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Prowling through palm: Exploring spatial patterns of male Sunda leopard cats across two oil palm plantations in Kinabatangan, Sabah

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Abstract

Industrial oil palm plantations are a major driver of biodiversity loss in Southeast Asia, alongside other industries like pulpwood production and logging activities that expedite habitat fragmentation and destruction. Despite this, some native species are highly adaptable within these environments. Our study investigates the space use of leopard cats (*Prionailurus javanensis*) within oil palm plantations adjacent to degraded forest fragments in the Kinabatangan floodplain, Sabah, Malaysian Borneo. From March to September 2020, we captured and collared four male cats with Global Positioning System collars, accumulating a total of 13,206 successful locational points. We estimated the home ranges using the Minimum Convex Polygon (MCP) and Adaptive Localized Convex Hull (a-LoCoH) methods. The average home ranges were 8.60 km^2 ± 1.98 (±SD) [95% MCP] and 5.39 km^2 ± 1.23 [95% a-LoCoH], with corresponding core areas of 2.55 km^2 ± 0.99 (±SD) [50% MCP] and 1.05 km^2 ± 0.30 [50% a-LoCoH]. The home ranges of male leopard cats overlapped (7% to 28%), while core areas remained exclusive. Despite significant variations in individual habitat use, these cats were detected more frequently in oil palm habitat, occupying 80.89% of their home range and 78.38% of core

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area. These cats relied more on buffer zones contiguous to plantation area rather than adjacent secondary forests, highlighting the importance of preserving High Conservation Value (HCV) forests.

KEYWORDS

fragmented landscape, generalist species, GPS telemetry, home range, spatial ecology

1 | INTRODUCTION

The increasing global demand for commodities such as vegetable oils for food production, biofuels, and commercial products has driven the rapid expansion of oil palm monoculture, one of the major causes of habitat loss in tropical forests (Nambiappan et al., 2018; Petrenko et al., 2016; Vijay et al., 2016). Alongside oil palm, industries such as pulpwood production and logging further exacerbate habitat degradation (Abood et al., 2015; Gaveau et al., 2016; Giam, 2017). Collectively, these industries have caused worldwide concerns as they have led to extensive habitat destruction within the equatorial region, a critical biodiversity hotspot (Myers et al., 2000; Payán & Boron, 2019; Savilaakso et al., 2014). Today, palm oil remains indispensable due to its cost-effectiveness in production and versatility compared to other oils, driving its widespread cultivation (Barcelos et al., 2015; Wiebe et al., 2019). These plantations bring severe environmental impacts including landscape fragmentation, disrupting ecological connectivity (Ocampo-Peñuela et al., 2020; Scriven et al., 2019), reducing biodiversity and ecosystem functionality (Barnes et al., 2014; Dhandapani, 2014; Dislich et al., 2017), and intensifying edge effects and pollution (Fitzherbert et al., 2008; Meijaard et al., 2020).

Previous research consistently reported that oil palm habitats support fewer and less diverse species communities compared to pristine forest (Barnes et al., 2014; Knowlton et al., 2019; Kwatrina et al., 2018; Luskin et al., 2017; Savilaakso et al., 2014). Monocultures are commonly inhabited by generalists that are more adaptable to environmental changes (Bernard et al., 2014; Meijaard & Sheil, 2013; Norwana et al., 2011). Although some species persist in these modified landscapes by altering their behavior, such adaptations often come with significant ecological costs (Dagtekin et al., 2024; Oeser et al., 2023; Ruiz-Villar et al., 2023). For instance, some mammals portray increased nocturnality, reduced positive interactions, and spatial and temporal avoidance of human activities, likely as responses to the disturbances and pressures in oil palm plantations (Guharajan et al., 2018; Holzner et al., 2021; Pardo et al., 2021). Additionally, human disturbances associated with anthropogenic landscapes can disrupt hunting strategies and behavior of wild cats such as European wildcats (*Felis silvestris*), pumas (*Puma concolor*), and Eurasian lynx (*Lynx lynx*) (Azevedo et al., 2021; Gehr et al., 2017; Ruiz-Villar et al., 2022, 2023, 2024). These carnivores often adapt by enlarging their home ranges or altering activity periods to avoid direct interactions with humans. These behavioral changes are typically survival strategies rather than optimal adaptations, which can result in reduced fitness or disrupted ecological roles (Iglesias-Carrasco et al., 2022; Wong & Candolin, 2015).

One example of these habitat generalists is the Sunda leopard cat (*Prionailurus javanensis*). This cat appears to be thriving in both natural and anthropogenic landscapes across Southeast Asia (Mohamed et al., 2013; Silmi et al., 2021), where it occupies a variety of habitats, ranging from forests to agricultural landscapes including rubber, sugarcane, and oil palm plantations (Mohamed et al., 2016). Similarly, mainland leopard cats (*Prionailurus bengalensis*) in Thailand are known to utilize different habitats based on occurrence within habitat matrices (Grassman et al., 2005b), whereas in eastern Asia, they tend to rely more on forest cover (Chen et al., 2016; Oh et al., 2010). These patterns align with broader findings that emphasize the importance of studying habitat use patterns across different land-use types, regardless of protection status. With a murid rodent-heavy diet (Chua et al., 2016; Rajaratnam et al., 2007), leopard cats frequently hunt rodent pests, mainly rats and mice in plantations (Rajaratnam et al., 2007; Silmi et al., 2021). Their presence in oil palm plantations may be influenced by higher prey catchability due to the lack of dense understory rather than prey abundance (Rajaratnam et al., 2007). While monocultures like oil palm plantations often support lower prey abundance (Yue et al., 2015), their open structure may facilitate efficient hunting, suggesting they could serve as suitable hunting grounds for generalist carnivores and potentially aid in pest control (Silmi et al., 2013).

