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Population density survey of white-bearded gibbons (*Hylobates albibarbis*) in high conservation value forest area of palm oil plantation company, Central Kalimantan, Indonesia

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Abstract. *Nurvianto S, Adrianti DT, Hamdan F, Triyanto J, Darmanto A. 2022. Population density survey of white-bearded gibbons (*Hylobates albibarbis*) in high conservation value forest area of palm oil plantation company, Central Kalimantan, Indonesia. Biodiversitas 23: 2245-2254.* Bornean white-bearded gibbon (*Hylobates albibarbis* Lyon, 1911) or Bornean agile gibbon or southern gibbon is an endemic primate of Borneo and its distribution is limited to the forest areas in Central Kalimantan and West Kalimantan, Indonesia. However, its habitat is not restricted to the natural and undisturbed forest because this species also utilizes some forest blocks around rubber and palm oil plantation as habitats. This study aimed to estimate this species' population density and distribution in the five conservation blocks of PT Sawit Sumbermas Sarana (PT SSS), Indonesia and identify factors affecting its distribution. A field survey was conducted in five high conservation value forest areas inside the PT SSS management area, namely Pondok Duku Block, East Bravo Rangda Block, West Bravo Rangda Block, Tanjung Biru Block, and forest blocks around Kenambui Lake. Data was collected from April to May 2019 using the auditory sampling method through predetermined fixed Listening Posts (LP) to record population data. In addition, the protocol sampling technique was employed to systematically record the habitat features within the research site by establishing 0.04 ha plots systematically with a distance between plots of 400 m. Factors affecting gibbon distribution were identified using binary logistic regression. From the field survey, we identified that the southern gibbon was only found in East Bravo Rangda Block and Tanjung Biru Block with a population density of 4.26 ± 0.12 group/km² or 8.53 ± 0.34 individual/km² and 4.26 ± 0.12 group/km² or 8.53 ± 0.34 individual/km², respectively. Gibbon distribution was significantly associated with the number of seedlings (0.024±0.010, *P*=0.015), saplings (0.128±0.042, *P*=0.002), and trees (0.225±0.110, *P*=0.042. This result showed that vegetation condition strongly influences the presence of gibbon in an area.

Keywords: Auditory sampling method, *Hylobates albibarbis*, high conservation value forest, population, palm oil plantation

INTRODUCTION

Tropical terrestrial ecosystems have dynamic conditions influenced by disturbances such as fires, floods, and storms. Moreover, the global change processes, including the melting of perennial ice and dominant vegetation dynamics, signify the system's vulnerability to changes in ecosystem processes(Goldammer and Furyaev 1996; Gunderson and Holling 2002). This phenomenon can change the response of the global climate system and affect the sustainability of the production of renewable natural resources and the abundance of flora and fauna required by local cultures (Elmqvist et al. 2004). In addition, species distribution and community structure have changed due to increasing global temperature (Elmqvist et al. 2004). The combination of global climate change and the direct effects of human activities has negative impacts on ecosystems, resulting in local extinction of flora and fauna species, relocation of species, as well as the introduction of new invasive species (Harvell et al. 2002; Walther et al. 2002; Elmqvist et al. 2004; Thomas et al. 2004; Wilmers et al. 2006).

Ecosystem resilience has been proposed as an important factor that must be considered in producing natural resources and ecosystem services in complex and uncertain systems (Gunderson and Holling 2002). Ecosystem resilience is the amount of disturbance absorbed by a system and remains in its original state (Holling 1973; 1996). Resilience also includes the ability of an ecosystem to re-organize and renew when disturbance or change occurs. The definition includes how the system can self-organize (versus a lack of organization or organization forced by external factors) and how the system expresses a capacity to learn and adapt (Carpenter et al. 2001). Since intrinsic disturbance is part of the ecosystem, it is impossible to eliminate (Elmqvist et al. 2004).

Natural disturbances tend to occur on a smaller scale in terms of their characteristics, frequency, and distribution. In contrast, human disturbances tend to turn these minor disturbances into larger and more severe ones and create even more complex combinations of disturbances (Bengtsson et al. 2003). The existence of species that have an important function in the ecosystem's renewal and re-organization is needed to maintain the sustainability of ecosystem functions and resilience. Therefore, efforts to preserve biodiversity need to be carried out to maintain ecosystem sustainability (Folke et al. 1996).

Biodiversity conservation has become a major concern for forest managers and conservationists worldwide and is also one of the foundational principles of forest ecological sustainability (Carey and Curtis 1996; Hunter 1999). Biodiversity conservation poses a major challenge to forest management as forests support approximately 65 percent of terrestrial taxa worldwide (WCFSD 1999). In addition, forest areas are the richest areas on earth, not only for vertebrates, such as birds (Gill 1995) but also for invertebrates (Erwin 1982) and microbes (Torsvik et al. 1990).

