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Home range of rehabilitated siamang (*Symphalangus syndactylus*) in fragmented forest areas of South Solok, West Sumatra, Indonesia

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Abstract. *Septiavi R, Aadrean, Rizaldi, Brule AF. 2026. Home range of rehabilitated siamang (*Symphalangus syndactylus*) in fragmented forest areas of South Solok, West Sumatra, Indonesia. Biodiversitas 27 (1): d270113. https://doi.org/10.13057/biodiv/d270113.* Effective post-release adaptation is critical to the long-term success of primate reintroduction programs, yet empirical data on how release duration influences ranging behavior remain limited. This study examined the home range size and spatial use of three rehabilitated siamang (*Symphalangus syndactylus*) pairs released in fragmented forest areas in the Bukit Tengah Pulau and Bukit Salo forests within the PT KSI concession of South Solok, West Sumatra, Indonesia. The subjects were released at different adaptation durations (9 months, 6 months, and 3 months) before observation. Home range estimates based on the Minimum Convex Polygon (MCP) method showed exploration areas of 26.64 ha, 23.45 ha, and 18.35 ha, respectively. Kernel Density analysis indicated that siamangs with shorter adaptation periods exhibited movements concentrated near feeding sites, whereas those with longer adaptation periods were more dispersed, reflecting greater foraging independence. The Kruskal-Wallis test revealed significant differences in home range size among groups ($p<0.05$). These findings indicate that longer post-release periods may facilitate greater ranging capacity, an essential factor for territory establishment and survival in the wild. These findings provide evidence-based guidance for optimizing release protocols in future primate conservation programs. Extended monitored release period conditioning combined with post-release habitat restoration is therefore recommended to improve long-term reintroduction success of siamangs and other arboreal primates.

Keywords: Kernel density, ranging behavior, rehabilitation, reintroduction, spatial ecology

INTRODUCTION

Global primate populations are undergoing severe declines, largely driven by habitat loss, hunting, and the illegal wildlife trade. Arboreal primates are particularly vulnerable to these pressures due to their reliance on continuous forest canopy for locomotion, foraging, and social interactions. In Indonesia, rapid land-use change has intensified forest degradation and fragmentation over recent decades. National data indicate that legal forest cover decreased from approximately 120.5 million ha in 2020 to about 114.7 million ha in 2022, primarily as a result of deforestation and land conversion. Such losses disproportionately affect canopy-dependent species by reducing habitat availability, altering resource distribution, and limiting dispersal opportunities.

The siamang (*Symphalangus syndactylus* Raffles, 1821), the largest extant gibbon species, exemplifies the vulnerability of arboreal primates to these processes. Endemic to Sumatra and Peninsular Malaysia, siamangs are characterized by strict arboreality, monogamous pair bonding, low reproductive rates, and extended parental care. These life-history traits constrain population recovery following disturbance. The species has been classified as Endangered on the IUCN Red List since 2008 and is listed in Appendix I of CITES, reflecting the severity of threats posed by habitat loss and illegal capture. The species is formally protected under existing legal frameworks; however, extensive forest fragmentation and persistent demand from the illegal pet trade continue to be associated with population declines across much of its range (Nijman et al. 2009; Purnama et al. 2014; Symes et al. 2018; Scheffers et al. 2019).

Rehabilitation and release programs have therefore become integral components of siamang conservation, particularly as a response to the illegal wildlife trade. These programs aim to restore confiscated individuals to physical, behavioral, and social conditions compatible with survival in the wild, followed by reintroduction into suitable habitats. In West Sumatra, the Kalaweit Indonesia Foundation conducts rehabilitation and release of siamangs into a fragmented conservation forest managed in collaboration with local communities. This landscape represents a common conservation scenario in Indonesia, where reintroductions occur outside strictly protected areas and within forests subject to human influence and spatial constraints.