In Borneo, the Kinabatangan floodplain has also sustained large oil palm plantation expansion which now dominates the landscape and is interspersed with riparian habitat and secondary forest fragments (Abram et al., 2014). While previous studies emphasize the role of forest fragments as shelter and denning sites for breeding female leopard cats (Rajaratnam et al., 2007), others suggest leopard cats thrive in these landscapes even in the absence of nearby forest patches (Silmi et al., 2021). Although leopard cats in Borneo appear to persist in oil palm plantations, this pattern is not universal across their range. For instance, island populations in Taiwan, the Philippines and Japan face threats from human disturbances and natural habitat loss (Chen et al., 2016; Chua et al., 2016; Lorica, 2015; Oh et al., 2010; Sun et al., 2024). As oil palm plantations are a significant driver of biodiversity loss in Southeast Asia (Vijay et al., 2016), these landscapes may also limit prey diversity and shelter availability for leopard cats (Hood et al., 2019). In Taiwan, leopard cats select different land-use types for nocturnal hunting and diurnal resting, indicating specific habitat requirements that may not be met in agricultural areas (van der Meer et al., 2023). Additionally, these cats may be exposed to risks such as disease transmission from domestic animals (e.g., Guerrero-Sánchez et al., 2021), hunting activities (Ross et al., 2010), toxic accumulation from pesticide use (Liao et al., 2020) and roadkill incidence (Laton et al., 2017). Hence, further research is needed to assess whether oil palm landscapes can fully support the long-term ecological needs of leopard cats, especially as their survival remains closely linked to human-driven changes (Verwilghen, 2015).

This adaptability in habitat selection demonstrates the propensity of leopard cats to adapt to the prevalence of various habitats within heterogeneous landscapes, including in human-altered landscapes (Silmi et al., 2021; van der Meer et al., 2023). In disturbed environments, anthropogenic influences can shape movement behavior, affecting home range size, habitat use, and activity patterns (Benson et al., 2021; Gaynor et al., 2018; Ripari et al., 2022; Serieys et al., 2023). Males typically range more widely due to territorial and reproductive behaviors (Chen et al., 2016), while females favor localized areas influenced by denning and prey availability (Grassman et al., 2005a; Rajaratnam et al., 2007). Similar sex-based differences occur in African leopards (*Panthera pardus*), where males use open landscapes, while females prefer denser vegetation to protect their cubs (Fattebert et al., 2015), and in smaller carnivores like American martens (*Martes americana*) and red foxes (*Vulpes vulpes*) (Kobryn et al., 2023; Thompson et al., 2012). Understanding these spatial dynamics has been enhanced by advancements in Global Positioning System (GPS) and accelerometer (ACC) technology, which provide detailed insights into animal movement ecology (Brown et al., 2012; Lush et al., 2016). Researchers can remotely assess space use, estimate home range size, and identify habitat preferences, while ACC sensors distinguish behaviors of free-ranging animals (Nathan et al., 2012; Williams et al., 2017).

By utilizing these tools, understanding the relationship between habitat use and activity states of leopard cats is key to developing conservation strategies that balance biodiversity and agricultural productivity, ensuring the species' resilience in an increasingly human-dominated landscape. Hence, the current study aims to discern the leopard cat's space use in an oil palm-dominated landscape by (1) estimating their home range size and overlapping range, as well as (2) assessing the association between type of activity and habitat type within an oil palm-dominated landscape to understand which habitat types are utilized during active versus inactive times. We expect that leopard cats within this modified landscape will have an average home range size larger than previous estimations in Rajaratnam et al. (2007), due to a larger proportion of oil palm to forest habitat ratio within this landscape. Specifically, we predict no or little overlap in these areas, particularly among male cats, consistent with prior research findings (Chen et al., 2016). Additionally, we anticipate leopard cats will exhibit varied time allocation between forested habitats and oil palm plantations, with individual patterns potentially influenced by habitat availability within the landscape matrix.

2 | METHODS

2.1 | Study site

We conducted this study in two oil palm plantations situated within the Kinabatangan floodplain (N°5.4749; S°5.3823 and E°117.9637; W°118.1488) in eastern Sabah, Malaysian Borneo (Figure 1). The Lower Kinabatangan floodplain is an extensively fragmented landscape, consisting of protected forest (420 km^2), state and private forest (100 km^2), encircled by agricultural plantations, primarily dominated by oil palm estates (Abram et al., 2014). Our study sites were located in two specific oil palm estates (Figure 1): Pontian Hillco Plantation (20.54 km^2) and Pontian Pendirosa Plantation (17.26 km^2). These plantations are in their first planting cycle, with palms aged 7–26 years. The palms are planted at a density of 136 palms per hectare, with approximately 8 m of spacing between them and an average palm height of 12 m. The ground vegetation cover varies, ranging from shrubby to sparse ground cover. Application of herbicides to eliminate unwanted vegetation within a radius of 5 m around the palms is done three times a year.

