. Sumatran tigers were found directly at the beginning of exploration activities in 2014 and recorded again in 2020 directly, but were not documented on camera traps either in the 2014-2016 or 2018-2021 ranges.

Table 2 Species richness of large mammals at exploration and construction stages

No	Family	Name			Relative Abundance Index	
		Scientific	Indonesian	English	Exploration	Construction
			Ordo: Carnivora			
1	Canidae	*Cuon alpinus*	*Anjing Ajag*	Dhole	14.29	0.51
2	Felidae	*Neofelis diardi*	*Macan Dahan*	Clouded Leopard		0.51
3	Felidae	*Pathera tigris*	*Harimau Sumatera*	Sumatran Tiger	√	√
4	Viverridae	*Arctictis binturong*	*Binturong*	Binturong		0.51
5	Ursidae	*Helarctos malayanus*	*Beruang*	Sun Bear	22.86	10.26
6	Mustelidae	*Arctonyx hoevenii*	*Babi Batang Sumatra*	Sumatran Hog Badger	22.86	28.72
			Ordo: Pholidota			
7	Manidae	*Manis javanica*	*Trenggiling*	Pangolin	2.86	1.03
			Ordo: Cetartiodactyla			
8	Cervidae	*Muntiacus muntjak*	*Kijang Muncak*	Southern red muntjac	25.7	18.46
9	Cervidae	*Rusa unicolor*	*Rusa Sambar*	Sambar Deer	2.86	
10	Bovidae	*Capricornis sumatraensis*	*Kambing hutan*	Serow	2.86	1.03
11	Suidae	*Sus scrofa*	*Babi hutan*	Wild Boar		13.85
			Ordo: Perissodactyla			
12	Tapiridae	*Tapirus indicus*	*Tapir*	Malayan Tapir	5.71	18.97
			Ordo: Primata			
13	Cercopithecidae	*Macaca nemestrina*	*Beruk*	Pig Tailed Macaque		2.05
14	Cercopithecidae	*Presbytis melalophos*	*Surili*	Sumatran Surili		3.08

Note: √ = Direct Finding

The species richness of this study tends to be similar to mammal species in corridor habitats in oil palm plantations and Tesso Nillo National Park in Riau, which recorded 13 mammals out of 19 mammal species found (Yaap *et al.*, 2016). The similar finding was also recorded in the Bukit Barisan Selatan National Park which is to the south of the Bukit Jambul Gunung Patah Protection Forest landscape. This landscape has a richness of 22 species of medium to large mammals (O'Brien and Kinnaird, 1996), with average annual species richness of 21.5 (range 19-24) mammal species in general (Allen *et al.*, 2020). A similar anthropogenic influence occurs in the natural gas industry in Bontang, East Kalimantan, where 23 mammal species from 15 families and 8 orders were recorded (Sudrajat and Putro, 2019). In addition, in the geothermal power plant area in Gunung Salak, there were 13 species from 12 families and 5 orders (Ario, 2007).

Habitat Change and Light Disturbance

This study used the influence of geothermal power plant activities as covariates in the model, including light disturbances and habitat changes. Referring to altitudinal ranges, the study area is located of the montane habitat zone (Laumonier *et al.*, 2010). Geothermal power plant activities bring about changes in habitat area in conditions before activities (2013), during exploration (2016), and during the construction period 2018-2020, as described in Table 3.

Table 3 Model selection of Critically Endangered (CR) and Endangered (EN) large mammals at construction stage

