

Factors affecting movement pattern of Sumatran elephant in Air Rami Production Forest, Bengkulu, Indonesia

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Abstract. *Laksmitha N, Santosa Y, Rahman DA. 2023. Factors affecting movement pattern of Sumatran elephant in Air Rami Production Forest, Bengkulu, Indonesia. Biodiversitas 24: 5539-5547.* The decline in the quality and quantity of elephant natural habitat is a trigger factor for human-elephant conflict and results in a decrease in the elephant population. Research related to movement and habitat factors determining elephant movement is important to obtain information that can be used as a basis for conflict management and mitigation in the long term. We analyzed collared GPS data from a female adult elephant (n=1) in Air Rami Production Forest with recordings from November 2020 to August 2022. This study aims to investigate the relationship between the Sumatran elephant's daily movement distance and movement period with habitat factors. The data obtained were analyzed using multiple regression analysis with tested variables, including secondary forest land cover, altitude, slope, distance from water sources, settlements, roads, and daily movement distance/movement period. The results showed that secondary forest land cover, slopes, movement period, distance from water sources, settlements, and roads influence the elephant's daily movement distance. Meanwhile, the relationship between the movement period is only influenced by slopes, distance from settlements and roads, and daily movement distance. Our study further provides information recognizing the preferred habitat factor of the Sumatran elephant, which gives stakeholders an essential tool for conservation.

Keywords: Movement distance, movement period, relationship, Sumatran elephant

INTRODUCTION

The increase in human population aligns with the increasing needs of agriculture and industry, so much forest land is converted to settlements (Parihar et al. 2021). Massive economic development in various sectors in Indonesia encourages the conversion of forest land into other uses, which is the leading cause of deforestation (Rahman et al. 2020), without exception on Sumatra Island (Rahman et al. 2022). This expansion of human settlements and agricultural fields has decreased the area and connectivity of elephants' natural habitat (Calabrese et al. 2017). The natural habitat of elephants that have been disturbed causes elephants to be progressively forced to make closer contact with humans (Liu et al. 2017; Sukmantoro et al. 2019a; English and Collins 2022). That problem is a trigger factor for human-elephant conflicts (HEC). This human-elephant conflict puts both parties in a mutually detrimental situation (Yang et al. 2023).

HEC is a complex social-ecological problem, multi-dimensional, and has multi-directional impacts (Selier et al. 2016). Human-elephant conflict causes economic losses and disrupts local people's activities and safety (Jiang et al. 2023). The presence of elephants damages cultivated crops (Nyirenda et al. 2018) and infrastructure, disrupting livestock, injuries and deaths, and economic losses (Berliani et al. 2016; Gunawansa et al. 2023). In addition, this conflict can cause elephants to be injured and killed by

humans (Gunawansa et al. 2023). Human-elephant conflict is one of the main factors driving the decline in Sumatran elephant populations. According to data from the Directorate General of Conservation of Natural Resources and Ecosystems in 2020, the elephant population has decreased to 61.3% of the population in the wild in the last 12 years from 2007 to 2019 and the elephant population is estimated at 1,694-2,038 individuals in 2017. Nowadays, the Sumatran elephant population is in 36 habitat pockets spread across seven provinces: Aceh, North Sumatra, Riau, Jambi, Bengkulu, South Sumatra, and Lampung (Rahman et al. 2022). About 85% of Sumatran elephants' population is outside conservation areas because the forests as their natural habitat are disturbed due to deforestation (Sukmantoro et al. 2019a). The impact resulting from the conflict between humans and elephants is a severe threat to biodiversity conservation. It places the Sumatran elephant as one of the priority animals that must be protected. Therefore, managing conflicts between humans and elephants is still the primary goal of elephant conservation (Shaffer et al. 2019) nationally and internationally.

Various efforts to deal with human-elephant conflicts have been actively and passively pursued. Active mitigation that has been carried out includes accosting tame elephants and expulsion by making noise. In contrast, passive mitigation is carried out by making trenches or fences with low electricity voltage (Qomariah et al. 2019). However, the efforts have not succeeded because human-

elephant conflicts still occur. Installing GPS collars is currently used as an alternative to monitoring elephant movements. This GPS-based technology makes it possible to monitor and map the movement of animals in detail (Cagnacci et al. 2010).