The Kalaweit program adheres to the IUCN Guidelines for the Rehabilitation and Translocation of Gibbons, which emphasize comprehensive health assessments, formation of stable social units, development of natural locomotor and foraging skills, and systematic post-release monitoring

(IUCN-SSC-PSG-SSA 2015). Among these components, post-release monitoring is particularly critical, as it provides empirical evidence of survival, adaptation, and behavioral competence in the release environment. However, monitoring rehabilitated gibbons in fragmented forests is logistically challenging, and data are often limited by difficult terrain, restricted visibility, and the disappearance of individuals from observation. These constraints hinder robust evaluations of release success and long-term conservation outcomes.

Gibbon rehabilitation initiatives have expanded across Southeast Asia; however, empirical data on post-release spatial ecology remain limited, particularly for siamangs in fragmented habitats. Home range size and spatial configuration are key indicators of ecological adaptation, reflecting an individual's capacity to secure sufficient food resources, maintain pair cohesion, and establish or defend a territory. In fragmented landscapes, altered or constrained home ranges may indicate limitations imposed by habitat structure, resource availability, or incomplete behavioral adjustment following release. Accordingly, understanding post-release ranging behavior is essential for evaluating release site suitability, refining rehabilitation protocols, and informing evidence-based reintroduction guidelines (Cheyne et al. 2009; Cheyne et al. 2012; Estrada et al. 2017; Speiran et al. 2023).

This study addresses this knowledge gap by estimating and comparing the home ranges of three rehabilitated siamang pairs released at different times (9 months, 6 months, and 3 months) prior to data collection, within the PT KSI conservation forest, West Sumatra. Using systematic direct observation methods, spatial locations were recorded to quantify home range size and evaluate movement patterns in a fragmented forest context. By comparing pairs with differing durations since release, the study examines whether time post-release influences ranging behavior and spatial independence.

By explicitly linking release history with post-release spatial ecology, this study contributes to a more nuanced understanding of siamang adaptation following rehabilitation. The results are expected to provide practical insights for improving release strategies, including considerations of adaptation period, monitoring duration, and habitat requirements in non-contiguous forests. More broadly, the findings contribute to the limited body of literature on post-release ecology of rehabilitated gibbons and support the development of evidence-based conservation interventions for arboreal primates facing increasing habitat fragmentation. It is hypothesized that siamang pairs with longer post-release periods will exhibit larger home ranges and greater spatial autonomy than those released more recently, reflecting progressive adjustment to natural resource distribution and territorial dynamics.

MATERIALS AND METHODS

Study area

This study was conducted in two fragmented conservation forests used as release sites for siamangs: Bukit Tengah Pulau (357.60 ha) and Bukit Salo (430.09 ha), South Solok, West Sumatra, Indonesia (Figure1). The research subjects consisted of three rehabilitated pairs of *S. syndactylus*, selected based on availability and health status. All pairs were released within the same calendar year but with different monitored release adaptation durations of 9 months, 6 months, and 3 months prior to observation. This uniform release year and staggered adaptation periods enabled a controlled comparison of home range establishment over time.