The Pontian Hillco plantation mainly has a flat landscape with elevations ranging from 3 to 38 m above sea

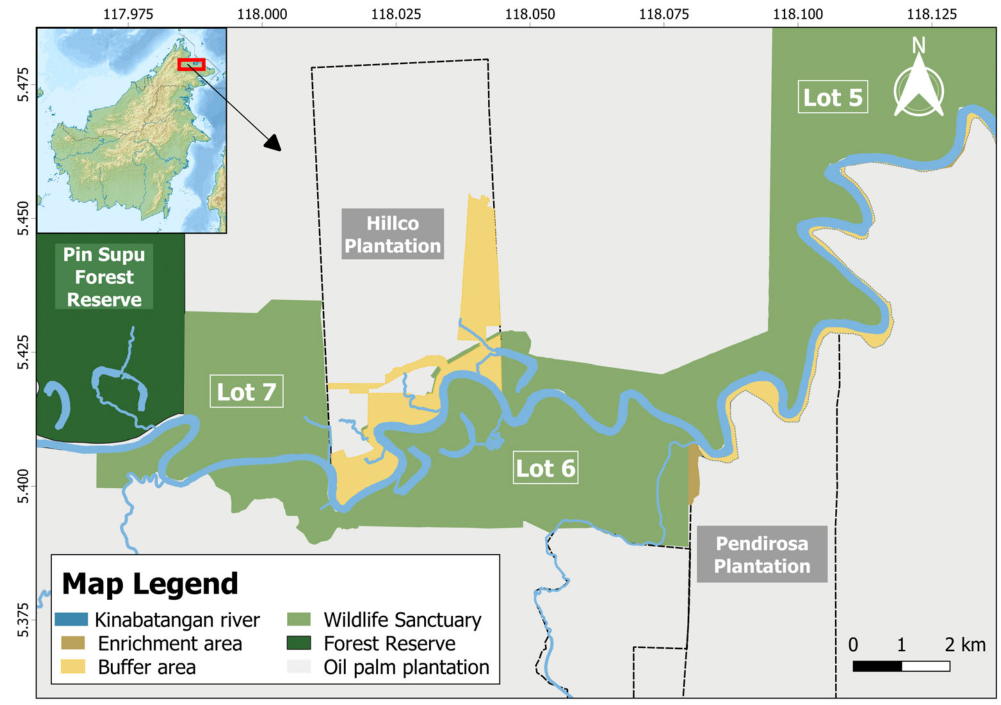

FIGURE 1 Map of the study area in the Kinabatangan floodplain in eastern Sabah, Malaysia (as shown in the inset). The Lower Kinabatangan Wildlife Sanctuary (lighter green) with other secondary forest reserves (dark green), buffer areas (yellow), and enrichment areas (brown) surrounded by industrial oil palm plantations (white).

level. It includes both peat swamp areas and forest identified as High Conservation value (HCV) forest, which cover an area of 4.95 km^2 of the plantation. These forest patches act as buffer zones within the plantation that are either directly connected to or very close to the plantation itself (Figure 1). Initially cleared for oil palm cultivation, these forest patches were allowed to undergo unassisted regeneration and were preserved for the purpose of biodiversity conservation. The adjacent existing forest patches along the Kinabatangan River, serving as a designated wildlife corridor, were also identified as riparian buffer zones. In comparison with Pontian Hillco plantation, the topography of Pontian Pendirosa plantation is also predominantly flat (2–60 m a.s.l.). Certain areas serve as buffer zones, including thin forest patches along a limestone quarry hill on its southern border, riparian buffer zones forming a Wildlife Corridor located at a distance of at least 100 m from the Kinabatangan River to the north, and enrichment areas bordering a tributary to the east. While no forest patches exist within the plantation, a 5–15 meter elevated bamboo ridge separates the plantation boundary from the Wildlife Corridor. Both plantations have extensive man-made water drainage systems to aid in draining floodwater from the plantations during the wet season, which typically occurs from November to February (Rusmin et al., 2015). The Pontian Hillco and Pontian Pendirosa estates were located between 50 and 400 m from the edge of the Kinabatangan River, which spans approximately 100–150 m in width.

2.2 | Animal trapping and collaring

A certified wildlife veterinarian was responsible for leading the capture and collaring procedure to ensure that all ethical considerations were carefully followed throughout the process. To locate the leopard cats, we conducted night surveys between 20:00 and 22:00 h on alternate nights within the oil palm plantations. We identified the presence of leopard cats through the eye shine. A team of six research staff was involved in locating the leopard cats. Upon spotting a leopard cat, we encircled the cat from multiple directions. When the cat was within close proximity, we used a modified pole net—a net with a rope loop (mesh size: 1.5 cm) fastened around a metal frame measuring 72 cm in diameter. Each net is affixed to an extended handle made from PVC poles (length: 150 cm), facilitating the safe capture of the animals. Once we securely confined the animal within the net, the veterinarian promptly administered anesthesia using intramuscular injections of Ketamine (5 mg/kg) and Medetomidine (0.05 mg/kg).

We recorded their weight, assessed their physical condition, and photographed both flanks (from the neck to the tail root) to document their distinctive pelt patterns (Grassman et al., 2005a). Each individual was sex-identified, and the age was estimated using four generic classifications of cat age in this study following Grassman (2000) and Haines et al. (2004), that is, juvenile, young adult, prime adult, and old adult. The age classes were based on tooth wear, tooth eruption, body size, and indicators of sexual development. We monitored anesthetized cats for their vital signs (i.e., heart rate, respiratory rate, and temperature) throughout the procedure to ensure the animals were in stable conditions. To facilitate future identification, we tagged each cat with an intradermal transponder microchip (Trovan A-100).