Human and elephant conflicts occur in almost all elephant distribution areas, including Bengkulu Province. The Seblat landscape in Bengkulu Province has been designated as an Essential Ecosystem Area because of its high ecological function. However, the frequency of elephant-human conflicts in the 2007-2009 period reached 78 conflicts. One adult female individual from the elephant group in the Air Rami Production Forest, Bengkulu Province, has been collared with GPS. Therefore, research on one individual in the elephant group at Air Rami Production Forest is a critical case study because it can provide an overview of the group's movement. On the other hand, movement is a fundamental characteristic of animal behavior where decisions influence individual, population, and ecosystem levels (Beirne et al. 2021). Animals move to find resources (food and mates) and to avoid threats like predators (Rahman 2020; Rahman and Mardiasuti 2021). At an individual level, movement affects fitness through the ability to find resources, survival, and reproduction. Meanwhile, at the population level, movement can affect interactions with competitors, predators, and disease (Kays et al. 2015; Rahman and Mardiasuti 2021). Research related to movements and habitat factors determining elephant movements is important to obtain information that can be used for consideration in mitigating human-elephant conflicts and managing Sumatran elephant habitat and populations. This study investigates the relationship between the Sumatran elephant's daily movement distance and movement period with habitat factors.

MATERIALS AND METHODS

Study area

In this study, our analyses focused on the Air Rami Production Forest, Bengkulu, Indonesia. This forest is part of the Seblat landscape, which has an area of around 13,968.71 ha and covers two districts, including North Bengkulu and Mukomuko in Bengkulu Province, Indonesia (Figure 1).

Seblat landscape consists of several forest area managements, including Kerinci Seblat National Park, Seblat Nature Recreation Park, Air Rami and Air Teramang Production Forest (HP), Air Ipuh and Lebong Kandis Limited Production Forest (HPT), Lebong Kandis Convertible Production Forest (HPK), and non-forestland (APL). The types of vegetation that dominate the Air Rami Production Forest include shorea (*Shorea* sp.), *sentubung* (*Gonocaryum gracile* Miq.), *medang* (*Litsea noronhae* Blume), *leban* (*Vitex pubescent* B. Heyne ex Wall.), *senduduk* (*Melastoma malabathricum* L.), Jackass breadnut (*Clibadium surinamense* L.), cogongrass (*Imperata cylindrica* (L.) Raeusch), and many more. Meanwhile, fauna that have been identified at the location are Sumatran elephant (*Elephas maximus sumatranus* Temminck, 1847), Sumatran tiger (*Panthera tigris sumatrae* Pocock, 1929), *siamang* (*Symphalangus syndactylus* Raffles, 1821), long-tailed macaque (*Macaca fascicularis* Raffles, 1821), Southern pig-tailed macaque (*Macaca nemestrina* Linnaeus 1766), wild boar (*Sus scrofa* Linnaeus, 1758), white-breasted waterhen (*Amaurornis phoenicurus* Pennant, 1769), rufous-tailed fantail (*Rhipidura phoenicurus* S. Muller, 1843), collared kingfisher (*Todiramphus chloris* Boddaert, 1783), etc.