Generally, in biodiversity conservation, wildlife in an area becomes the benchmark for its management (Caro 1999; Caro and O'Doherty 1999). The definition of wildlife is quite varied; however, wildlife is often restricted to terrestrial and aquatic vertebrates other than fish (Krausman 2002). Wildlife was chosen because wildlife is at the top of the food chain. If the species at the top of the food chain are sufficiently diverse, the species at the bottom are likely diverse (Elmhagen and Rushton 2007; Gordon et al. 2015). In addition, wildlife also plays an important role as an environmental quality indicator (Caro and O'Doherty 1999). For example, most primates living in tropical forests are biodiversity indicators (Chapman 1995; Mittermeier et al. 2006) that can be used as flagship species in conservation activities (Caro and O'Doherty 1999).

Threats to primate conservation have increased in the last 40 years (Lovett and Marshall 2006). Many primatologists have tried to develop primate conservation strategies to reduce the pressure and extinction threat. However, the number of threatened primates increases (Lovett and Marshall 2006). Habitat loss and hunting are the main causes that threaten primate sustainability (Mittermeier et al. 2006). Weak political will and low funding support for primate conservation are other causes of this threat (Oates 2013). Currently, most conservation activities are still focused on protected areas that only have a small proportion of the natural distribution of protected primates (Meijaard et al. 2011). Therefore, involving areas outside protected areas is very important in conserving primates and other species (Lindenmayer and Franklin 2002).

The Bornean agile gibbon or southern gibbon *(Hylobates albibarbis* Lyon, 1911) is an arboreal ape species whose distribution is limited to the island of Borneo especially in the area between the Kapuas River and the Barito River (Brandon-Jones et al. 2004). Southern gibbons inhabit primary forests, secondary forests, and former selective logging forests to swamp forests (Buckley et al. 2006). This gibbon can also be found in the forests disturbed by human activities, where orangutans generally can not be found (Cheyne et al. 2016). Southern gibbon population density is generally influenced by several factors such as canopy cover, tree height, the density of large trees, and food availability (Hamard et al. 2010). In addition, elevation or altitude also affects the distribution of gibbons (Marshall et al. 2009). This gibbon is more commonly found in lowland forests because the availability of large trees and food tends to be more abundant (Hamard et al. 2010). The main diet of southern gibbon is fruits; therefore, gibbons have the potential to play an important role in the process of seed dispersal (Dillis et al. 2015).

All gibbon species in Indonesia, including the southern gibbon, are endangered species according to the International Union for Conservation of Nature (IUCN) Red List. This is because the population of this family tends to decline, and the threats to the existence of these species are very high (Cheyne 2010). For example, the southern gibbon population has decreased by more than 50% in 30 years. Hunting for animal trade is a major threat to preserving the southern gibbon. In addition, the destruction of the southern gibbon habitat, which is generally in the form of swamp forest, also can cause a decline in the population of this species (Nijman et al. 2008). Therefore, the gibbon population trend that tends to decline needs to be taken seriously to not lead to extinction. Currently, the southern gibbon is a protected species by the Republic of Indonesia Government through the Regulation of the Minister of Environment and Forestry Number P.106/MENLHK/SETJEN/KUM.1/12/2018 on the Second Amendment to Regulation of the Minister of Environment and Forestry Number P.20/MENLHK/SETJEN/KUM.1/6/2018 on Protected Plant and Animal Species. In addition, the southern gibbon is also listed as a species in the Appendix I category according to the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora list.

Many forest areas that are not protected areas still function as primate habitats. One example is the conservation area of PT Sawit Sumbermas Sarana Limited Company (PT SSS). Based on the High Conservation Value Forest (HCVF) identification survey conducted by the company in 2015, it was known that there were several types of primates in the conservation area, including the southern gibbon (*H. albibarbis*). Considering this species has high conservation status, PT SSS intends to conduct management and conservation efforts. However, making management plans and conservation strategies for this species requires actual baseline data related to its ecology (Sutherland et al. 2004), especially population and habitat (Morrison 2002; Morrison et al. 2006). For this reason, research on the population and habitat of this species was conducted.

MATERIALS AND METHODS

Study area

The survey was conducted in the PT SSS conservation area, Indonesia, which has a total area of 817.3 ha, all of them have a High Conservation Value (HCV) areas status. This location is located within the administrative area of Kota Waringin Barat, Central Kalimantan, Indonesia. Generally, the study areas are forest patches located within palm oil companies (Figure 1). The size of each patch quite varied, and generally, the habitat type was a secondary forest. Human activities in these forest patches were quite intensive because apart from being part of a palm oil company, the study area also found indications of agricultural activities by local people, especially rubber plantations.