We attached GPS collars to three adult and one young adult leopard cats, all healthy individuals weighing between 1.9 and 2.6 kg. This weight threshold was established to ensure that the collar's weight remained below 3% of the animal's body mass, following Dickinson et al. (2020) and Soulsbury et al. (2020). We employed GPS collars of the model e-obs 1AA GPS/ultrahigh frequency (UHF), weighing 55–60 g, and equipped with accelerometer (ACC) sensors from Grünwald, Germany. The GPS unit was configured to capture one set of GPS coordinates every 30 min during the hours from 16:00 to 07:00 on high-resolution settings to capture nocturnal activity (Mohamed et al., 2013; Rajaratnam et al., 2007). Concurrently, the ACC was programmed to record data in bursts every minute, maintaining continuous recording throughout the entire 24-h day. The collar's belt was constructed from degradable material that breaks down gradually and eventually is expected to detach itself after 12 months. Once the collaring procedure was completed, Atipamezole was administered intramuscularly at a dosage five times that of Medetomidine (0.25 mg/kg) to reverse the anesthesia. We ensured that all cats fully regained consciousness before releasing them at the capture site, following the protocol outlined by Chen et al. (2016).

We tracked the collared cats in the morning (0800–1100 h) using a hand-held, directional UHF 7E 868 MHz Yagi antenna (e-obs GmbH), an AOR AR-8200D hand scanner radio receiver (AOR Ltd., Tokyo, Japan), and a Base Station (E-obs GmbH). Tracking of the collared animals commenced daily during the initial week after their release and gradually shifted to a weekly frequency in the following months. The base station (BaseStation II, e-obs GmbH) had to be about <150 m from the collar for data download. We used the DataDecoder software v10_s1 (e-obs GmbH) to extract data by converting encrypted data (logger.bin-files) into a comma-separated value (csv) format. For each successful GPS point detected, the collar recorded the GPS coordinates, date, time, time to first fix, battery voltage, temperature, estimated speed, and heading.

2.3 | GPS fix success and data filtering

We defined the attempted GPS fixes as the number of times the GPS collars tried to obtain a location coordinate, whether it resulted in precise location coordinates or not, at 2D or 3D resolution. Successful GPS fixes are the number of times the GPS collars successfully obtained a location coordinate at 3D resolution. We calculated the percentage of GPS fix success as the successful GPS fixes divided by the attempted GPS fixes multiplied by a 100. We calculated the GPS fix success for all animals combined as well as for individual animals to assess the overall functionality and reliability of the collars. We defined active collaring nights as the number of calendar days the collars remained attached to the animals. Initially, we filtered all the successful GPS fix attempts to remove locational coordinates that were fixed by less than four satellites and locations with noticeably high horizontal inaccuracy estimates (>7 m) as observed by continuous points over time. For example, locational points that were located further away from previous and subsequent points or locational points that were offset to the middle of the river due to a large error (Stark et al., 2017).

2.4 | Home range estimation

Prior to home range estimation, we looped each dataset into 10 and 20 iterations of 95% Minimum Convex Polygon (MCP) to deduce the minimum number of locational points needed to stabilize the output. We estimated the home ranges of leopard cats using MCP to first indicate the total possible area used by an individual during the tracking period and for comparative purposes with home range estimates in previous studies using a similar method (Pebsworth et al., 2012; Quinton, 2016). Then, we used the Adaptive Localized Convex Hull (a-LoCoH) to identify inaccessible and frequently used areas within the home range areas. This method is an extension of the LoCoH method, which uses all nearest neighbors within a local convex hull and adjusts the radius of the circle circumscribing it. We chose this method due to its superiority and robustness to other LoCoH modifications (e.g., k-LoCoH, r-LoCoH), as it more effectively captures irregular, non-convex boundaries, adapting to the actual shape and extent of the animal's movements (Getz et al., 2007). This is particularly relevant in a study area that is characterized by fragmented landscapes with diverse habitat types. Additionally, a-LoCoH can accurately identify core use areas by focusing on regions with higher frequency of use, rather than smoothing over less utilized areas (Signer & Fieberg, 2021).

To address potential autocorrelation, we first filtered GPS data to remove inaccurate fixes and conducted home range estimations by month to assess variability before using the full dataset, ensuring biologically relevant estimates (Silva et al., 2022). Additionally, we tested multiple *a*-values—which control the inclusion of nearest neighbors in hull construction—and selected the threshold where home range estimates stabilized, balancing fine-scale habitat representation with appropriate smoothing to prevent overestimation or excessive fragmentation (Getz et al., 2007). a-LoCoH inherently mitigates autocorrelation by clustering spatially dense points rather than assuming independence between fixes, making it well suited for our study objectives (Getz et al., 2007). We considered the 95% and 50% contour as the home ranges and core area for each individual leopard cat, respectively (Hinton et al., 2015; Huck et al., 2008; Kie et al., 2010). We conducted all analyses related to home range estimations using R version 4.3.1 (2023-06-16) in RStudio software (version 1.3.1093) (R Core Team, 2020). We used the adehabitatHR (version 0.4.19) and move (version 4.0.6) (Bart et al., 2020; Calenge, 2011) packages for these analyses. We visualized the product of the home range estimation overlaid on the map of study area using an open-source QGIS3 (version 3.16.11) software (QGIS Development Team, 2020).