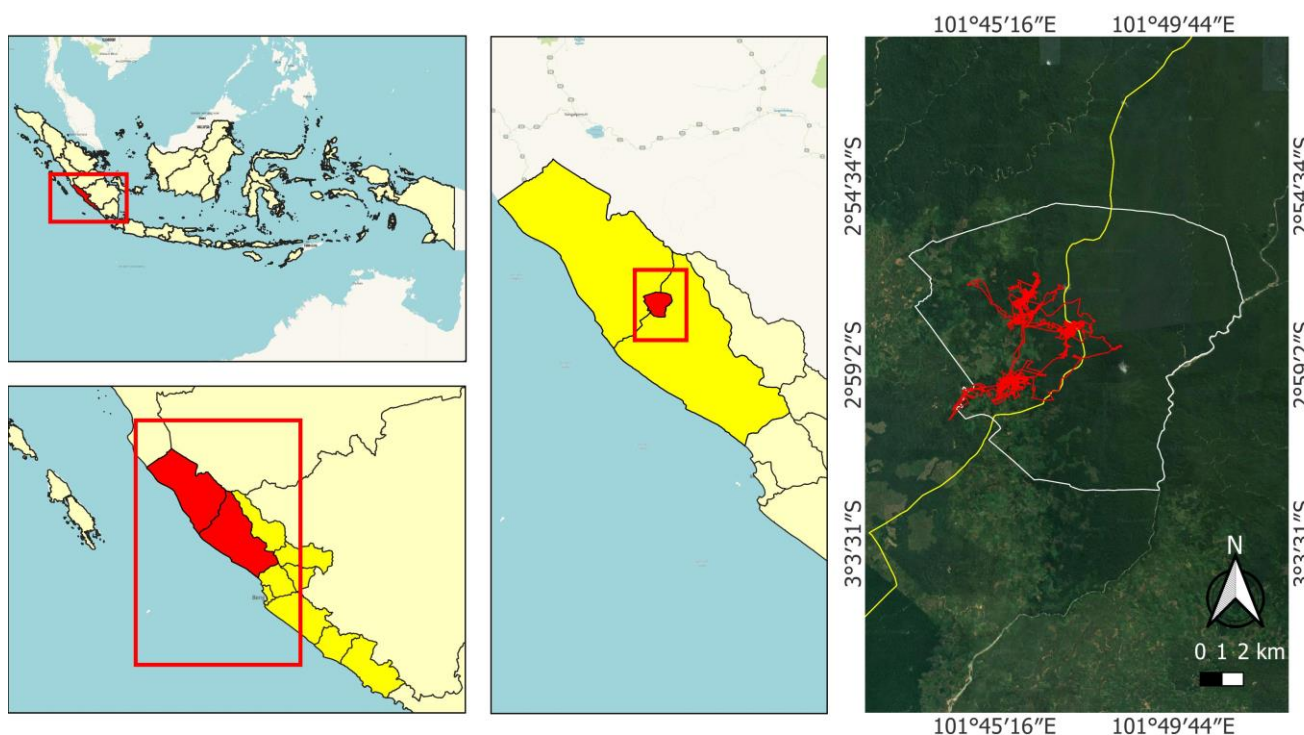


Figure 1. Research site map in Air Rami Production Forest, Bengkulu, Indonesia

Data collection

The main data used in this study are movement patterns (movement distance and movement period) and habitat factors (land cover, altitude, slope, and distance from water sources, settlements, and roads). Data on the movements of Sumatran elephants were obtained through GPS collar recordings attached to an adult female representing the group (n=1). The GPS collar data used is the result of recordings from November 2020 to August 2022 with a total of 2,419 points in 631 days. Data related to habitat factors were generally obtained by downloading spatial data from various sources, with data processing carried out from May to August 2023. Administrative boundaries were downloaded from <http://GADM.org>. Landsat 8 imagery was used as a data source to obtain land cover maps and was obtained through download on <http://earthexplorer.usgs.gov>. Environmental factors such as altitude, slope, and distance from settlements and roads were obtained through download data DEM (Digital Elevation Model) and Indonesia's terrain on <http://tanahair.indonesia.go.id>. Meanwhile, the river network map was downloaded from www.hydrosheds.org.

Data analysis

Daily movement distance and movement period

Daily movement distance measurements were performed using points to line feature in ArcMap. The working principle of this feature is to form a line by connecting coordinate points. We calculated the movement period by dividing the length of time in a day by the movement distance. Descriptive statistics also analyzed both data to obtain the lowest, average, and highest value.

Habitat factors

Land cover maps were obtained by supervised classification analysis of Landsat 8 imagery (<http://earthexplorer.usgs.gov>). We created maps with classified land cover data from 2020-2022. The classification was divided into three categories: primary forest, secondary forest, and open land (shrubs and grasslands). Altitude data were obtained by analyzing DEM data using the reclassify feature. The altitude category was divided into five classes, namely 100-160 masl, 161-220 masl, 221-280 masl, 281-340 masl, and 341-400 masl. The slope data were obtained through altitude data, which is processed using the slope feature and then graded using the reclassify feature. The slope category was divided into five classes, namely flat (0-8%), sloping (8-15%), rather steep (15-25%), steep (25-45%), and very steep (>45%). The distance we mean was the closest distance to water sources, settlements, and roads. The closest distance data were performed using the near feature in ArcMap with daily movement distance (polyline) as input.

The relationship between daily movement distance and movement period with habitat factors

The relationship between the daily movement distance and movement period with habitat factors was analyzed using multiple regression analysis (MRA) methods. We performed all statistical analyses using SPSS version 24.