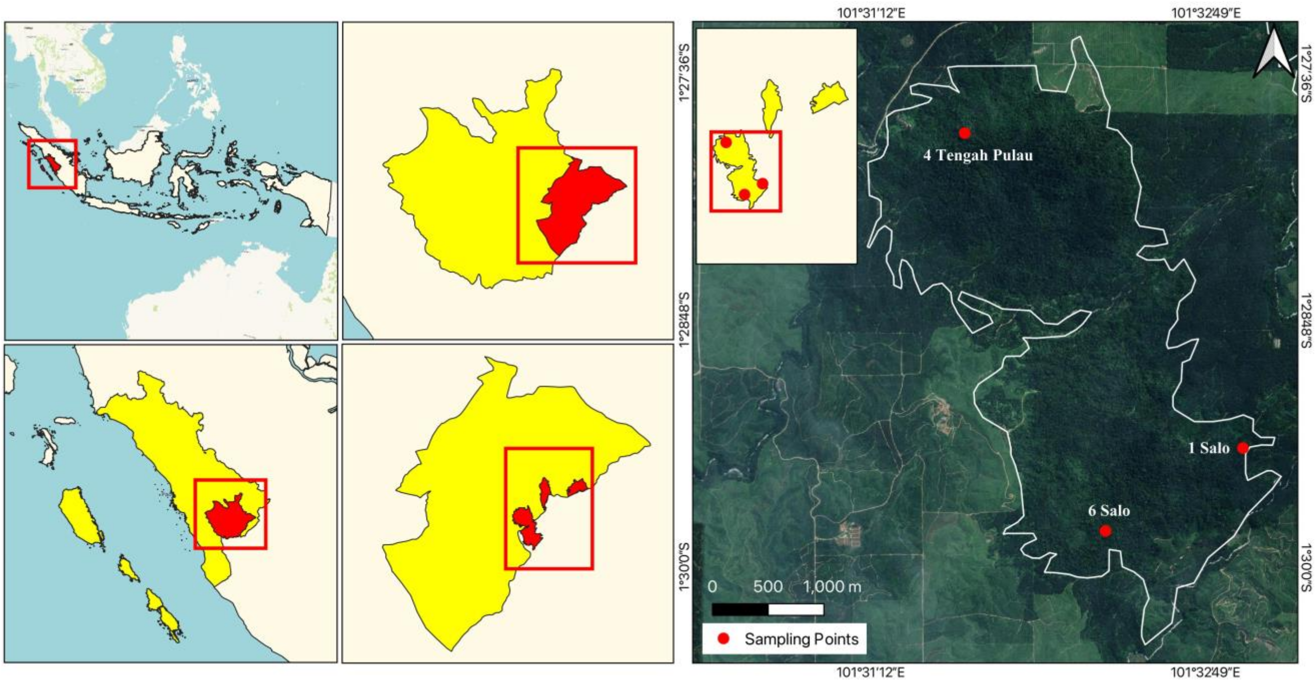

Figure 1. Research location in the fragmented conservation forest of PT.KSI, South Solok, West Sumatra, Indonesia

Data collection

Siamang location data were collected using the Visual Encounter Survey (VES) method. The initial encounter points each morning, generally near the pre-release enclosure, was recorded as the day's starting position. New coordinate points were logged whenever a siamang moved approximately 15 meters from the previous location. In total, 977 GPS coordinate points were collected across all groups. Spatial data were processed using QGIS version 3.22.9 (QGIS Development Team 2022). The spatial distribution and exploration maps were generated with GIS, featuring precise coordinate points overlaid with buffers representing movement thresholds. The maps included a north arrow, scale bar, and legend for clarity and standard cartographic presentation.

Data analysis

Home range size was estimated using the Maximum Convex Polygon (MCP) method, while core-use areas were identified through Kernel Density Estimation (KDE). To test for differences in home range size across the three release durations, the non-parametric Kruskal-Wallis test was employed due to violations of normality and homogeneity of variance assumptions. Significance was set at $p<0.05$, with values above this threshold interpreted as no significant difference, and below indicating a significant difference in home range size among groups.

RESULTS AND DISCUSSION

Minimum convex polygon

According to the results of the Minimum Convex Polygon (MCP) for three pairs of siamangs (Figure 2), distinct home range areas were obtained. The siamang released at 9 months had an exploration area of 26.64 ha, the siamang pair released at 6 months covered an area of 23.45 ha, and the siamang pair released at 3 months had an exploration area of 18.35 ha. The Kruskal-Wallis test results showed a significant difference in the exploration area based on release time (9 months, 6 months, and 3 months) with a p-value less than 0.05 (Figure 2). The post-rehabilitation exploration area of siamangs in the fragmented conservation forest with the longest release time, namely 9 months, recorded the widest exploration area at 26.64 ha.

Kernel density

The use of the Kernel Density method on the encounter points of siamangs yielded results indicating that the movements of two pairs of siamangs at the release locations, namely 4 Tengah Pulau (6 months) and 6 Salo (3 months), were dominated at the feeding site locations (Figure 3). This suggests that, post-rehabilitation siamangs exhibited a preference for locations associated with feeding activities. The feeding site, in these cases, emerged as a central activity area for the siamangs, highlighting the significance of this aspect in their post-release behavior.