2.5 | Habitat use

We quantified habitat composition within each home range by calculating the proportional coverage of three primary habitat types: (1) forest habitats (encompassing secondary logged forest within contiguous wildlife sanctuary), (2) oil palm plantations, and (3) buffer zones (including degraded HCV areas, designated riparian reserves and enrichment area within plantation area), using spatial overlays between home range polygons and land cover layers in QGIS3 (version 3.16.11) software (QGIS Development Team, 2020). Simpson's Diversity Index (SDI) was then calculated to assess landscape heterogeneity within home range and core areas of each cat, with higher values indicating greater habitat diversity (Morris et al., 2014). To examine the relationship between home range size and habitat heterogeneity, we conducted a Pearson correlation analysis, after ensuring normality using the Shapiro–Wilk test in RStudio software (version 1.3.1093) (Schober & Schwarte, 2018; Shapiro & Wilk, 1965; R Core Team, 2020).

To investigate the association between the type of activity and habitat type used by the leopard cats, GPS data for all individuals were filtered and processed in RStudio software (version 1.3.1093) (R Core Team, 2020). Here, we define the type of activity as the movement states or activity level of an animal at a given time. The type of activity is classified into two categories: (1) active, characterized by higher movement intensity, typically associated with behaviors such as foraging, hunting, exploring, or social interactions, and (2) inactive, which encompasses periods of minimal movement or stationary position, often corresponding to resting or sleeping. However, we acknowledge that ACC data alone do not directly confirm specific behaviors, only movement intensity. As for ACC burst data, multiple sets of data points for three axes (*X*, *Y*, and *Z* axes) were obtained for every minute. Within every minute, the Euclidean distances and speed between consecutive points in a 3D space were calculated and then averaged into hourly intervals. The hourly averages of ACC data based on three axes (*X*, *Y*, and *Z*) were used to determine the type of activity at each GPS coordinate interval. We classified the type of activity based on a movement threshold, with a mean overall speed greater than 50 (in accelerometer counts, which are dimensionless) indicating an active state. These counts represent the intensity of movement detected by the accelerometer but do not correspond to a standard physical unit. This threshold was selected to distinguish between active movement and periods of lower activity, such as resting or inactivity, based on the accelerometer's data calibration. Specifically, we graphed ACC counts against movement speed and observed a clear breakpoint at 50, distinguishing low-movement periods from active movement.

Shapefile layers of habitat cover in the study area were obtained from the Danau Girang Field Centre (DGFC, 2020) and prepared for this study based on figure maps provided by oil palm stakeholders and satellite imagery from Google Earth Pro (Google Earth Pro, 2021) to digitize land cover features using QGIS3 (version 3.16.11) software (QGIS Development Team, 2020). These layers were then imported, manipulated, and overlaid with spatial data points for analysis in RStudio software (version 1.3.1093) (R Core Team, 2020). The type of activity at each given point were then classified into the three primary habitat types. The GPS unit recorded data only during nocturnal hours (16:00–07:00) and did not capture daytime coordinates (07:00–16:00). This may limit the accuracy of habitat associations for resting periods, as daytime resting spots could be underrepresented. However, as leopard cats are predominantly inactive during this period, the last GPS point at 07:00 is expected to correspond to the first point at 16:00. While this introduces some uncertainty, it is unlikely to significantly affect the overall analysis. We employed the non-parametric chi-square contingency table test to test for the independence or relatedness (Mchugh, 2013; Rana & Singhal, 2015) of the association between type of activity of each individual leopard cat and the three different habitat types: plantation, forest, and buffer zone.

3 | RESULTS

3.1 | GPS collaring and monitoring of wild leopard cats

We captured and fitted GPS collars on a total of four male leopard cats between March and June 2020. Two of the animals (LCM02 and LCM03) were caught at Pontian Hillco plantation and two (LCM04 and LCM05) at Pontian Pendirosa plantation (Table 1). The leopard cats consisted of three prime adults (LCM02, LCM03, LCM05) and one young adult (LCM04, estimated age ≥6 months). Three collars remained functional for 5–7 months, whereas one individual died (LCM04) after 1 month of collar deployment (Wilson et al., 2022). Individual LCM04 appeared to be in good health prior to collar deployment, with movement data remaining consistent until the mortality event. While the exact cause of mortality cannot be confirmed due to insufficient evidence, there is no indication that the collar or the capture procedure directly contributed to the death. Wilson et al. (2022) utilized accelerometer-informed GPS data to describe the events and possible scenarios leading to the death of this individual. Although the collar may have indirectly increased vulnerability, no clear evidence suggests impaired movement or survival. The collar followed recommended weight guidelines (<3% of body weight), and other collared individuals showed normal activity and survival.

The number of collaring nights and the percentage of successful fixes of GPS locational coordinates varied among collared animals (Table 1). The total number of collaring nights for all cats combined was 590 nights. The longest number of collaring nights recorded was 230 nights (LCM03) and the shortest was 31 nights (LCM04). We successfully accumulated a total of 13,206 GPS location coordinate fixes across all cats, representing 96.72% ± 2.23% (mean ± SD) of attempted locational coordinates. Individual cat collar GPS location fix success rates ranged from 93.71% to 99.11%. On average, we recorded 22.60 ± 0.30 (mean ± SD) GPS locations per active collaring night for all cats combined, with the highest average recorded for LCM03 (24.29 ± 0.25) and the lowest for LCM02 (19.32 ± 0.29).