The dependent variable (Y) is the daily movement distance and movement period, while the independent variable (X) predicted is the habitat factor determining elephant movement consisting of land cover (X₁), altitude (X₂), slope (X₃), distance from water sources (X₄), settlements (X₅), and roads (X₆) and also movement period/daily movement distance (X₇). The data analysis results have fulfilled the classical assumptions of multiple regression analysis, such as normality, heteroscedasticity, multicollinearity, and autocorrelation. MRA is calculated using the following equation formula:

$$Y = b_1X_1 + b_2X_2 + \dots + b_nX_n + c + e$$

Where:

- Y : dependent variable
- X : independent variable
- B : regression coefficient
- c : constant
- e : error

RESULTS AND DISCUSSION

Sumatran elephant's daily movement pattern characteristics

The total distance recorded from November 2020 to August 2022 was 264.75 km. The daily movement distance's minimum, average, and maximum values in each month show varying results. The average daily movement distance of elephants at the study location was 430.64 m, with the longest distance in March 2022 at 2,517.16 m and the shortest in December 2020 at 13.19 m (Figure 2). The average daily movement distance of elephants in Bengkulu has relatively different results from previous studies. Research by Sukmantoro et al. (2019a) shows that the length of the elephant's daily movement ranges from 0-3 km. Khairani (2023) showed almost the same results, the elephant's average daily movement distance in Way Kambas National Park ranged from 1.9 to 5.1 km. Meanwhile, the research results by Sitompul et al. (2013a) stated that the average movement of elephants was 1.5±0.3 km daily and 36.6±4.6 km monthly. Two groups of elephants studied in Bukit Barisan Selatan National Park have an average daily movement distance of 2.8 km (Bunga Group) and 3.57 km (Citra Group) (Hadinata et al. 2023). In comparison, forest elephants (*Loxodonta cyclotis*) in Gabon, Central Africa, traveled on average 7-8 km daily and 2,840 km annually (Mills et al. 2018). Meanwhile, Asian elephants in Gua Musang Malaysia have an average daily movement of 94.57 m in fragmented forests (Bahar et al. 2018). Habitat conditions influence this significant difference in average daily movement distance. The research site is a relatively open production forest close to oil palm plantations. Therefore, the average daily movement distance of elephants at the study site tended to be shorter than the results of other studies located in national parks.

The characteristics of the movement pattern are also identified according to the season period with the

classification of wet season period 1 (November 2020-March 2021), dry season period 1 (April 2021-September 2021), wet season period 2 (October 2021-March 2022), and dry season period 2 (April 2022-August 2022). Figure 2 shows that the average daily movement distance in the dry season period is slightly higher than the average daily movement in the wet season. The average daily movement distance according to the season period respectively was 488.60 m, 499.07 m, 359.40 m, and 376.05 m. In general, this study did not observe any significant differences in Sumatran elephants' pattern and length of movement based on the season (Figure 3). When calculated based on the closest distance of the track to the river, the 3 season periods show the most significant percentage at a distance of 0-400 m from the river with successive values of 61.11% (Figure 3.A), 62.84% (Figure 3.B), and 48.35% (Figure 3.C). Meanwhile, the dry season period 2 (Figure 3.D) showed a different trend of results where the elephant movement mainly was far from the river at 1,201-1,600 m (27.46%) and 1,601-2,000 m (28.17%) with the farthest distance from the river is 1,946.04 m. Seblat landscape has a relatively high availability of water, tributaries, and rainfall and a small elephant home range so that the elephant's movement is never far from water sources (Sitompul et al. 2013a). Asian elephants in South India also show a similar pattern; they will congregate at higher densities near rivers (Sukumar 1989).

Elephant research in Balai Raja and Tesso Nilo showed results that there was no difference in niches between the wet and dry seasons (Sukmantoro et al. 2019b). Research by Sitompul (2011) shows that the season is more influential on elephant feeding behavior, whereas elephant Seblat tended to browse more than graze in the wet season. This trend in feeding behavior is probably related to the high availability

and nutritional value of browse plants in Seblat. In contrast with forest elephants (*L. cyclotis*) in Central Africa, they will spend more time in grassland during the short-wet season, along with the time when the grass starts growing (Mills et al. 2018). Research by Baskaran et al. (2010) also showed similar results, the browsing feeding behavior of Asian elephants in Southern India was greater during the dry season.

On the other side, the movement period can be influenced by the availability of habitat resources that support the fulfillment of elephant needs, such as feed and water (Khairani 2023). The movement period at the study site ranged from 0.57 minutes/meter to 48.61 minutes/meter, with an average of 5.40 minutes/meter (Figure 4).