Species	Model					
	Model	nPars	AIC	delta	AICwt	cumltvWt
Ajag/Dhole	ψ (.) p (.)	2	19.32	0	0.393	0.39
Cuon Alpinus	ψ (elevation) p (.)	3	20.32	1.01	0.237	0.63
	ψ (distance) p (.)	3	21.07	1.75	0.163	0.79
	ψ (elevation + distance) p (.)	4	22.32	3.01	0.087	0.88
	ψ (elevation + light) p (.)	4	22.32	3.01	0.087	0.97
	ψ (light + elevation + distance) p (.)	5	24.32	5.01	0.032	1
	ψ (light) p (.)*	-	-	-	-	-
	ψ (light + distance) p (.)*	-	-	-	-	-
Macan dahan/ Sumatran	ψ (distance) p (.)	3	16.99	0	0.446	0.45
Clouded Leopard	ψ (elevation + distance) p (.)	4	18.99	2	0.164	0.61
Neofelis diardi ssp.	ψ (.) p (.)	2	19.32	2.33	0.139	0.75
diardi	ψ (elevation) p (.)	3	19.96	2.97	0.101	0.85
	ψ (light + elevation + distance) p (.)	5	20.99	4	0.06	0.91
	ψ (light) p (.)	3	21.32	4.33	0.051	0.96
	ψ (elevation + light) p (.)	4	21.96	4.97	0.037	1
	ψ (light + distance) p (.)*	-	-	-	-	-
Tapir/Malay Tapir	ψ (elevation) p (.)	3	119.72	0	0.5435	0.54
Tapirus indicus	ψ (light + elevation + distance) p (.)	5	121.58	1.86	0.2144	0.76
	ψ (elevation + light) p (.)	4	121.72	2	0.1998	0.96
	ψ (distance) p (.)	3	125.87	6.15	0.0252	0.98
	ψ (light) p (.)	3	127.52	7.8	0.011	0.99
	ψ (.) p (.)	2	128.69	8.96	0.0061	1
	ψ (light + distance) p (.)*	-	-	-	-	-
	ψ (elevation + light) p (.)*	-	-	-	-	-
Trenggiling/Sunda	ψ (.) p (.)	2	19.32	0	0.435	0.44
Pangolin	ψ (elevation) p (.)	3	20.32	1.01	0.263	0.7
Manis javanica	ψ (distance) p (.)	3	21.07	1.75	0.181	0.88
	ψ (elevation + light) p (.)	4	22.32	3.01	0.097	0.98
	ψ (light + elevation + distance) p (.)	5	25.07	5.75	0.024	1
	ψ (light) p (.)*	-	-	-	-	-
	ψ (light + distance) p (.)*	-	-	-	-	-
	ψ (elevation + light) p (.)*	-	-	-	-	-

* = un-convergent model

This information indicates that there was a gradual decrease in the dryland forest cover area after geothermal power plant development activities. However, the area of agricultural land, shrubs, and barren land increased after the geothermal power plant activity. Residential land and water bodies do not change in size either before or after the geothermal power plant activity is running. Habitat changes occurred during the exploration stage, namely the 2013-2016 range (Table 4). The development of the geothermal power plant area changes other habitats with a total area of 77.1 ha consisting of 52.2 ha of dry land forest, 24.5 ha of dry dryland agriculture, and 0.4 ha of shrubs. Meanwhile, in the construction phase until 2020, the land was still being cleared for the development of the new wells. The area of habitat that has been modified into a geothermal power plant has a total area of 62.8 ha, consisting of 59.5 ha of dryland forest and 3.3 ha of shrubs.

Table 4 Changes in habitat area at the research site

Habitat Type	Areas (hectares)		
	2013	2016	2020
Natural Habitat			
Motane Forest	6 015.5	5 863.5	5 433.8
Shrub	16.3	52.9	78.6
Water Body	13.2	13.2	13.2
Modified Habitat			
Geothermal Area	0	77.1	139.9
Barrenland	12.5	18.9	12.9
Dryland Agriculture	3 066.6	3 098.6	3 445.9
Settlement	9.9	9.9	9.9
Total	9 134.0	9 134.0	9 134.0

Exploration and construction activities have an impact in the form of night light disturbances. Artificial light projected on terrestrial mammals results in disturbances in foraging patterns, increased risk of predation, disturbances in the biological clock, increased risk of road deaths, and disturbances in roaming (Beier, 2006). Figure 3 depicts the value of the amount of night light based on the VIIRS DNB satellite image. Increased radiance value from satellite imagery was observed at the gate locations, employee camps, and wells. The increase in value was seen in September 2013 at security gate 1 (security gate #1), with a value range of 1.49-3.55 nanoWatts.sr/cm^2, while at the construction stage, the increasing value was shown by employee camp and wells locations. The data suggests that the increasing night light generally occurs in areas of intense human activity, such as office areas or security gates, that occur throughout the activity time.