3.2 | Home range size of collared leopard cats

The 95% MCP area of all cats has reached an asymptote after about 300–500 locational fixes have been recorded, suggesting that the sampling effort employed in this study was adequate for accurately estimating the actual home range and core area sizes of the leopard cats. The home range areas (95% MCP) vary from 3.60 to 11.84 km^2 (mean ± SD: 8.60 ± 1.98) (Table 2). The core areas (50% MCP) vary from 0.67 to 4.85 km^2 (mean ± SD: 2.55 ± 0.90), which were substantially smaller compared to the total home range sizes. The size of total home ranges based on LoCoH estimator (95% a-LoCoH) ranged from 2.20 to 8.16 km^2 (mean ± SD: 5.39 ± 1.23) and the core areas (50% a-LoCoH) ranged from 0.33 to 1.57 km^2 (mean ± SD: 1.05 ± 0.30) (Table 2). On average, the core areas (50% a-LoCoH) accounted for only 19.5% (range: 14.7%–22.7%) of the total home range area (95% a-LoCoH), highlighting their reduced size relative to the broader home range. The estimated percentage of overlap

TABLE 1 Information of collared leopard cats and the total GPS fixes accumulated.

ID	Period of collar deployment (month day)	Site	Sex	Weight (kg)	Age	Total attempted GPS fixes	Total successful GPS fixes	Total active collaring nights	Fix success (%)
LCM02	March 14 to September 10	Hillco	Male	2.60	Adult	3734	3499	181	93.71
LCM03	April 7 to November 22	Hillco	Male	2.00	Adult	5636	5586	230	99.11
LCM04	May 14 to June 20	Pendirosa	Male	1.90	Young adult	743	720	31	96.90
LCM05	June 15 to November 9	Pendirosa	Male	1.95	Adult	3501	3401	148	97.14

Abbreviation: GPS, Global Positioning System.

TABLE 2 Home range size of collared leopard cats in the Kinabatangan floodplain based on different estimators.

Minimum Convex Polygon (km^2)			
ID	**Number of relocations (*n*)**	**95%**	**50%**
LCM02	3499	3.60	0.67
LCM03	5586	7.24	3.01
LCM04	667	11.73	1.68
LCM05	3401	11.84	4.85
Mean (±SE)	3288.25 (1008.62)	8.60 (1.98)	2.55 (0.90)
Adaptive Localized Convex Hull (km^2)			
ID	**Number of relocations (*n*)**	**95%**	**50%**
LCM02	3492	2.20	0.33
LCM03	5586	6.02	1.57
LCM04	657	5.18	0.77
LCM05	3400	8.16	1.54
Mean (±SE)	3301.50 (997.16)	5.39 (1.23)	1.05 (0.30)

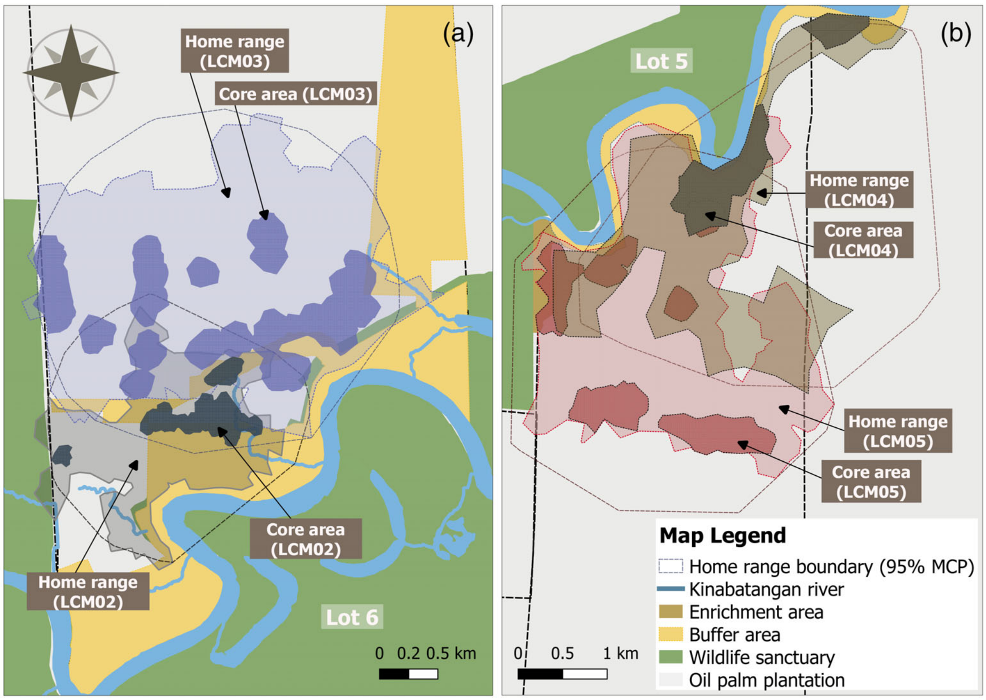

FIGURE 2 The home range area of four collared male leopard cats (LCM02, LCM03, LCM04, and LCM05) estimated in (a) Pontian Hillco and (b) Pontian Pendirosa oil palm plantations within the Kinabatangan floodplain. The lighter shaded polygons represent the home range areas based on 95% Adaptive Local Convex Hull (a-LoCoH), while the darker shaded polygons represent the core areas estimated at 50% a-LoCoH. The dashed lines represent the 95% Minimum Convex Polygon (MCP) estimation of home range area which was used for comparison with previous studies. MCP is a commonly used method that creates the smallest possible polygon around all Global Positioning System (GPS) points, while a-LoCoH provides a more detailed estimation of home range by considering the density of GPS points and landscape barriers.

of the home range (95% a-LoCoH) between LCM04 and LCM05 (at Pontian Pendirosa plantation) was 28%, while for LCM02 and LCM03 (at Pontian Hilco plantation) was 7%. No overlap was observed in the core areas between the individuals within each plantation (Figure 2).