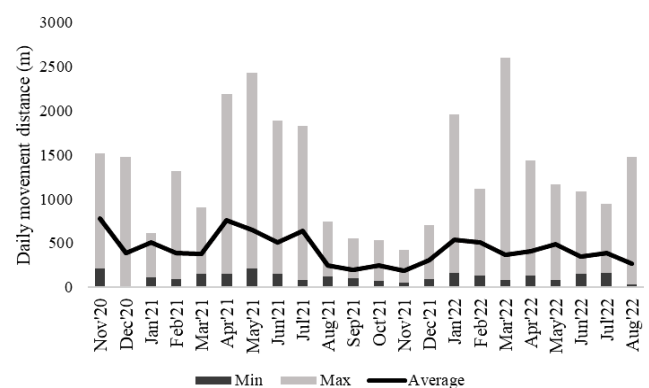


Figure 2. Characteristics of Sumatran elephant's daily movement distance

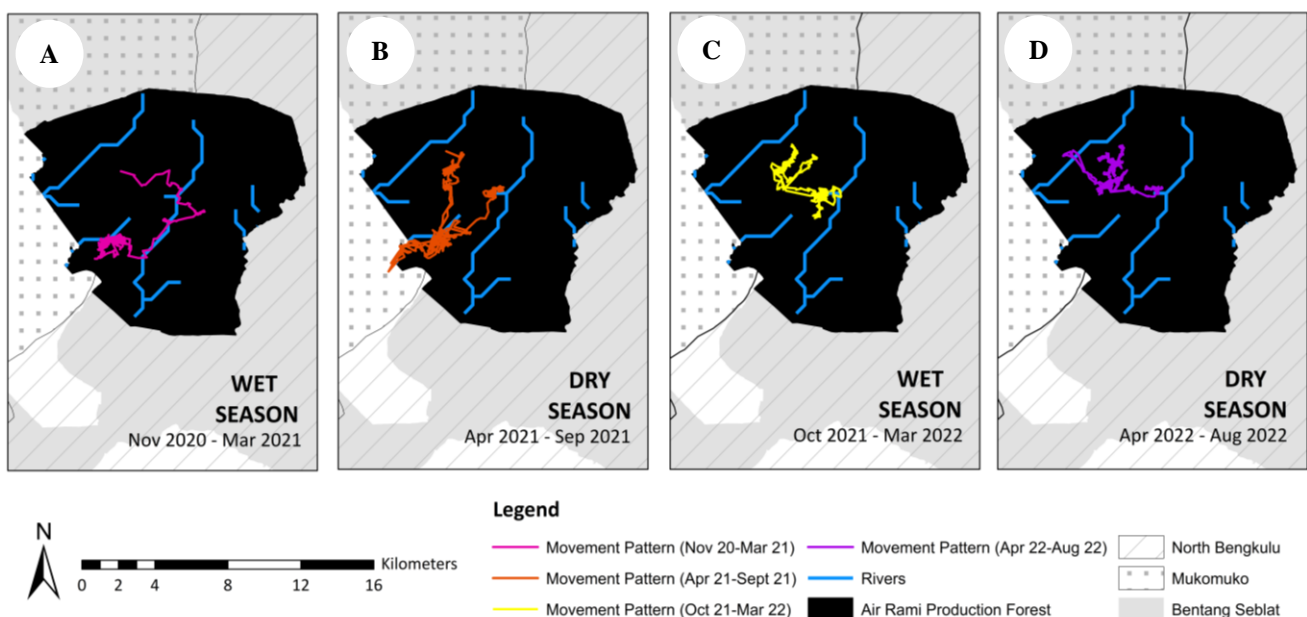


Figure 3. Differences in the Sumatran elephant's movement pattern according to season