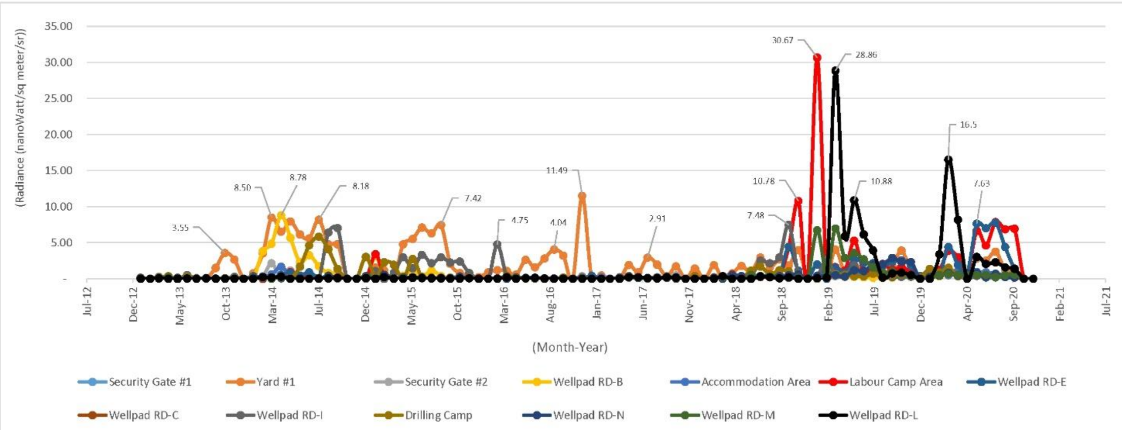

Figure 3 Monthly artificial light on research study area

Large Mammal Occupancy

This study analyzes the data based on the geothermal power plant development stage. In both stages, the pattern of activity impacts tends to be the same. According to the species richness, almost all large mammal species found in the exploration stage were still found in the construction stage, although with a lower detection rate. In general, the model with constant occupancy and detection (ψ(.) p(.)) was the best model for most large mammals at both stages (Table 5).

Table 5 The best scenario model for large mammals in geothermal development areas

Stage	Species	Occasion	Model	Occupancy		Detection	Chi-square	Note
				Naive	Estimate			
Exploration (2014)	Dhole	3	ψ (.) p (.)	0.22	0.60 (0.55)	0.04 (0.04)	0.080	
	Sun bear	8	ψ (.) p (.)	0.33	0.48 (0.23)	0.12 (0.05)	0.170	
	Hog Badger	3	ψ (distance) p (.)	0.33	0.67 (0.03)	0.03 (0.02)	0.340	
	Muntjak	2	ψ (.) p (.)	0.22	1.00 (0.07)	0.02 (0.01)	0.760	
	Sambar Deer	1	ψ (.) p (.)	0.11	0.98 (1.22)	0.01 (0.01)	0.500	
	Pangolin	1	ψ (.) p (.)	0.11	1.00 (0.17)	0.01 (0.01)	0.430	
Exploration (2016)	Dhole	1	ψ (.) p (.)	0.13	1.00 (0.14)	0.01 (0.01)	0.290	
	Hog Badger	5	ψ (elevation) p (.)	0.50	0.63 (0)	0.08 (0.03)	0.480	
	Muntjak	7	ψ (.) p (.)	0.38	0.42 (0.19)	0.15 (0.06)	0.820	
	Serow	1	ψ (.) p (.)	0.13	1.00 (0.19)	0.01 (0.01)	0.490	
	Tapir	1	ψ (distance) p (.)	0.13	0.14 (0.16)	0.20 (0.33)	0.190	
Construction (2018-2020)	Dhole	1	ψ (.) p (.)	0.091	1.00 (1.39E-08)	0.001 (0.001)	0.099	
	Wild Boar	19	ψ (distance + elevation) p (.)	0.364	0.36 (0.009)	0.054 (0.01)	0.079	
	Sun bear	1	ψ (.) p (.)	0.091	1.00 (0.004)	0.001 (0.001)	0.455	
	Pig Tailed Macaque	3	ψ (distance + elevation + light) p (.)	0.250	0.25 (0.004)	0.004 (0.002)	0.010	unfit
	Binturong	1	ψ (.) p (.)	0.091	1.00 (0.002)	0.001 (0.001)	0.079	
	Hog Badger	42	ψ (elevation) p (.)	0.818	0.83 (0.13)	0.06 (0.01)	0.505	
	Sunda Leopard	1	ψ (distance) p (.)	0.091	0.09 (0.01)	0.01 (0.01)	0.010	unfit
	Muntjak	25	ψ (.) p (.)	0.917	1.00 (0)	0.04 (0.01)	0.980	
	Serow	1	ψ (.) p (.)	0.091	1.00 (NaN)	0.001 (0.001)	0.030	unfit
	Surili	4	ψ (distance + elevation) p (.)	0.100	0.10 (0.002)	0.07 (0.03)	0.060	
	Tapir	13	ψ (elevation) p (.)	0.364	0.46 (0.003)	0.03 (0.01)	0.812	
	Pangolin	1	ψ (.) p (.)	0.091	1.00 (NaN)	0.001 (0.01)	0.010	unfit

The beta coefficient value describes the effect of large mammal occupancy on the covariate component (Table 6). Edge distance and elevation are covariates that affect several species, including hog badger (*Arctonyx hoevenii*), *tapir* (*Tapirus indicus*), wild boar (*Sus scrofa*), and *surili* (*Presbytis melalophos*). Light covariate is not a covariate that affects occupancy and detection. One of the reasons is that the radiance value produced is much lower than the sensitive threshold for land mammals, which is 120 candel/m2 (1.8x108 nanoWatts.sr/cm2) (Beier, 2006). Our study showed that tapir (*Tapirus indicus*) and wild boars (*Sus scrofa*) responded positively to edge distance covariates. In line with our findings, Lynam *et al.* (2012) stated that tapir (*Tapirus indicus*) tend to respond positively to edge distance, rainfall, and altitude, while wild boar (*Sus scrofa*) tend to give negative responses to the three covariates.

