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Distribution and Density Estimation of Siamang (*Symphalangus syndactylus*) in Way Rilau Block, Way Sekampung Resort, Batutegi Protection Forest, Lampung Province

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Abstract
Siamang (*Symphalangus syndactylus*) is a seed-dispersing primate in forest conservation. Batutegi Protection Forest is one of the siamang habitats, but there is little information on siamangs in this location, including distribution and population density. Therefore, this study was conducted to (1) map the spatial distribution and analyze the distribution pattern of siamangs, (2) analyze the individual composition of siamangs, and (3) estimate the group density of siamangs in Way Rilau Block, Way Sekampung Resort, Batutegi Protection Forest, Lampung Province. Data collection of siamangs was conducted using two methods, namely roaming (direct data) and concentration point center count modification based on the direction of siamang sounds (indirect data). Roaming was conducted on three distinct transect with two repetitions. Point centers were determined by purposive sampling according to siamang sound detection points within a radius of <700 m and the distance between siamang groups ≥200 m. The area of Way Rilau Block that became the location of this study amounted to 3 km² or 300 ha. The results of nine days of data collection showed five groups in direct encounters and an estimated nine groups in indirect encounters from 67 sound detections. The distribution pattern of siamangs in Way Rilau Block was random (I_d = 1 and I_p = 0). The individual composition of siamangs from direct encounters was 12 individuals with the highest number in the adult age class (83.3%). Based on direct encounters, the siamang group size was 2.4 individuals/group with an estimated density of 1.6 groups/km², while the estimated density in indirect encounters was 3 groups/km².

Keywords: Primates; distribution patterns; sightings; groups.

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INTRODUCTION

Indonesia as a megabiodiversity country has a high biodiversity. Specifically for the primate class, there are at least 64 primate species native to Indonesia, belonging to 5 families, with 38 of these species being endemic (Supriatna et al., 2020). One of the family, Hylobatidae, commonly known as gibbons, is a group of frugivorous small apes that play a significant ecological role in forest regeneration within their habitat (Atmanto et al., 2014). Indonesia is home to a significant portion of the world's gibbon diversity, with four species found in Sumatra, four in Kalimantan, and one in Java. The siamang (*Symphalangus syndactylus*) is a Sumatran endemic species characterized by its larger body mass and increased muscularity compared to other gibbon species (Gibbonesia, 2021). As frugivores, siamangs disperse seeds through both synzoochory (by spitting out seeds) and endozoochory (by swallowing seeds whole), enabling seed dispersal hundreds of meters away from the parent tree (Atmanto et al., 2014).

Wildlife populations worldwide are declining due to anthropogenic activities such as large-scale habitat destruction, disturbance, and fragmentation (Hughes, 2017). That action negatively impacts arboreal species, as the loss of trees creates canopy gaps, thereby hindering their movement (Phoonjampa et al., 2011). Approximately 60% of the 504 primate species are threatened with extinction, with gibbons accounting for a significant majority (95%) (Estrada et al., 2017). All gibbon species, including the siamang, are protected under the Indonesian Minister of Environment and Forestry Regulation No. P.106/MENLHK/SETJEN/KUM.1/12/2018. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species has classified the siamang as endangered since 2008 (Nijman et al., 2020).

A considerable amount of research has been conducted on gibbons, covering aspects such as their ecological roles, activities, distribution, density, population studies, and habitat preferences (Annisa et al., 2017; Atmanto et al., 2014; Bismark et al., 2019; Gultom et al., 2019; Hankinson et al., 2021; Kwatrina et al., 2013; Meylia and Mustari, 2022; Rasyid et al., 2024). However, there has been no research conducted on siamangs in the Protected Forest of Lampung Province, thus necessitating further elaboration and exploration of siamang populations in this region. As one of the provinces in Sumatra, Lampung possesses relatively well-preserved forest vegetation suitable for siamang habitation. Nevertheless, the population of siamangs in this region is currently threatened by anthropogenic activities.