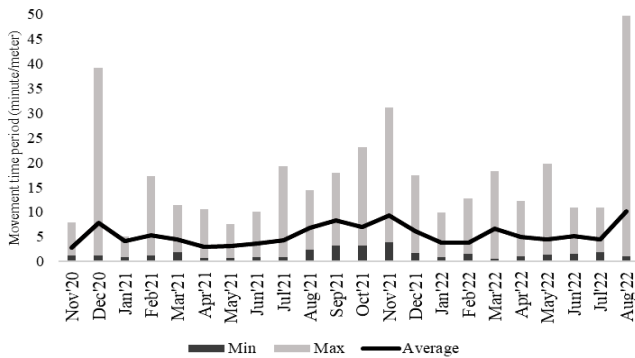


Figure 4. Characteristics of the Sumatran elephant's movement period

When compared with the results of other studies, the results of the acquisition of the elephant's movement period at the study location tend to be smaller. Research by Hutchinson et al. (2003) showed that elephants' movement speed can reach a range of 4-6 ms⁻¹. The results of other studies related to the length of use of elephant tracks in Way Kambas National Park have an average of 2.90-5.09 minutes/km (Khairani 2023). In Bukit Barisan Selatan National Park, the movement period of elephants is in the range of 166-174 minutes/km (Hadinata et al. 2023). Mills et al. (2018) stated that the movement of forest elephants (*L. cyclotis*) becomes faster in the short-wet season due to the availability of abundant feed. The movement of animals is very varied and complex, influenced by various intrinsic and extrinsic factors. Intrinsic factors include the sex and body conditions of individuals, while extrinsic factors include habitat conditions and anthropogenic factors (Beirne et al. 2021).

Relationship between the Sumatran elephant's daily movement distance with habitat factors

MRA analysis showed a coefficient of determination (R^2) value (0.865) which means that all habitat factors (X) tested contributed 86.5% to the model. The F test rejects the null hypothesis (H_0) because the significance value is smaller than 0.05 (α). Based on these gains, it is known that all habitat factors (X) simultaneously affect the daily movement distance (Y). The altitude of the place (X_2) has a significance value of 0.728, so the variable partially does not significantly affect Y. This is because the altitude class in this location only ranges from 0-400 masl. This is different from the Bukit Barisan Selatan National Park, which has an altitude range of up to 1,900 masl, affecting the movement of elephants (Hadinata et al. 2023).

Wilson et al. (2021) stated that elephants were preferred in mean elevation <200 m. Other than that, six other habitat factors have a significance value of <0.05, which means that the variable partially affects Y. Based on the partial r, it can be seen that flat slopes (X_3) have the highest value (0.747), so this variable has the highest level of closeness of relationship with daily movement distance. The regression analysis results in more detail can be seen in Table 1.

Secondary forest

The secondary forest variable (X_1) has a positive regression coefficient (+) of 0.328. A positive value indicates a directly proportional relationship. The longer the movement passes through the secondary forest, the total distance of the elephant's daily movement will also increase. Secondary forests are indicated to have the structure and composition of plant species that support the activity/movement of elephants. Sumatran elephants spend time foraging and resting in secondary forests during the day. In high solar radiation, elephants prefer habitats with closed canopy conditions and avoid open areas to maintain their body temperature (Sitompul et al. 2013b). Another study explains that Sumatran elephants prefer secondary forests more because they provide fast-growing feed vegetation (Collins 2018). Asian elephants in Sabah and Peninsular Malaysia prefer vigorous plants (English et al. 2014) and fast-growing trees commonly found in disturbed vegetation (de la Torre et al. 2022), such as secondary forests.

Slope

The topography at the study site varied from flat to very steep. However, elephant encounters are more on flat slopes (0-8%), so multiple regression analysis focuses on flat slopes. The regression coefficient value for the flat slope variable is (+) 1.135. The distance of the elephant's daily movement increases when the movement that passes through areas with flat slopes also gets longer. A flat slope is an essential factor that determines the movement of elephants. This is closely related to the large body size, so moving on steep topography is difficult. Various studies also show that flat topographic conditions tend to be preferred and chosen elephants for their activities (Moßbrucker et al. 2016; Rendana et al. 2023). In comparison, Asian elephants in Nepal have a higher preference for habitats with slopes of 0-5° (Sharma et al. 2019). Wall et al. (2006) stated that many factors influence elephant avoidance of steep hills, such as risk of injury, lack of water, or unsuitability of forage.

Table 1. Results of multiple regression analysis of daily movement distance to habitat factors

Equation	R^2	F-test	T-test	r partial
$Y=183.703+0.328X_1-0.010X_2+1.135X_3-0.040X_4-0.020X_5+0.078X_6-3.408X_7$	0.865	0.000	$X_1=0.000$ $X_2=0.728$ $X_3=0.000$ $X_4=0.000$ $X_5=0.000$ $X_6=0.000$ $X_7=0.022$	$X_1=0.340$ $X_2=-0.014$ $X_3=0.747$ $X_4=-0.168$ $X_5=-0.219$ $X_6=0.170$ $X_7=-0.091$

Note: Y: daily movement distance; X_1 : secondary forest; X_2 : altitude; X_3 : slope; X_4 : distance from water sources; X_5 : distance from settlements; X_6 : distance from roads; X_7 : movement period