3.3 | Habitat use of leopard cats

A total of 33,636,600 records of ACC readings (per minute) were collected, averaged, and used to determine the hourly activity states of the collared leopard cats. All

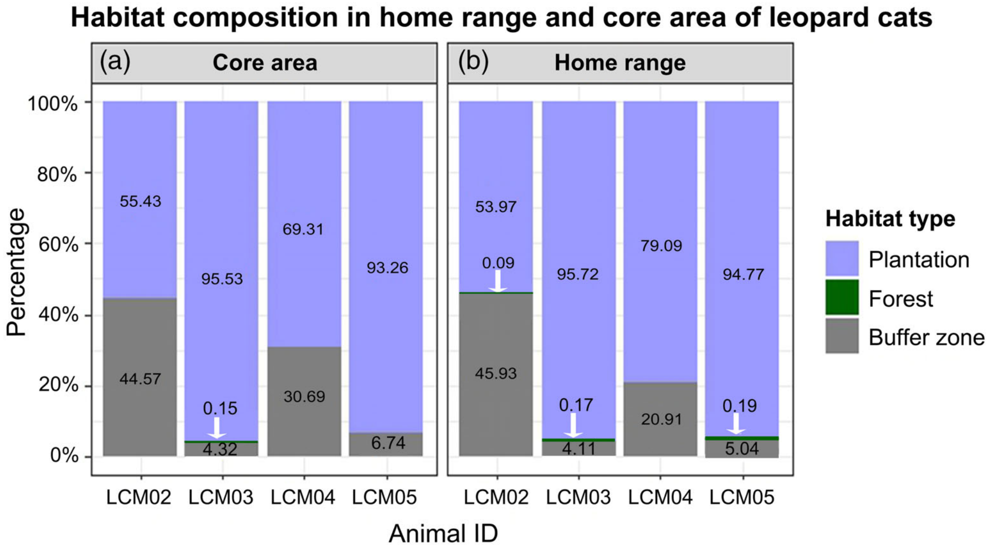

FIGURE 3 Percentage of habitat composition in the home range and core area of leopard cats across four individuals (LCM02, LCM03, LCM04, LCM05). (a) The proportion of habitat composition within the core area; (b) the proportion of habitat composition across the entire home range of the leopard cats. Each bar represents the proportion of plantation, forest, and buffer zone habitats used within both the core area and home range.

collared cats showed variations in habitat preferences, with plantation being the dominant habitat type in their home range and core areas (Figure 3). The average oil palm plantation coverage within the total home ranges of the leopard cats was 80.89% (range: 53.97%–95.72%). Within the core areas of all individuals, the average oil palm coverage stood at 78.38% (range: 55.43%–95.53%). Forested areas constituted approximately 0.11% (range: 0%–0.19%) of leopard cats' home ranges, and 0.04% (range: 0%–0.15%) within their core areas. The forested habitat coverage within the leopard cats' home ranges encompassed the surrounding continuous secondary forests, specifically the Lower Kinabatangan Wildlife Sanctuary.

Buffer areas such as enrichment areas, HCV areas, and riparian reserves allocated by both plantation companies accounted for an average of 19% (range: 4.11%–45.93%) of the home range of all cats. Whereas 21.58% (range: 4.32%–44.57%) of the core areas overlapped with buffer areas. Among the individual cats, LCM02 exhibited the smallest total home range and core area sizes, displaying the least overlap with oil palm habitat compared to the other cats. Notably, there was an observable overlap in home ranges among the individual cats, particularly within the oil palm plantation areas. Based on GPS point counts during these active hours (nightly 15 h of data fixation), 85.45% of locations were recorded in oil palm plantations, while only 14.55% were in forest and buffer habitats combined (Table 3). On average, male leopard cats predominantly utilized plantation habitats, accounting for 15.85 ± 4.71 (mean ± SD) GPS points per night compared to forest habitats and buffer zones combined (mean ± SD: 7.3 ± 5.45 GPS point per night) (Figure 4).

Pearson's correlation analysis showed a negative relationship between home range size and SDI ($r = -0.896$, $p = 0.104$), though it was not statistically significant. Similarly, core size exhibited a significant negative correlation with SDI ($r = -0.987$, $p = 0.013$). The chi-squared test of independence revealed that there was a significant association between the type of activity and the habitat use across different habitat types for three of the male cats, that is, LCM02, LCM03, and LCM05, within this landscape (Table 3). However, LCM04 does not show a significant association between type of activity and habitat type (chi-squared = 0.60; df = 2; p-value = 0.740). These results suggest that the type of activity of leopard cats in these study sites may vary across habitat types, with certain habitats being more associated with either active or inactive states. Male cats spent the majority of their time in oil palm plantations, regardless of activity type, followed by buffer zones and secondary forest. However, activity types differed within these habitats. While oil palm plantations were predominantly associated with the active state, buffer zones were more likely to be used during inactive periods.