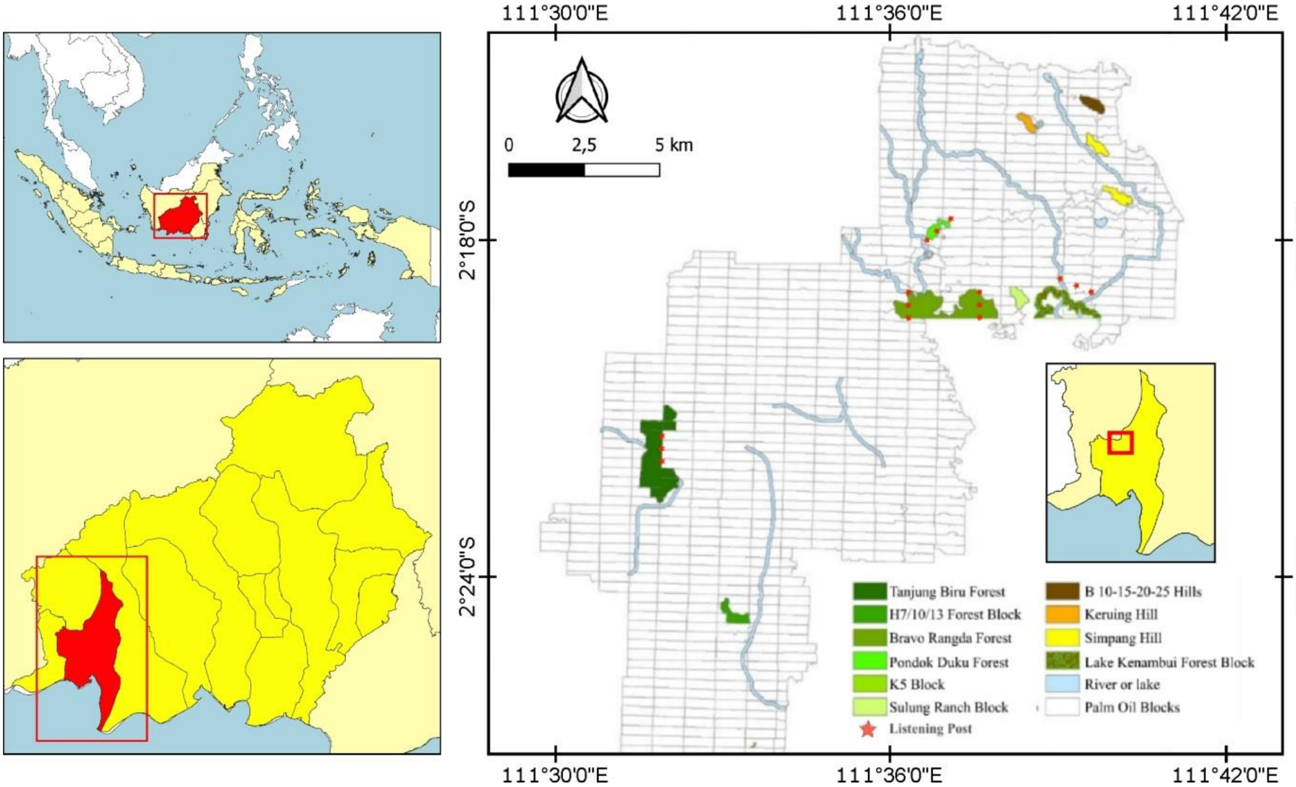

Figure 1. The research locations in the PT Sawit Sumbermas Sarana, HCV area, Indonesia, which is marked in blue (river border), green (forest area) and magenta (hilly area)

Identification of gibbon population and distribution

Population data has been collected using the line transect sampling (LTS) method combined with the triangulation method. This sampling method is widely used to estimate the relative density of wildlife populations (Ringvall et al. 2000). In addition, researchers have used this method to estimate animal abundance in various taxa such as birds (Usieta et al. 2013), terrestrial mammals (Caro 1999; Wanyama et al. 2010; Kumara et al. 2012), primates (de Thoisy 2000; Bardsen and Fox 2006; Marshall et al. 2008; Fonkwo et al. 2011) and marine mammals (Calombokidis 2004; Thomas et al. 2007; Buckland et al. 2009; Buckland et al. 2010).

The transect length that we used was adjusted to the size of the study area. Generally, transects were between 400-1200 meters in length. In addition, several transects were made by following existing trails, especially for locations with small and elongated areas, such as areas on the riverbanks. The survey using this LTS started at 10:00 after the observations in each listening post were conducted.