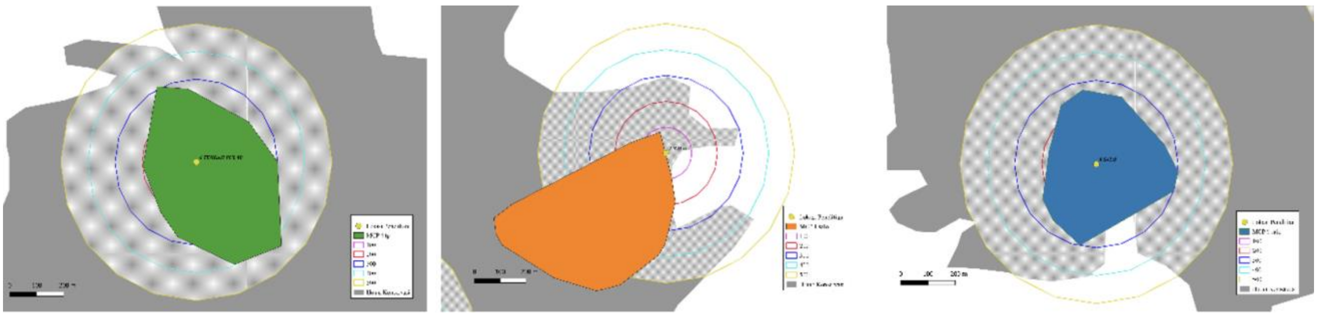

Figure 2. The map of the exploration area using the MCP method

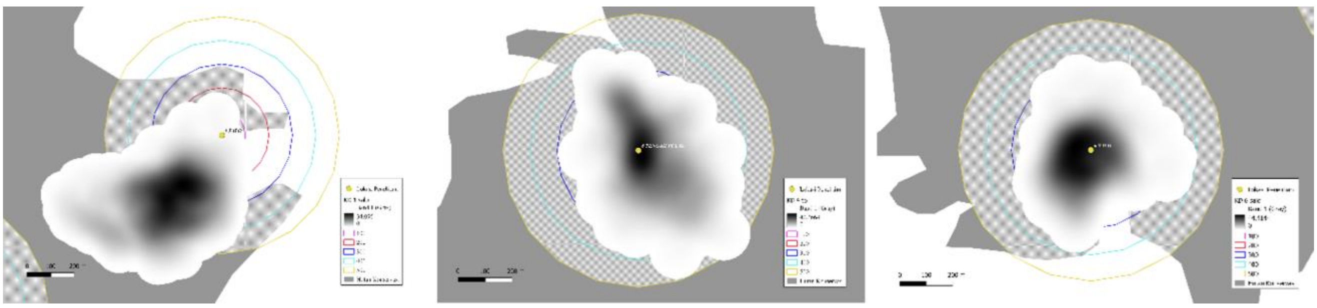

Figure 3. Mapping the exploration area using the Kernel Density method

Daily travel distance of siamang post-release

Figure 4 presents the pattern of the daily ranging area over a 20-day observation period involving three different subjects. Data analysis shows that the blue subject has the most significant ranging area, with an increase in the size of the ranging area reaching a peak around day 16 at nearly 14 ha, followed by a decline in the subsequent days. This pattern indicates high mobility fluctuations, likely related to resource needs or adaptive behavior in response to environmental conditions. In contrast, the siamang with a 6-month release time exhibits a more gradual and relatively stable increase, with a ranging area between 1 and 9 ha, indicating a more consistent ranging pattern but with a smaller capacity compared to the siamang paired with a 9-month release time. Meanwhile, the siamang with a 3-month release time shows the most constant and limited ranging pattern, ranging between 2 and 5 ha, which may reflect a conservative space-use strategy focused on energy conservation or minimized risk. The data gap occurred because the siamang was not observed, not because of natural behavior.

Accumulated daily travel distance of the siamang post-release

Figure 5 illustrates the development of the cumulative ranging area over a 20-day observation period for three siamang subjects released at different times, namely 9 months, 6 months, and 3 months. The graph shows that all three siamang pairs experienced gradual increases in ranging area, but with differing rates and patterns.