The total protected forest area in Lampung Province amounts to 317.615 hectares, with Batutegi Protected Forest being the largest at 58.162 hectares. The topography of this forest is characterized by gentle slopes and undulations, interspersed with hills and mountains (Ruchyansyah, 2014; Huda, 2022). The high habitat heterogeneity and extensive area contribute to the high plant biodiversity (approximately 346 species) in Batutegi Protected Forest, supporting the habitat for siamangs (Huda, 2022). Most studies on siamangs in Lampung have been conducted within national park areas. Information on siamang populations, including their distribution and density in Batutegi Protected Forest, remains scarce. Data-driven population monitoring and conservation strategies need to be targeted to preserve siamangs. Therefore, it is very necessary to conduct this research to map the spatial distribution, analyze dispersion patterns and individual composition, and estimate the density of siamang groups in the Batutegi Protection Forest, especially in the Way Rilau Block, Way Sekampung Resort.

MATERIALS AND METHODS

This research was conducted as part of the Yayasan Inisiasi Alam Rehabilitasi Indonesia (YIARI) program. The research was carried out from January to February 2024 in the Way Rilau Block, Way Sekampung Resort, Batutegi Protected Forest, Lampung Province. Geographically, Batutegi Protected Forest is located between 104°27'–104°54' East Longitude and 5°5'–5°22' South Latitude, covering an area of 58.162 hectares (Huda, 2022). Siamang data were collected on three distinct transects (transects A, B, and C) in the Way Rilau Block (Figure 1) using direct and indirect methods.

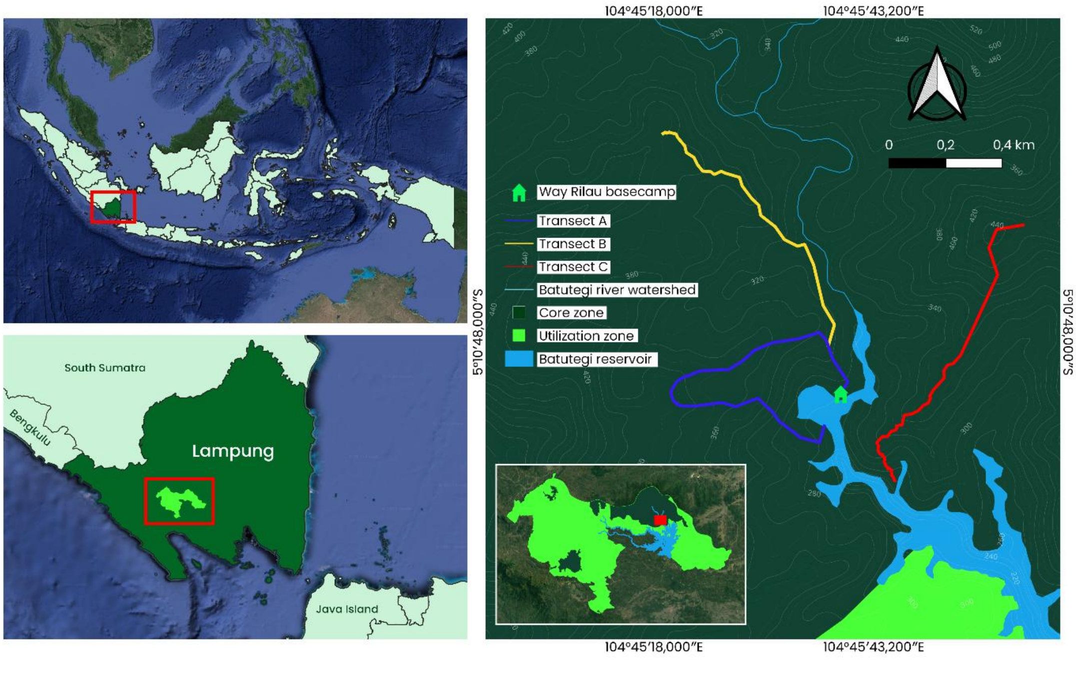

Figure 1. Research location.

Siamang data collection was carried out using two methods roaming for direct data collection by utilizing predetermined paths and concentration point center count modification for indirect data collection based on the sound of siamang group within a 700 m radius (Hankinson et al., 2021). Center points were determined by purposive sampling based on the sound siamangs being heard. In this research, external factors such as wind, rain, and temperature did not not affect the results (Bismark et al., 2019).