In addition to LTS, we also use the triangulation method to estimate the gibbon population density (Brockelman and Srikosamatara 1993; Buckley et al. 2006; Kidney et al. 2016). This method has been conducted by establishing a series of listening posts at three points placed in a straight line with a distance between plots ranging from 300-500 m (Hankinson 2016). Listening to posts made in a linear form is proven to reduce variance and bias compared to posts made with a triangular shape (Kidney et al. 2016). The minimum distance between a series of listening posts with one should not be less than 2 km. We have established a set of listening posts for each forest block. In this study, listening posts are locations that the researcher has determined as observation points, and no special buildings were built at these observation points.

Observations were conducted by listening to the gibbon sound, including calls and singing. Researchers must be in the listening post at 05:00 am and remain at their respective posts to record the gibbon sound until 10:00 am or 30 minutes after the last gibbon was heard (Höing et al. 2013). Gibbon individuals or groups seen directly during the observation process were also recorded. We recorded the time, direction, and estimated the distance of the calls or singing using binoculars. We synchronized the angle of the singing every 3 minutes intervals, and the duration was calculated using a stopwatch. The singing was considered to stop if the gibbon was silent for more than 2 minutes. Only gibbon sounds with one great call indicating a family group was included in the analysis to avoid counting solitary gibbon (Brockelman and Ali 1987). Individual gibbon singing or calls were not used for this calculation. We conducted cross-confirmation between teams in each listening post after hearing the gibbons sound using handy talky. The gibbon sound direction and its approximate position were recorded and then used as a reference for determining the exact gibbon position using Q-GIS software. The directly detected gibbons were marked with a global positioning system (GPS) to determine the group position and the gibbon number in the group. Observations were made at least 4 times at each location to anticipate if gibbon groups did not make a sound on a certain day (Höing et al. 2013) because gibbons could not make any sound for several days, even in clear weather (Cheyne et al. 2008).

To estimate population density, we use the number of detected groups as a basis. For this reason, the identification of gibbon groups that perform singing or calls on the same day was a crucial factor. Group identification was conducted by considering singing time, singing direction, and the 500 m rule. If there are many small groups less than 500 m apart, in the same area, and on the same day, it can be assumed that they are the same group (Brockelman and Srikosamatara 1993). In this way, we can distinguish the sounds produced by gibbon groups on the same day. Therefore, the calculation of gibbon population density uses the largest group found on one day, this assumption was used because we cannot distinguish gibbon singing that appears on different days (Brockelman and Srikosamatara 1993). To avoid the bias caused, because gibbons did not make any singing every day, it was necessary to use a correction factor. The correction factor requires information about the group composition and behavior of the gibbons when singing, which is difficult to obtain in observations for a short duration. Therefore, a correction factor is needed to minimize errors caused by variability by converting singing frequency into an estimate of population density (Cheyne et al. 2016).

The effective listening area is the maximum area where the gibbon's voice can still be heard from the listening post. Generally, the sound of gibbons can still be heard from 1.5 km (Rawson et al. 2011). This assumption was used to make zoning in the forested area around the listening post an effective listening area. The zoning was made by determining the buffer from a series of listening posts. The buffer used was a maximum of 1 km from the listening post center (Hamard 2008; Cheyne et al. 2016). All non-forested areas were excluded from the effective listening area. Furthermore, determining an effective listening area was conducted by using Q-GIS software.

Procedures for habitat variables collection

We used two methods to measure habitat features in the study area: independent exploration and the quadrat sampling method. The free exploration method was conducted by identifying each species encountered during exploration in the study area. This method produces a list and number of flora species found in the field. The quadrat sampling plot size used in this vegetation analysis was 1 x 1 m for grass, 2 x 2 m for seedlings and undergrowth (height below 1.5 m), 5 x 5 m for saplings (diameter below 10 cm and height above 1.5 m), 10 x 10 m for poles (10-20 cm in diameter) and 20 x 20 m for trees (over 20 cm in diameter). The number of species and individuals was counted manually in the respective squares. We used the book "Trees of Tropical Asia: an illustrated guide to diversity" (La Frankie 2010) as a field guide to identify flora species.

A circular plot with 0.04 ha has been used to identify the habitat features. All circular plots were systematically placed in the study area with 400 m between the center points of the plots. In research related to habitat, this sampling method is also often referred to as Protocol Sampling (PS) (Noon 1981). Habitat features measured in the 0.04 ha (r = 11.3 m) circle are shrub density, canopy cover, ground cover, canopy height, slope, understory foliage volume, microclimate, woody stem density, herbaceous stem density, and surface components. We also recorded all habitat disturbances and human activity around the circular plot. A circular plot is placed in the center of quadrat sampling plots. The total plots that we have established in this study are 178 plots, systematically placed in the HCV area of PT. SSS.