Table 6 Beta coefficient covariate model of large mammals occupancy

Stages	Species	Occasion	Model	Beta Covariate (SE)		
				Distance	Light	Elevation
Exploration (2014)	Hog badger (*Arctonyx hoevenii*)	3	ψ (distance) p (.)	-12.85 (68)		
Exploration (2016)	Hog badger (*Arctonyx hoevenii*)	5	ψ (elevation) p (.)			83.4 (-0.21)
	Tapir (*Tapirus indicus*)	1	ψ (distance) p (.)	30.96 (-0.7)		
Construction (2018-2020)	Wild Boar	19	ψ (distance + elevation) p (.)	49.4 (0.33)		39.3 (-0.26)
	Hog badger (*Arctonyx hoevenii*)	42	ψ (elevation) p (.)			2.21 (0.31)
	Surili	4	ψ (distance + elevation) p (.)	92.2 (0.94)		64.6 (0.92)
	Tapir (*Tapirus indicus*)	13	ψ (elevation) p (.)			133.00 (-0.13)

Although the species richness was higher at the construction stage than at the exploration stage, sumatran hog badger (*Arctonyx hoevenii*) and Southern red muntjac (*Muntiacus muntjak*) have occupancy opportunities that tends to not experience significant changes despite having a higher naive occupancy rate at the construction stage. Muntjak has a high degree of adaptation, this species tends to be found in high abundance in disturbed areas (Heydon, 1994; Duff *et al.*, 1984; Meijaard *et al.*, 2005; Lynam *et al.*, 2012; Yaap *et al.*, 2016). This condition is inversely proportional to the data analysis in this study which shows that the best model for southern red muntjac (*Muntiacus muntjak*) is with constant occupancy and detection, while the Sumatran hog badger (*Arctonyx hoevenii*) is influenced by occupancy with distance covariates with geothermal power plant activities (ψ (distance) p (.)) and altitude (ψ (elevation).) p(.)).

Sumatran hog badgers (*Arctonyx hoevenii*) tend to have a negative response to the road at the exploration stage and are positively responding to the height of the forest ecosystem at the construction stage. Ecologically, the hog badger spreads from an altitude of 800 m above sea level to the highest peak (Mossbrucker, 2020). This study cannot explain the different effects of covariates on the probability of occupancy at the exploration and construction stages. The impacts that occur during the exploration and construction stages are cumulative (Watkins *et al.*, 2015; Meijaard *et al.*, 2019).

A significant decrease in detection occurred in sun bear (*Helarctos malayanus*) and dhole (*Cuon alpinus*), which are known as generalist species in the selection of habitat types with a high level of forest habitat dependence (Scotson *et al.*, 2017; Kamler *et al.*, 2015). This study found that the best model for Sun Bear is constant occupancy and detection. Different results state that Sun bear occupancy has a negative response to forest cover (Yaap *et al.*, 2016). The best Dhole model is consistent in both stages of geothermal power plant, namely the constant occupancy and detection model (ψ (.) p (.)). The results show a much lower detection estimate (p). This result is consistent with the study of Nurvianto *et al.* (2015) mentions Dhole's tendency to avoid logging and anthropogenic activities.

The different study approaches at the two stages, including the difference in the selection of camera trap locations, became a weakness in this study. Study design influences detection and rarity statistics (Steenweg *et al.*, 2018. Several analysis resulted in weak and biased models causing the occupancy model to be difficult to estimate because it tends to be unstable so that it is difficult to interpret even under ideal conditions. When abundance varies from site to site and detection is dependent on abundance, standard analysis is subject to bias and an asymmetric sampling distribution. Slow convergence from the sampling distribution to normality (Welsh *et al.*, 2013). In addition, there are limitations in systematically comparing changes in detection results at the two stages of geothermal power plant activities.

CONCLUSION

Our research showed that large mammal species have varying responses toward geothermal powerplant activity. Some exhibit adaptive responses, while others respond differently or negatively, as a matter of fact. In other words, despite the prevalent impact of Anthropocene activity, large mammals are able to adapt and utilize the disturbed habitat. However, the varied detection and occupancy rates noted the need to evaluate the powerplant natural resources monitoring system. A standardized approach is needed to collect reliable data to monitor impacts on wildlife which then serve as references for developing an ecologically resilience management framework and in turn leads to building the sustainability aspects of the industry.

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