The path used is 1000 meters long with a 50 meters line of sight towards both sides of the path, meaning a total path width of 100 meters (Maulana et al., 2019). One day of observation with two replicates of each lane. In accordance with Sibarani and Utoyo (2020) ideally each predetermined path should be repeated at least twice. To avoid double counting, siamang groups were determined based on distances ≥200 meters (Rasyid et al., 2024). Observations were made with binoculars.
Data collection was carried out every 06.00 to 11.00 in one lane. Every detection of siamang outside of the observation time was recorded. The selection of time is based on the siamang's daily activity pattern, which is between between 06.00 to 07.00 (Larasati et al., 2023) and actively vocalizes at 08.00 to 11.00 , then decreases towards 14.00 (Zulamri et al., 2019). The parameters of the observed siamang data, number direct and indirect detections, cardinal direction of indirect detections, number of individuals in a group, age class of individuals, estimated sound distance, detection time, and detection coordinates.

Spatial distribution data was obtained based on the direction of siamang sound, obtained using a compass, and the coordinates of the location where the sound direction was taken using the using SMART Mobile application. Data was analyzed using QGIS 3.22.8 and Microsoft Excel 2021 software. Mapping the actual position of siamangs in the field, further analysis with coordinate data, azimuth, and estimated sound distance analyzed using the Shapefile Layer and azimuth features in QGIS.

Spatial distribution patterns of siamangs were analyzed by identifying individuals that rely on specific habitat conditions. Analysis was performed using the Morisita index of dispersion (I_d), calculated using Krebs (1989) formula, was employed to quantify this dependence.

$$I_d = n\left[\frac{\sum x^2 - \sum x}{(\sum x)^2 - \sum x}\right]$$

I_d = Morisita index of dispersion
n = number of transects
x = total number of siamangs per transect
Σx = total number of siamangs observed

The standardized distribution pattern of siamangs was obtained through the following calculations.

Uniform index (M_u)

$$M_u = \frac{x^2_{0,975} - n + \sum x_i}{(\sum x_i) - 1}$$

Clustering index (M_c)

$$M_c = \frac{x^2_{0,025} - n + \sum x_i}{(\sum x_i) - 1}$$

$x^2_{0.975}$ = value from the table with degrees of freedom (df) equal to (n-1) corresponding to a 97.5% confidence interval
$x^2_{0.025}$ = value from the table with degrees of freedom (df) equal to (n-1) corresponding to a 2.5% confidence interval
$\sum x_i$ = total number of siamangs in quadrat i (i = 1, ...n)
n = total number of quadrats

Based on the calculated values of M_u d and M_c, then the standardized morisita index (I_p) can be determined using one of the following equations.

If: $I_d > 1$ and $I_d \geq M_c$, then $I_p = 0{,}5 + 0{,}5\left(\frac{I_d + M_c}{n - M_c}\right)$

$I_d \geq 1$ and $I_d < M_c$, then $I_p = 0{,}5\left(\frac{I_d-1}{M_u-1}\right)$

$I_d < 1$ and $I_d > M_u$, then $I_p = -0{,}5\left(\frac{I_d-1}{M_u-1}\right)$

$I_d < 1$ and $I_d < M_u$, then $I_p = -0{,}5 + 0{,}5\left(\frac{I_d-M_u}{M_u}\right)$

The standardized morisita index (I_p) range [-1,1]. A value of $I_p = 0$ indicates a random distribution pattern, $I_p > 0$ indicates a clumped distribution pattern, and $I_p < 0$ indicates a uniform distribution pattern (Krebs, 1989).