Data analysis

The gibbon density was calculated by adding up all individuals found at the study site and then dividing by the area of the study site. Individual density estimates will be analyzed using Distance 6.2 software (Buckland et al. 2001; Thomas et al. 2010). The gibbon group data obtained from the listening post through the triangulation method were analyzed using the equation to calculate group density (D) developed by Brockelman and Ali (1987):

$$D = n / [p(m) \times E] \quad (1)$$

$$p(m) = 1 - [1 - p(1)]m \quad (2)$$

Where n is the number of groups listened to in one area on a certain day, p(m) is the correction factor or the proportion of groups that sing for *m* days and E is the effective listening area. The correction factor p(m) is calculated using formula (2), where p (1) describes the probability of a great call sound at a certain time, namely the ratio of the number of days where gibbons make great calls with the number of days of observation m. The effective listening area is obtained by determining the forested area based on a maximum buffer of 1 km from the center of the listening post.

The gibbon presence frequency (PF) was used to describe the even distribution of the species across the study area. The following equation can calculate the presence frequency:

$$PF = \frac{\text{Number of plots where gibbons detected}}{\text{Total number of Plot}} \times 100\%$$

The normality test by plotting the frequency on each raw data was used to identify the normality of the data. The research data was not normally distributed, so binary logistic regression analysis was used. The presence of gibbons will be written to the binary code as 1, and the absence will be written as 0. Data analysis for habitat selection was conducted using logistic regression analysis with the following equation:

$$p(y=1) = \frac{1}{1+\exp(-(b_0+b_1x_{1i}+b_2x_{2i}+\ldots+b_kx_{ki}))}$$

Where: p is the probability that the event y occurs. An area with certain habitat characteristics that allow the value of p greater than or equal to 0.5 is said to be a suitable habitat for gibbons, on the other hand, if the value of p is less than 0.5, it is unsuitable habitat for gibbons.

RESULTS AND DISCUSSION

The gibbon population in the HCV area of PT. SSS

Singing is a gibbon's habit of marking its territory and strengthening bonds between individuals in the group (Cheyne 2010). During the research, 216 singing events were recorded, and 140 of them were great calls (Table 1). Calls made by a single individual were not used in this analysis. Singing is density-dependent, where vocalization will occur less in locations with low gibbon group density (Nijman 2004).

A singing event is crucial in determining the number of groups to identify the density of gibbon groups and individuals in an area. Eight groups of gibbons were identified in the PT SSS HCV area, four each in the East Bravo Rangda Forest Block and four groups in the Tanjung Biru Forest Block. The number of groups was determined based on the number of days the most groups were identified, assuming that observers could not distinguish vocalizations on different days (Brockelman and Srikosamatara 1993). No gibbon groups were found for the Lake Kenambui, Bravo Rangda Barat, and Pondok Duku Borders. However, for the Pondok Duku Forest and the Bravo Rangda Barat Forest, 9 and 6 solo calls were identified, respectively (Table 1).

During the study, five direct encounters occurred, four times with a group of gibbons and once with individual gibbons (Table 1). All direct encounters took place in the Bravo Rangda Timur Forest Block. The total number of gibbon individuals in the group was two individuals; thus, the average group size was two individuals (out of 4 encounters). This direct encounter occurred either because the observer approached the origin of the sound or because the gibbons could be seen directly from the listening post. The East Bravo Rangda Forest consists of forest patches that allow observers to see the gibbons from a considerable distance, especially when the gibbons sing in the upper tree canopy.

Observers could hear singing even from a considerable distance. Singing can usually be heard up to a distance of 1.5 km; however, this distance may vary due to topographical conditions (Hankinson 2016). For this reason, it is important to determine the effective listening area. The effective listening area can be determined by creating a 1 km buffer for each listening post (Hamard 2008; Cheyne et al. 2016). Based on the calculation results, the effective listening area in Rangda Timur Bravo Forest and Tanjung Biru Forest is 0.97-1.03 km^2 and 1.65-2.24 km^2, respectively (Table 2). However, the effective listening area at each observation location may differ from one location to another. This is due to the difference in the size of the forested area in each location.

Observers note that gibbons do not always sing. Because of that, this study needs to use a correction factor to avoid calculation bias. This assumes that the vocalizations of all gibbon groups in the region can be heard (Brockelman and Srikosamatara 1993). Based on the calculations, the correction factors for East Bravo Rangda Forest and Tanjung Biru Forest are 1 and 0.94, respectively (Table 2). No calculations were conducted for the West Bravo Rangda Forest, Pondok Duku Forest, and the Kenambui Lake Border because the great calls were not recorded in these areas.

The results showed that the gibbon's population density in East Bravo Rangda Forest and Tanjung Biru Forest was 4.26 ± 0.12 groups/km^2 and 2.1 ± 0.32 groups/km^2, respectively. The average number of individuals in one group was two individuals because no juveniles were identified during the observation, so only adult males and females were found (Table 1).