Distance from water sources

Sumatran elephants have a high dependence on water (water-dependent species) to meet their large needs for drinking and wallowing. Distance from water sources is a limiting factor and has a higher preference level because elephants need water for bathing (Abdullah et al. 2021). The variable distance from the water source has a regression coefficient of (-) 0.040. The value shows the relationship between the daily movement distance and the distance from the water source, which is inversely proportional. The closer the distance to the water source, the longer the elephant's daily movement. Based on the results of GPS collar recordings, it can be seen that the distribution of elephants is found in riparians with movement following water sources. Thus, the daily movement distance of elephants is longer when close to water sources because there are no obstacles to meet their water needs. Elephants can adjust their range to meet water needs during the dry season (Chan et al. 2022). This follows the statement of Wilson et al. (2021) that elephants choose to be close to rivers as a reflection of the low energy costs incurred to meet their needs.

Distance from settlements

This variable has a regression coefficient value of (-) 0.020, indicating that the closer the elephant is to the settlement, the longer its daily movement will increase. In general, elephants are sensitive animals and stay away from crowded locations. The daily movement of elephants tends to be longer when close to settlements, indicating other factors that influence elephant movement, such as expulsion efforts by surrounding communities. This eviction effort allows elephants to continue walking away from settlements. Following Rendana et al. (2023), areas close to settlements have low suitability for Sumatran elephants. Wilson et al. (2021) explain that areas near human settlements tend to be used at night because human presence and activities influence elephant habitat use and avoidance. Bhuyan and Kar (2018) stated that the presence of elephants near humans poses a threat to humans and causes damage to homes, so eviction efforts are often carried out to prevent losses. The overlap between elephant routes and settlements creates fear and worry in the community, so it is not uncommon for elephants to be killed (Mariki et al. 2015).

Distance from roads

The distance from the road variable has a positive coefficient value of 0.078. The farther the distance from the road, the longer the elephant's daily movement distance. However, based on the data obtained, it is seen that the daily movement of elephants will be longer when they are close to the road. This difference is caused by many tracks intersecting the road so that the most relative distance to the road is calculated at 0 meters and interactions negate each other with other variables. The movement of elephants near the road is a form of their movement efficiency. In addition, former community pioneers or patrol officers near the road have the potential to produce new shoots that are a source of elephant feed. In line with the research of Berzaghi et al. (2023) leaves are among the

most preferred parts of elephants because they contain protein.

Movement period

The daily movement distance and the movement period have an inverse relationship. The longer the daily movement distance taken by the elephant, the shorter the movement period (minutes/meter). Vice versa, the movement period will increase if the movement distance taken is shorter. The availability of feed can influence this relationship. Feeding activity ranked first in the daily activity pattern of elephants to reach $82.2 \pm 5.0\%$ (Sitompul et al. 2013c). This means that the time used by elephants to eat in one day is very high. In line with (Yoza et al. 2022), if the availability of feed in a location has not been able to meet their needs, they will quickly move. This also follows the optimal foraging theory, which states that the distribution and movement of animals are influenced by habitat quality and feed availability (Riha and Prchalova 2022). They tend to move to find food at the closest distance for efficient use of time and energy. In other words, animals will improve their fitness by minimizing the time and energy required to obtain maximum energy from food.

Relationship between the Sumatran elephant's movement period with habitat factors

The linear regression results showed a coefficient of determination (R^2) value obtained of 0.410, which means that all habitat factors (X) tested only contributed 41% to the movement period. The significance value in the F-test is 0.000, so the null hypothesis (H_0) is rejected and all habitat factors (X) tested simultaneously affect the movement period (Y). Another 59% were explained by other factors not tested in the study. As many as three (3) out of seven (7) habitat factors (X) tested had a significance value higher than 0.05 (α), so it did not significantly affect the dependent variable. These variables are secondary forest (X_1), altitude (X_2), and distance from water (X_4). Meanwhile, the highest r partial value is indicated by the distance from the settlement, at 0.174, which means that the variable partially affects the movement period. The results of the regression analysis in detail are presented in Table 2.

Slope

The slope variable has a regression coefficient of -0.007. The longer the distance that passes through areas with flat slopes, the shorter the movement period (minutes/meters) will be. Flat slopes have a high level of preference because they facilitate the movement of elephants so that elephants do not need a long time to cross long distances. Steep slopes are avoided by elephants (Moßbrucker et al. 2016) because they limit their movement. Steep slopes make it difficult for elephants to move and require a longer time. The difficulty of elephants traversing steep and undulating areas is due to their size and physiological structure (Larramendi 2016; Jiang et al. 2023).