Age class was analyzed by comparing the number of individuals in each age class of a siamang population, with age classes defined as infant (0-2 years), juvenile (2-6 years), and adult (>6 years) (Sampurna et al., 2014). Group size, or the number of individuals in a siamang group, was calculated using the equation of Sultan et al. (2009).

$$\text{group size} = \frac{\text{Total number of individuals identified}}{\text{Total number of groups identified}}$$

Siamang population size, defined as the number of individuals encountered, was estimated using the equation of Herriott (1978).

$$\text{P} = Nmax$$

P = population size of siamang individuals (individuals)
Nmax = Maximum population size of siamang individuals found

The density of gibbon groups can be estimated using the equation Seber (1986).

$$\text{D} = \frac{P}{A}$$

D = estimated density of siamang groups (groups/km²)
P = siamang group size (number of individuals)
A = representative area (km²)

RESULTS

Direct data collection from three distinct transects (transects A, B, and C) in the Way Rilau Block, Way Sekampung Resort, over nine days yielded five siamang groups, as presented in Table 1. Transects A and C each yielded two groups, while transect B yielded only one. Based on the results of direct data collection, Morisita's index (I_d) analysis indicated a random distribution pattern of siamangs in the Way Rilau Block.

Table 1. Siamang groups encountered during direct observations in the Way Rilau Block, Way Sekampung Resort

No	Transect	Siamang group	Σ
1	A	(A-1) (A-2)	2
2	B	(B-1)	1
3	C	(C-1) (C-2)	2
		Number of siamang groups	**5**

Indirect data collection from three distinct transects (transects A, B, and C) in the Way Rilau Block, Way Sekampung Resort, over nine days resulted in 67 sound detections. These data, summarized in Table 2, suggest the presence of approximately nine gibbon groups. Transect C recorded the highest number of sound detections (33), indicating the potential presence of four groups in that area.

Figure 2 presents the spatial distribution of gibbons derived from both direct and indirect sampling methods. The “siamang” icon represents direct data collection, while the “siamang vocalization point” indicates indirect data collection.

Table 2. Estimates of siamang groups encountered during indirect observations in the Way Rilau Block, Way Sekampung Resort

No	Transects	Sound detections	Estimates of siamang groups
1	A	26	3
2	B	8	2
3	C	33	4
	Number (Σ)	67	9