The group density for both blocks is normal. This is based on a review of research conducted by Chivers (1977), which stated that the low-density limit for the gibbon group was less than two groups/km^2 (Brockelman and Srikosamatara 1993). Thus, the individual gibbons' density in the two forest blocks was 8.53 ± 0.34 individuals/km^2 in the East Bravo Rangda Forest block and 4.20 ± 0.89 individuals/km^2 in the Tanjung Biru Forest, which indicates that the gibbon density in both blocks was normal (Chivers 1977).

Table 1. The comparison of gibbon singing numbers and its direct encounters in each location

Locations	∑ Singing		Direct Encounters	
	GC	SC	Group	Individual
Pondok Duku	0	9	0	0
Lake Kenambui	0	0	0	0
West Bravo Rangda	0	6	0	0
East Bravo Rangda	42	18	4	1
Tanjung Biru	98	43	0	0
Sub-Total	140	76	4	1
Total of singing			216	
Total of direct encounter			5	
Average number of individuals in the group			2	

Note: ∑ Singing: number of singing, GC: Great Calls, SC: Solo calls

Table 2. Gibbon population density in the High Conservation Value area of PT SSS, Indonesia

Location	ELP (km^2)		∑GG	CF	dGG (km^2)	dGI (km^2)
	Min	Max				
Pondok Duku	0.23	0.23	0	0	0	0
Lake Kenambui	0.46	0.65	0	0	0	0
W. Bravo Rangda	0.72	0.97	0	0	0	0
E. Bravo Rangda	0.97	1.03	4	0.94	4.26 ± 0.12	8.53 ± 0.34
Tanjung Biru	1.65	2.24	4	1	2.10 ± 0.32	4.20 ± 0.89

Note: ELP: Effective area of each listeing post, ∑GG: Number of gibbon group, dGG: Gibbon group density, dGI: Density of Individual gibbon

Factors affecting the gibbon distribution

The secondary forest is the gibbon habitat in the PT SSS conservation area, and the location has a status as HCV area. The gibbon's presence can be detected by singing and by the direct encounter. During the study, from 176 grids, 16 of them showed some signs of gibbon presence, which means that the frequency of gibbon presence in all study areas was only 9%. The location where the gibbons were encountered can be seen in Table 1. The gibbon presence signs were analyzed using multiple regression with the binomial family. This analysis was used to identify the variables that had a significant correlation (P<0.05) with the gibbon presence in the study area. From the results of the analysis, it is identified that three variables have a significant influence on the gibbon presence in this study area: number of seedlings (0.024±0.010, P=0.015), number of saplings (0.128±0.042, P=0.002), and number of trees (0.225±0.110, P=0.042) (Table 3). From this value, the number of trees was the variable that had the strongest positive association with the gibbon presence in the study area. Another variable is the number of seedlings and saplings, which also positively affects the gibbon presence. These two variables are most likely the effect of gibbons' presence in a location. When gibbons are present at the location, gibbon droppings carry various seeds from the vegetation they eat. This ability makes gibbons a key seed disperser in tropical forests (Hai et al. 2018; Phiphatsuwannachai et al. 2018).

Trees have a very important role for gibbons because they use trees for play, movement, and (Gittins and Raemaekers 1980). In addition to this function, tall trees with open canopies are often used as jousting spots for males to monitor their territory (Gittins 1980). Based on the field survey results, 61 tree species were identified in 170 observation plots. The following ten species with the highest INP in the research location are presented in Table 4. Table 4 also presents the use of these species as fed by other types of gibbons based on a literature review (Gittins and Raemaekers 1980; Inoue et al. 2016; Clink et al. 2017).

Not all the tree species that dominate the study area are edible by gibbons. However, at least five tree species were known to be consumed by gibbons, namely *Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg., *Artocarpus champeden* (Lour.) Spreng., *Ficus retusa* L., *Campnosperma* sp. and *Bhesa paniculata* Arn. *Ficus retusa* is a species of the family Moraceae and has a type of small fruit, lots of water, and when ripe, the fruit becomes soft. In the feed classification, this species is included in the figs category, one of the feed types preferred by gibbons (Clink et al. 2017).

Pole growth forms play an important role in providing food for the animal. Therefore, the composition of plants at the pole and sapling levels will reflect the forest in the future (Swaine and Hall 1988). Based on the field survey results, 57 pole species were identified, and 70 species of sapling were identified. The list of 10 tree species at the pole life stage with the highest INP can be seen in Table 5, while at the seedling stage it is presented in Table 6.

This study also measured the seedling and understorey communities to determine their effect on the gibbon presence. The condition of seedlings and understorey does not directly affect gibbons, but research shows that these factors significantly impact climatic conditions under the tropical forest canopy (Fetcher et al. 1985; Norris et al. 2012). In the study area, 135 species of seedlings were identified, and the ten dominant species in the community are presented in Table 7.