Table 2. Results of multiple regression analysis of movement period to habitat factors

Equation	R ²	F-test	T-test	r partial
Y = 5.461 - 6.822E-5X ₁ - 0.001X ₂ - 0.007X ₃ - 3.829E-5X ₄ + 0.000X ₅ + 0.002X ₆ - 0.002X ₇	0.410	0.000	X ₁ =0.948 X ₂ =0.251 X ₃ =0.000 X ₄ =0.880 X ₅ =0.000 X ₆ =0.001 X ₇ =0.022	X ₁ =-0.003 X ₂ =-0.046 X ₃ =-0.166 X ₄ =-0.006 X ₅ =0.174 X ₆ =0.135 X ₇ =-0.091

Note: Y: movement period; X₁: secondary forest; X₂: altitude; X₃: slope; X₄: distance from water sources; X₅: distance from settlements; X₆: distance from roads; X₇: daily movement distance

Distance from settlements

The value of the regression coefficient of this variable is 0.000. The movement period will increase when it is far from settlements. In other words, when close to settlements, travel time per minute will be faster because expulsion efforts from the community cause elephants to move more. Similar results were also obtained in the research of Khairani et al. (2022), where the distance from settlements affects the movement period in one of the elephant groups in Way Kambas National Park. Therefore, minimal human interference allows elephants to spend a longer time reaching a certain movement distance. Rohman et al. (2019) stated that efforts to expel elephants from areas adjacent to humans affect their daily home range preferences.

Distance from roads

The regression coefficient of the variable is +0.002. The longer the distance of elephant movement from the road, the movement period will increase. Similar to the distance from settlements, the distance from the road is closely related to human activity (Sulistiyono et al. 2019). As a sensitive animal, human existence will significantly determine the movement of elephants. The farther from the road, the less disturbance and human activity will be, so that elephants can travel longer distances. In line with the anti-predator theory, wild animals prefer locations away from disturbances or threats. The existence of roads can both harm and benefit the movement of elephants. On one side, elephants will avoid unprotected roads due to the higher threat of poaching and human disturbance. Conversely, secondary roads or abandoned roads become comfortable movement paths for elephants (Mills et al. 2018), so the movement period is relatively faster because it makes the movement easier. The results of Abram et al. (2022) study show that there is no significant relationship between elephant's entire extent and the proportion of time spent in hot spots that intersect with roads, but there is a very significant correlation between the proportion of time spent by elephants in hot spots with the proportion of time spent in hot spots that intersect with roads.

Implication for Sumatran elephant conservation

The movement of elephants according to the dimensions of space and time is important information that can be used as one of the bases for determining Sumatran

elephant management policies. The movement of Sumatran elephants is not random. However, it has a significant relationship with several habitat factors, including secondary forest land cover, altitude, flat slopes, distance from water sources, settlements, and roads. With the knowledge of certain habitat conditions that elephants prefer, further mapping can be carried out on HP Air Rami and surrounding areas so that priority locations that are suitable to support the activities and needs of Sumatran elephants are obtained.

The fact that elephant movement coexists with human activity causes the potential for elephant-human conflict in HP Air Rami to be inevitable. It can be seen that the movement of elephants at a close distance to water sources has the impact that the use of the same water source needs to be avoided. People should not use the Aek Simunggur River as a water source to meet their needs because this river is the primary source of water used by elephants in HP Air Rami. In addition, by knowing the locations of roads that have the potential to be passed by elephants, the community is expected to be able to take other road access that does not intersect with elephant movement patterns. Thus, contact and conflict between elephants and humans can be minimized.

The creation of corridors connecting habitat pockets in the Seblat landscape is a good step that has been pursued by the government and in collaboration with various stakeholders. In addition, considering that feed is one of the critical factors that greatly affect the movement of Sumatran elephants, the need for elephant feed and habitat-carrying capacity must be considered so that planned conservation efforts produce optimal results. Other than that, GPS collar installation can be done on all identified elephant groups in the Bengkulu area so that monitoring can be carried out more thoroughly. The success of Sumatran elephant conservation efforts is the responsibility of many parties, so cooperation from various parties, such as the government, managers, non-governmental organizations (NGOs), and the community is very important.

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