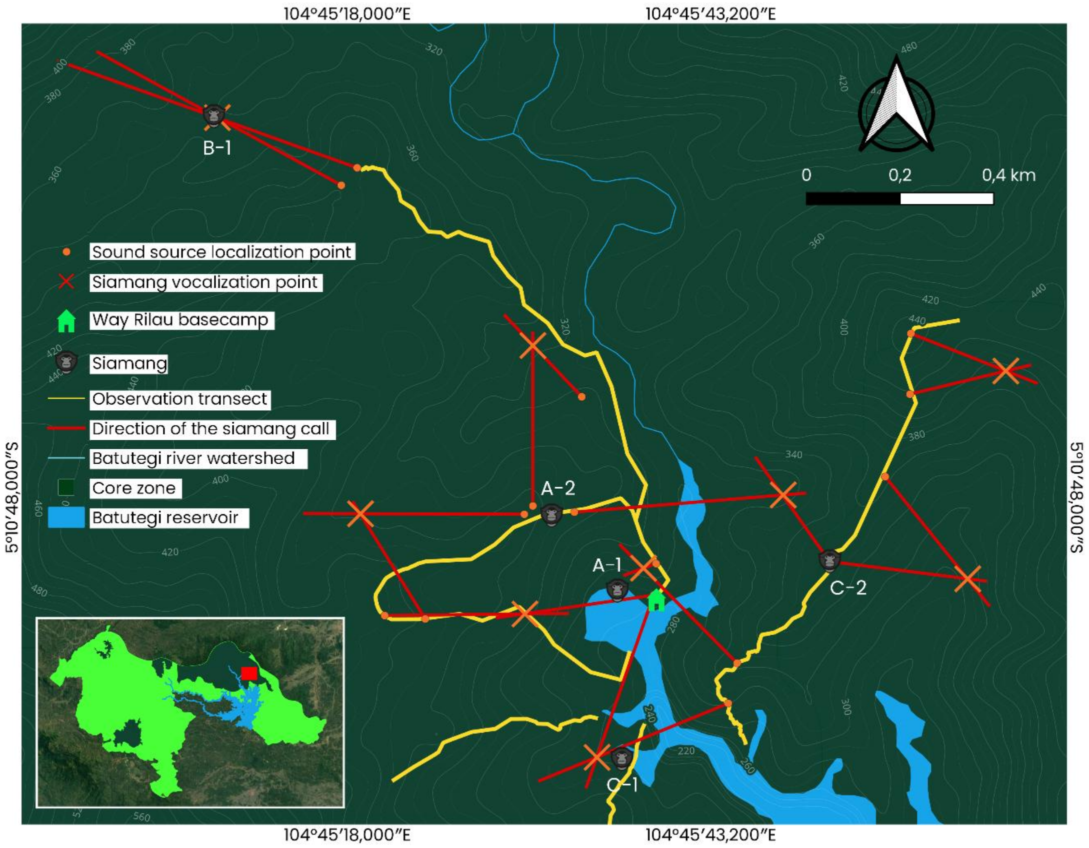

Figure 2. Spatial distribution of siamang in the Way Rilau Block, Way Sekampung Resort.

Table 3. Individual composition of siamang encountered during direct observations in the Way Rilau Block, Way Sekampung Resort

No	Siamang	Age class			Number of individuals
		Infant	Juvenile	Adult	
1	A-1	-	-	2	2
2	A-2	-	-	2	2
No	**Siamang**	**Age class**			**Number of individuals**
		Infant	**Juvenile**	**Adult**	
3	B-1	-	-	2	2
4	C-1	-	-	2	2
5	C-2	-	2	2	4
	Total number of individuals				12

The individual composition of siamang analysis focused on the age class and group size of siamang based on direct data collection. The results of the analysis are presented in Table 3. Siamang group C-2 exhibited a more favorable individual composition compared to other groups. Siamang group C-2 consists of two juveniles and two adults.

Direct data collection from three distinct transects from the three transects in the Way Rilau Block revealed that the adult age class constituted the majority of the siamang population, comprising 83.33% of the observed individuals. Juveniles represented 16.67% of the population, as shown in Figure 3.

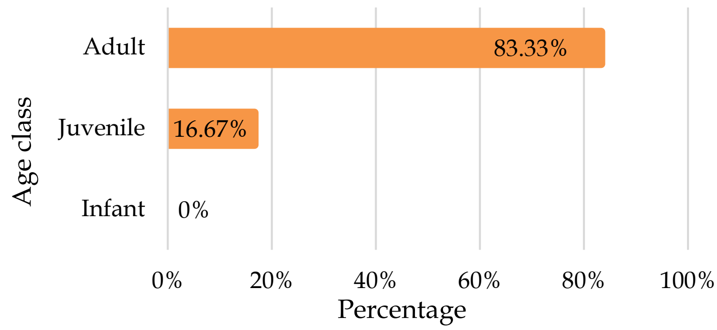

Figure 3. Age class of siamang encountered during direct observations in the Way Rilau Block, Way Sekampung Resort.

DISCUSSION

This research was conducted in the Way Rilau Block, situated at elevations ranging from 200 to 450 meters above sea level, categorized as lowland areas. Lowland and hilly forests <750 meters above sea level generally support higher densities of Hylobatidae due to abundant food trees and lower risks of habitat disturbance by humans (Kwatrina et al., 2013; Bismark et al., 2019; Kamaruzaman et al., 2023). As a lowland area, this location does not provide significant sound reflections, enabling the effective detection of siamang through indirect methods. Typically, sound characteristics in tropical rainforests can be categorized into three types low reverberation and high attenuation in lowlands, high reverberation, and low attenuation in highlands, and moderate reverberation and moderate attenuation in mountainous regions (Khadijah and Indrawan, 2021).

This research has been conducted in the Way Rilau Block with an altitude of 200 to 450 meters above sea leveland includes lowland areas. Generally, lowland forest and hilly <750 meters above sea level support population densities of Family Hylobatidae, due to the abundance of food trees and low risks of habitat disturbance by humans (Kwatrina et al., 2013; Bismark et al., 2019; Kamaruzaman et al., 2023). As a lowland area, this location does not provide significant sound reflections, so indirect sightings can be made. In general, the sound character in tropical rainforests is divided into three; low echo and high attenuation at low altitude, high echo and low attenuation at high altitude, and moderate high echo and moderate low attenuation in the mountains (Khadijah and Indrawan, 2021).