Table 3. The best minimal model is adequate to predict the presence of gibbons at the study site. The significance level for each explanatory variable was tested using the Z test. The significance value for each variable was indicated by: ***P<0.001, **P<0.01, and *P<0.05

Variables	Estimate	Std. error	Z value	Pr(>|z|)
Intercept	-3.836	0.552	-6.943	3.84e-12 ***
∑ seedlings	0.024	0.010	2.439	0.015*
∑ saplings	0.128	0.042	3.025	0.002**
∑ trees	0.225	0.110	2.038	0.042*

Note: Model: Gibbon Presence~ Number of seedlings + Number of saplings + Number of trees, Res.Dev.= 82.274, df=170) AIC = 89.8

Table 4. The list of the top 10 species in tree growth form with the highest IVI (Importance Value Index) and tree species that gibbons can consume in the HCV area of PT SSS, Indonesia

Species	Family	IVI	GD
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	39	
Macaranga gigantea (Rchb.f. & Zoll.) Müll.Arg.	Euphorbiaceae	28	x
Schima wallichii (DC.) Korth.	Theaceae	23	
Alstonia scholaris (L.) R.Br.	Apocynaceae	13	
Artocarpus champeden (Lour.) Spreng.	Moraceae	9.8	x
Gardenia anisophylla Jack ex Roxb.	Rubiaceae	8.8	
Planchonia sp.	Lecythidaceae	5.8	
Ficus retusa L.	Moraceae	5.7	x
Bhesa paniculata Arn.	Centrolacaceae	5.4	x
Campnosperma sp.	Anacardiaceae	5.1	

Note: IVI: Importance Value Index, GD: Gibbon diet

Table 5. The list of the top 10 species in pole growth form with the highest IVI (Importance Value Index) and species that gibbons can consume in the HCV area of PT SSS, Indonesia

Species	Family	IVI	GD
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	51.15	
Schima wallichii (DC.) Korth.	Theaceae	34.75	
Syzigium maingayi Chantar. & J.Parn.	Myrtaceae	30.98	x
Macaranga gigantea (Rchb.f. & Zoll.) Müll.Arg.	Euphorbiaceae	28.52	x
Eusideroxylon zwageri Teijsm. & Binn.	Lauraceae	25.81	x
Ficus alba Reinw. ex Blume	Moraceae	17.04	x
Pternandra echinata Jack	Melastomataceae	15.95	x
Vitex sp.	Verbenaceae	15.75	
Lithocarpus conocarpus (Oudem.) Rehder	Fagaceae	14.84	
Vitex trifolia L.	Verbenaceae	11.87	

Note: IVI: Importance Value Index, GD: Gibbon diet

Table 6. The list of the top 10 species in sapling growth form with the highest IVI (Importance Value Index) and tree species that gibbons can consume in the HCV area of PT SSS, Indonesia

Species	Family	IVI	GD
Leea indica (Burm.fil.) Merr.	Vitaceae	22.5	
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	15.2	
Eusideroxylon zwageri Teijsm. & Binn.	Lauraceae	10.2	x
Syzygium megalanthum (C.B.Rob.) Merr.	Myrtaceae	9.69	x
Rhodamnia cinerea Jack	Myrtaceae	8.39	x
Vitex pinnata L.	Verbenaceae	7.8	
Macaranga gigantea (Rchb.f. & Zoll.) Müll.Arg.	Euphorbiaceae	7.57	x
Gonocaryum gracile Miq.	Icacinaceae	5.75	
Schima wallichii (DC.) Korth.	Theaceae	5.46	
Pternandra echinata Jack	Melastomataceae	5.4	x

Note: IVI: Importance Value Index, GD: Gibbon diet

Table 7. The list of the top 10 species in seedling growth form with the highest IVI (Importance Value Index) and tree species that gibbons can consume in the HCV area of PT SSS, Indonesia

Species	Family	IVI
Nephrolepis exaltata (L.) Schott	Polypodiaceae	31.1
Ageratum conyzoides L.	Asteraceae	16.6
Borreria alata (Aubl.) DC.	Rubiaceae	10.2
Stenochlaena palustris (Burm.fil.) Bedd.	Polypodiaceae	9.58
Davallia sp.	Polypodiaceae	7.88
Peperomia pellucida (L.) Kunth	Urticaceae	7.77
Asystasia gangetica (L.) T.Anderson	Acanthaceae	7.73
Phyllanthus niruri L.	Phyllantaceae	6.96
Melastoma malabatrichum L.	Melastomataceae	6.34
Mucuna bracteata DC. ex Kurz	Fabaceae	5.82