The siamang with a 9-month release period exhibited the most significant and sustained increase in cumulative ranging area, with the range expanding almost continuously throughout the observation period, reaching a maximum of nearly 27 ha by day 19. This indicates a greater capacity for adaptation and spatial exploration, as well as high mobility potential in territorial acquisition. The siamang with a 6-month release showed a more moderate increase in ranging area, beginning to plateau from day 13 through to the end of the observation period, with cumulative ranging area around 23-24 ha. This suggests that the utilized territory reached its upper limit more quickly compared to the 9-month release siamang. The siamang with a 3-month release displayed the slowest increase pattern, reaching a plateau from day 13 onwards, with a cumulative ranging area of approximately 18-19 ha. This reflects a more conservative spatial use strategy and stability in mobility within a relatively limited area. The data gap occurred because the siamang was not observed, not because of natural behavior.

Discussion

Effect of adaptation duration on space use and feeding dependency

The findings of this study indicate that the duration of the monitored release adaptation period plays a crucial role in determining post-release spatial patterns and feeding behavior of siamangs (*S. syndactylus*). The group with the longest adaptation period (9 months) exhibited the largest exploration area (26.64 ha), significantly wider than those with shorter adaptation durations of six months (23.45 ha) and three months (18.35 ha) ($p<0.05$). This suggests that longer adaptation enhances spatial competence and ecological independence.

Throughout this period, siamangs reestablished core behavioral competencies, including effective arboreal locomotion, coordinated social behavior, and natural foraging patterns, enabling more efficient canopy use and post-release exploration of new territories. This pattern is consistent with findings from other gibbon species, which demonstrated that extended adaptation promotes dietary diversity and reduces dependence on artificial feeding. Kernel Density analysis further supports this trend, showing that pairs with shorter adaptation periods exhibited movements concentrated around feeding sites, whereas pairs that underwent 9 months of adaptation displayed a broader and more dispersed spatial distribution, indicative of greater foraging independence and reduced reliance on provisioning (Reichard 2016; Harrison 2019).

These results are consistent with Cheyne (2009), who emphasized that reduced feeding dependency and post-release site fidelity are key indicators of successful gibbon rehabilitation. Therefore, longer adaptation periods appear to allow more complete ecological learning processes, including the ability to recognize natural food resources, assess risks, and construct complex spatial maps of their surroundings.

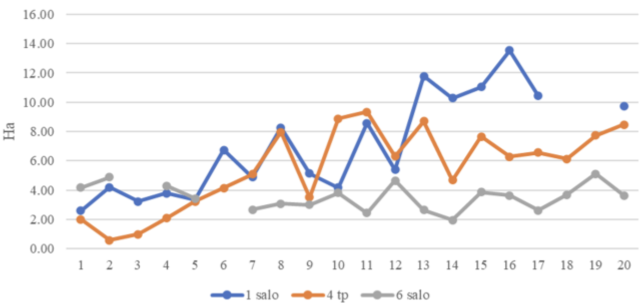

Figure 4. Daily range area siamang post-release

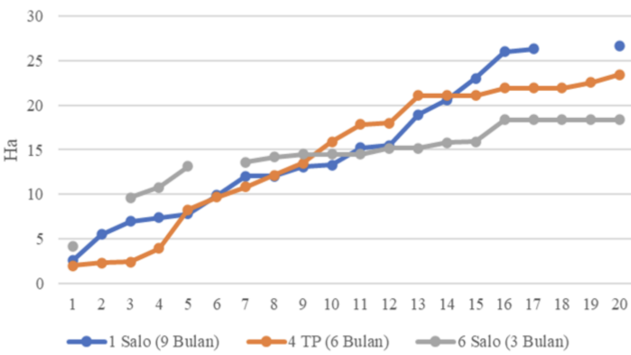

Figure 5. Accumulation range area siamang post-release

Influence of habitat fragmentation on ranging plasticity

Although all individuals were released within a similarly fragmented conservation forest, they exhibited distinct levels of ranging plasticity. The group with a nine-month adaptation period showed higher mobility and a continuous increase in cumulative ranging area, reaching nearly 27 ha by day 19. This pattern suggests a capacity for behavioral adaptation to the challenges posed by complex and fragmented landscapes. Individuals that experienced longer adaptation periods may have developed enhanced spatial cognition, enabling more efficient navigation through discontinuous canopy structures, including the ability to negotiate canopy gaps, identify safer movement pathways, and reduce energetic costs during locomotion. Such adaptations are likely to be particularly important in fragmented habitats, where increased structural heterogeneity can constrain arboreal movement and influence post-release survival and ranging behavior (Yanuar et al. 2010; Cheyne et al. 2016; Hankinson et al. 2021).