The area of Way Rilau Block which is the location of this research an area of 3 km² or 300 ha. This area is part of the Way Rilau watershed, so there are many fruit trees that are a source of food for gibbons. Watershed can provide rich food resources (Kwatrina et al., 2013). Therefore, gibbon detections in direct and indirect observations showed significant variability.

In this research, weather conditions did not significantly affect the research results. Weather conditions, such as rain, occurred in the afternoon when siamang activity began to decline. However, the siamangs high instinct in estimating the weather made them speed up their activities and move to safer parts of the forest that were not far from the sleeping trees (Sari and Harianto, 2015).

Direct observations in the Way Rilau Block showed that siamang groups were more easily found in Transects A and C with two groups, while only one group was found in Transect B (Table 1). This difference in sightings suggests that habitat quality in Transects A and C is better than in Transect B. Good habitat can support a larger siamang populations than poor habitat conditions such as anthropogenic disturbances (Maulana et al., 2019). There was one group of siamangs found in a very close location to humans on two different occasions, namely in front of the Way Rilau Basecamp at 11.00 to 11.44 AM. The group was observed resting, indicating a high level of adaptation to human presence. The continued presence of humans in the area suggests that the siamang do not perceive a significant threat (Soimin andNahlunnisa, 2023).

Indirect observation in the Way Rilau Block estimated the highest number of groups in Transect C four groups (Table 2). This estimate correlates with the greatest number of sound detections recorded on this transect. Variations in the number of sound detections across transects can be attributed to inconsistencies in data collection, primarily due to researcher stops. These pauses resulted in differing numbers of detections and were influenced by the number of siamang groups audible along each transect. Detections were obtained by determining the direction of siamang vocalizations with an estimated distance of <700 m and an inter-group distance of ≥200 m (Hankinson et al., 2021; Rasyid et al., 2024; Meylia and Mustari, 2022). Estimations were made based on the repeated location of consistent vocalization directions from different days, as well as the acquisition of vocalization directions from multiple locations during a single vocalization event. Siamang sound varies in duration from 10 to 30 minutes with an average of 11 to 15 minutes (Zulamri et al., 2019; Castiglioni et al., 2022).

Siamang distribution is influenced by the availability food, so so the siamang daily travel route is not just one direction. However, abundant food in the territorial area makes siamang travel activity decrease (Sari and Harianto, 2015; Asensio et al., 2011). Based on the result of direct data collection, the spatial distribution of siamangs in the Way Rilau Block was found to be random (I_p = 0). Morisita index (I_d) analysis results in a value of 1and the clustering index (M_c) result in a value of 1.48. Since Mc > Id ≥ 1, the dispersion index (Ip) was calculated as 0. This indicates that the secondary forest has a suitable habitat for siamang survival because it is able to provide sufficient food sources for siamang groups with the maximum number. The random pattern also shows that siamang have the same opportunity to occupy a point in the habitat due to homogeneous environmental factors, no competition, and no tendency to cluster in the population (Hidayatullah et al., 2018).

In addition to siamang sightings, agile gibbons (*Hylobates agilis*) were recorded in the Way Rilau Block. More direct observations were in three groups each group averaging three individuals. According to Sari and Harianto (2015), siamangs social relationships with other animals are quite good because they share areas searching for food. Although both species utilize the same food tree species in similar forest strata, there are different ecological niches (Kamaruzaman et al., 2023). In addition, neighboring groups will share home ranges in search of food (Cheyne et al., 2019). However, during observations in Transect C, a group of siamang was detected making alarm calls upon encountering a group of long-tailed macaques (*Presbytis melalophos*). Alarm calls are alarm sounds emitted in conditions of danger due to predators (Annisa et al., 2017).

Siamang group C (C-2) had the largest group size four individuals, consiting of two juveniles and two adults (Table 3). Two or more juveniles in a group indicates the presence of individuals who have not formed a new groups. The phenomenon of groups with ≥4 individuals is due to the presence of adult offspring that have not formed a new group (Bangun et al., 2009). Other siamang group encountered consistend of only one adult male and one adult female.