Discussion

The Tanjung Biru Forest and the Bravo Rangda Timur Forest are surrounded by oil palm plantations, even though the Tanjung Biru Forest is isolated from other forest patches. Meanwhile, the Bravo Rangda Timur Forest is still connected to the Bravo Rangda Barat Forest and the forests along the Arut River. However, both forests can provide habitat for gibbons, even with a fairly good population density. This is because the southern gibbon is an animal that is quite tolerant of human activities in its habitat (Cheyne et al. 2016). Gibbons prefer forests with closed canopies, higher canopy levels, and trees with large diameters (Cheyne et al. 2013). In Sabangu, for example, gibbons tend to use habitats with continuous canopy conditions, so in disturbed forests, gibbons must adapt to existing conditions (Cheyne et al. 2013). In habitats disturbed by human activities, especially logging, gibbons tend to choose large trees because of the availability of canopy, food, and protection from predators (Cheyne et al. 2012). Even in forests that have suffered severe damage due to logging, gibbons are known to walk on the ground (Cheyne et al. 2013).

Gibbon population density is influenced by several factors such as canopy cover, tree height, large tree density, and food availability (Hamard et al. 2010). Forests in the Tanjung Biru and East Bravo Rangda blocks are still well preserved, although the existing habitat types are secondary forest and swamp forest. Compared to other places, the two blocks can still provide food sources, covers, and tall trees.

Elevation also affects gibbon density, where gibbon density decreases in mountain forests (Marshall et al. 2009). Mountain forests generally have lower forage diversity and fewer large trees than lowland forests (Marshall et al. 2009). Tanjung Biru Forest and East Bravo Rangda Forest are located in the lowlands, so tall trees and feed sources are also more varied. The dominant tree species in the area are rubber (*Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg.), ironwood (*Eusideroxylon zwageri* Teijsm. & Binn.), puspa (*Schima wallichii* (DC.) Korth.), merkubung (*M. gigantea*), and pulai (*Alstonia scholaris* (L.) R.Br.). Local people cultivated rubber plantations in the area. Currently, rubber plantations are in the old-state age, so they can provide for the gibbons' needs, which generally prefer the upper canopy (Cheyne et al. 2013). While ironwood, puspa, merkubung, and pulai are capable of providing a high canopy and provide food sources for gibbons (Gittins and Raemaekers 1980; Inoue et al. 2016; Clink et al. 2017; Ario et al. 2018).

The close relationship between feed availability and gibbon population density in a particular area needs to be examined more deeply. Gibbon's main diet is fruits, although, under certain conditions, such as a long summer, gibbons can also consume flowers and leaves (Cheyne 2010). Feeding preferences like this make gibbons a seed-predator primate and seed disperser (Lambert and Garber 1998). This ecological function is very important for the sustainability of forest ecosystems. Primates are one of the key species that can determine the success of forest rehabilitation and help the process of plant species diversification (Lambert and Garber 1998). Thus, the local extinction of a primate species can have implications for drastic changes in plant communities because plants with large seeds are generally inaccessible to smaller seed dispersal species (Bufalo et al. 2016). The abundance and diversity of fauna capable of dispersing plant seeds are very important for the seed dispersal process from various plant species (Rumeu et al. 2017). The extinction of seed dispersal species potentially reduces the fitness of various plants, especially in terms of seed dispersal distances, increasing clumped spatial patterns, reduced geographic ranges, limited genetic variation, and increased among-population structuring (Guimarães et al. 2008). The interrelation of these species is a complex system and is crucial for maintaining the health of the overall ecosystem (Valiente-Banuet et al. 2015).

We are currently facing a large-scale rate of biodiversity extinction (Barnosky et al. 2011; Ceballos et al. 2015), which has implications for environmental degradation and has the potential to threaten human well-being (Naeem et al. 2016). It is important to suppress the rate of biodiversity decline, both fauna and flora. This effort can be made by maintaining forest ecosystems so that they are not diverted (Williams et al. 2021). These efforts need to be intensified considering the rate of ecosystem damage in Indonesia still occurs, especially on the islands of Borneo and Sumatra. The rate of deforestation and forest degradation on the island of Borneo in the last few decades has reached a critical stage due to logging activities, fires, and conversion to plantations (Gaveau et al. 2013; Gaveau et al. 2014). Given that this trend is likely to continue, it is necessary to emphasize the conservation efforts of the remaining forest ecosystems. Conservation of wildlife in forests with disturbances of human activity also needs to be considered. Species such as the southern gibbon are known to be able to adapt to disturbed habitats (Cheyne 2010). In addition, southern gibbon also has the ability as good seed dispersal. Thus, in disturbed habitats, conservation of this species becomes more crucial because apart from being an effort to protect the species from extinction, it is also an effort to improve its habitat.

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