In contrast, siamangs with 6 and 3-month adaptation periods displayed smaller and more stable daily ranges, reaching a plateau around day 13, with cumulative areas of approximately 23-24 ha and 18-19 ha, respectively. Such restricted movement patterns may reflect conservative behavioral strategies that prioritize energy conservation and risk avoidance when individuals are confronted with fragmented environments. Habitat fragmentation can disrupt canopy connectivity, restrict access to key food resources, and increase exposure to anthropogenic disturbances, including noise, human activity, and edge effects. Under these conditions, the observed patterns highlight the combined influence of behavioral readiness and habitat structure in shaping post-release spatial strategies. Thus, longer adaptation periods appear to support not only improved behavioral preparedness but also greater spatial flexibility, facilitating more effective adjustment to the ecological constraints of degraded habitats (Lappan et al. 2017; Lappan et al. 2021).

Management implications for reintroduction programs

These findings emphasize the importance of implementing a monitored release period of at least nine months to allow rehabilitated individuals sufficient time to attain behavioral maturity, establish stable social relationships, and become adequately familiar with the ecological characteristics of the release environment prior to full release. During this adaptation phase, supplementary feeding should be reduced in a structured and gradual manner, with careful monitoring, in order to promote the development of natural foraging behaviors while progressively minimizing dependence on human-provided resources (IUCN SSC PSG SSA 2015; Dunbar et al. 2019; Howell et al. 2019). The introduction of native plant species and feeding enrichment that mimics natural conditions can further reinforce ecological adaptation.

At the habitat level, conservation efforts should place strong emphasis on landscape-scale management approaches, particularly those aimed at restoring canopy connectivity and establishing functional ecological corridors between isolated forest patches. Such interventions are essential for mitigating the effects of habitat fragmentation and facilitating safe arboreal movement for strictly canopy-dependent primates. Reforestation programs that prioritize the planting of key food and structural tree species, including *Ficus* spp. and *Artocarpus* spp., can substantially enhance food resource availability while simultaneously increasing habitat complexity and expanding potential ranging areas for reintroduced individuals. In addition, the integration of post-release spatial monitoring using drone-based technologies is strongly recommended as part of an adaptive management framework, as it enables the identification of movement constraints, canopy discontinuities, and high-risk zones, thereby supporting timely habitat interventions and improving long-term post-release outcomes (Reichard and Preuschoft 2016; Lappan et al. 2017; Kalaweit Gibbon Rehabilitation Project 2023).

Although this study has limitations, including a small sample size (n=3) and a relatively short observation period (20 days), the consistent behavioral patterns observed among individuals provide strong preliminary evidence for the relationship between adaptation duration, spatial behavior, and feeding dependency in rehabilitated siamangs. Future research with longer monitoring periods and larger sample sizes is needed to strengthen these findings. Nevertheless, the results presented here offer an important empirical foundation for developing evidence-based protocols in future siamang rehabilitation and reintroduction programs.

In conclusion, this study highlights that the duration of the monitored release adaptation period is a key determinant of post-release ecological independence in rehabilitated siamangs (*S. syndactylus*). Longer adaptation allows individuals to develop more natural ranging patterns, reduce dependence on supplementary feeding, and better adjust to fragmented forest environments. Individuals with a nine-month adaptation period exhibited the largest home range (26.64 ha) and greater ranging flexibility compared to those adapted for six (23.45 ha) and three months (18.35 ha). Longer adaptation facilitated ecological independence, reduced reliance on feeding sites, and enhanced mobility within fragmented forests. These findings underline the necessity of implementing adaptation periods of at least nine months, accompanied by a gradual and structured reduction of artificial feeding. Furthermore, integrating landscape-scale habitat management, such as enhancing canopy connectivity and mitigating human disturbance, is essential to ensure the long-term success of siamang reintroduction and the ecological integrity of their habitats.

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