Group size refer to the number of individuals in a group, so the group size obtained at the research site was 2.4 individuals/group. This group size is smaller than the results of Rasyid et al. (2024) in the Damaran Baru Forest which obtained 3 individuals per group in the research area of 251 hectare. Similarly, Meylia and Mustari (2022) in the Batang Toru Ecosystem, Tapanuli obtained 3.6 individuals per group in the research area of 1.251 hectares. The size of the group is indicated by how many members are in a group. According to Rasyid et al. (2021), the small size of group can be caused the process of forming a new group in one of the groups or not having many children.

Food souces and the environmental are factors in siamang group size, especially during the nurturing or growth period of the siamang population (Meylia and Mustari, 2022). According to Gultom et al. (2019), food availability is key to wildlife survival and if the habitats does not meet the nutritional needs of animals, animals will look for food sources from alternative habitats. Information on the food composition of siamangs in Way Rilau Block is still lacking, but based on field data, the presence of Ficup sp. indicates a potential food source for siamangs.

The adult age class exhibited the highest number among all age classes within the Way Rilau Block siamang population (Figure 3). Notably, no infants were observed. The adult class comprised adult pairs (83.3%) and a proportion of adolescents (16.67%). The prevalence of adult pairs suggests that many of the siamang groups in this area are newly formed. Age is a critical parameter for assessing wildlife population regeneration. The high proportion of adult pairs indicates the establishment of new groups and the potential for population growth provided habitat conditions remain favorable (Maulana et al., 2019).

A stable population typically exhibits a higher proportion of young individuals compared to adults. However, the scarcity of young individuals in this research, coupled with the relatively long generation time of siamang. According to Nijman et al. (2020), siamang birth interval range from 3-4 years. While the gestation period range from 7-8 months and can only live up to 25 years or during life and can give birth up to four times (Sari and Harianto, 2015). However, the presence of many adult groups allows siamangs in Way Rilau Block to have the potential to start regeneration, if habitat conditions are good.

Based on direct obeservation data on three distinct transects in the Way Rilau Block, there was a population size of 12 individuals. This results is less than that of the Damaran Baru Forest by

Rasyid et al. (2024) which had a population size of 15 individuals and 23 individual siamangs in Dolok Sipirok, North Sumatra by Kwatrina et al. (2013). However, the population size of siamangs in this location is larger than the population size in the Kedah Rainforest in 2021 of 8 individuals. The difference in population size is influenced by the habitat carrying capacity of each location and factors such as availability of the food tress, sleeping tree, reproduction, immigration, emigration, and the age of sexual maturity (Rasyid et al., 2024). So that these factors affect population dynamics in variatious location, which caues different in population numbers at different research sites.

The ideal population density in the Way Rilau Block area remains undetermined due to a lack of baseline data. In this research, the direct observation method yielded a density of 1.6 groups/km², while the indirect method estimated a density of 3 groups/km². These results are comparable to those reported by Rasyid et al. (2024) in Damaran Baru Forest, suggesting a similar habitat quality 251 ha obtained 2.3 groups/km². These suggest that the Way Rilau Block, Batutegi Protected Forest and Damaran Baru Forest share similar supportive habitat conditions. A sustained increase in siamang group density can mitigate the risk of inbreeding. However, habitat fragmentation can isolate small populations and increase the likelihood of inbreeding (Cheyne et al., 2019; Geissmann, 2007).

CONCLUSION

Five siamang groups were directly encountered, and an estimated nine groups were indirectly detected from 67 sound detections across three distinct transects in the 3 km² research site of Blok Way Rilau, Batutegi Protected Forest, Way Sekampung Resort. The siamang distribution pattern in Blok Way Rilau was random (I_d = 1 and I_p = 0). Direct encounters revealed 12 individuals, with adults being the most abundant age class (83.3%). Based on direct encounters, the average group size was 2.4 individuals/group, with an estimated density of 1.6 groups/km². Indirect encounters estimated a higher density of 3 groups/km².

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CONFLICT OF INTEREST

There is no conflict of interest.

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