4 | DISCUSSION

Despite various studies on the ranging habits of leopard cats using radiotelemetry (see Table 4), this study used

TABLE 3 The chi-squared test results (χ^2 values, *p*-values, and degrees of freedom) assessing the association between type of activity (active vs. inactive) and habitat type, based on percentage of GPS point counts, for each male leopard cat in the study.

	Active			Inactive					
Animal ID	**SF (%)**	**OPP (%)**	**Buffer (%)**	**SF (%)**	**OPP (%)**	**Buffer (%)**	**Chi-square value (χ^2)**	***p*-value**	**Degrees of freedom**
LCM02	1.09	77.80	52.11	2.39	40.01	72.60	130.38	4.89×10^{-29}	2
LCM03	0.31	92.60	4.33	0.00	93.18	6.72	9.21	0.010	2
LCM04	0.35	75.20	19.05	0.91	82.73	22.73	0.60	0.740	2
LCM05	0.45	93.38	4.52	0.00	89.68	9.52	13.26	0.0013	2
Total	0.45	85.45	14.10	0.90	75.96	24.13			

Abbreviations: Buffer, buffer zone; GPS, Global Positioning System; OPP, oil palm plantation; SF, secondary forest.

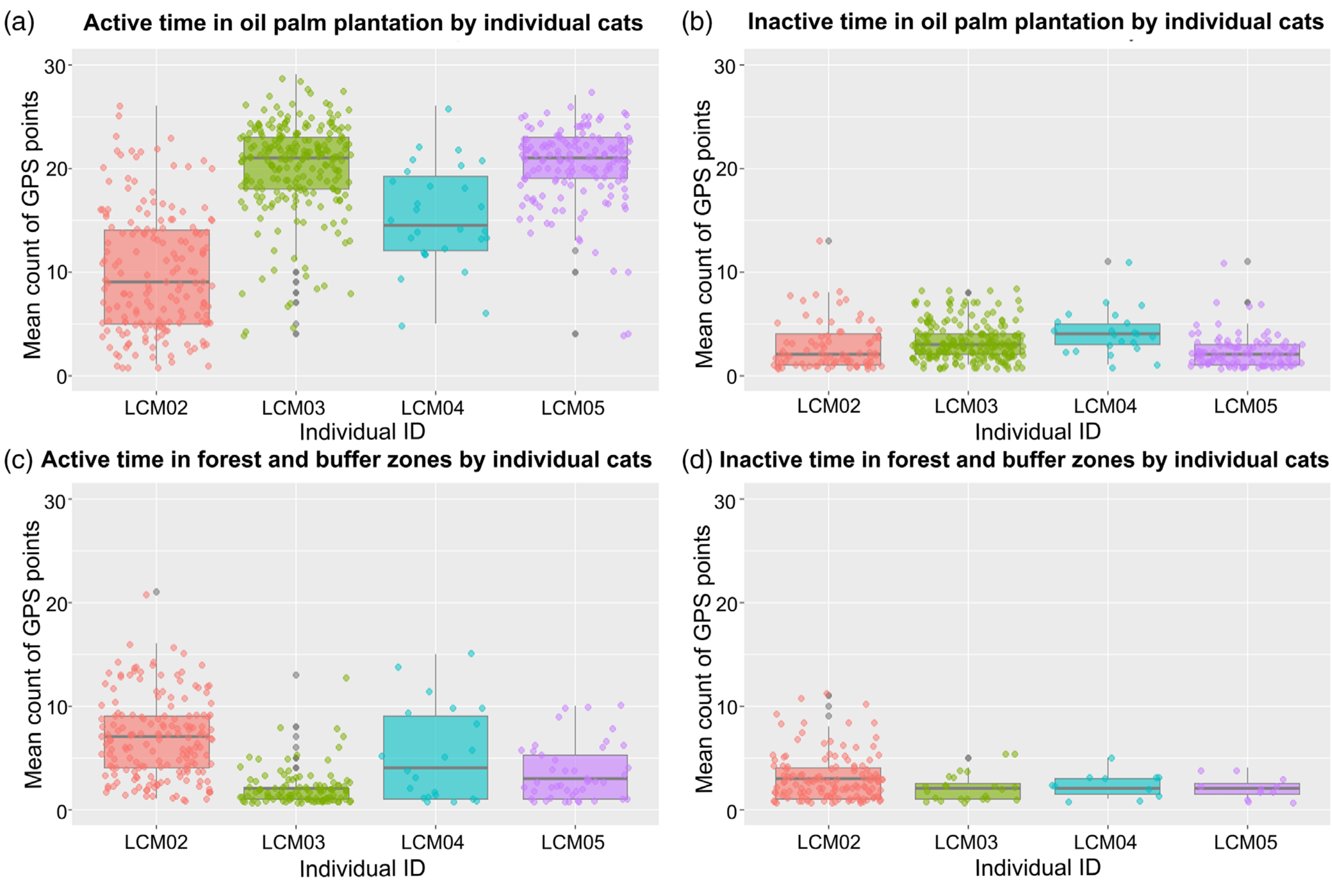

FIGURE 4 Mean of daily count of Global Positioning System (GPS) points, representing both active and inactive time, spent by individual leopard cats (LCM02, LCM03, LCM04, and LCM05) in oil palm plantations and forest areas (including buffer zone areas). (a) Active time in oil palm plantation; (b) the inactive time of leopard cats in oil palm plantations. (c) Active time of leopard cats in forest areas and buffer zones; (d) the inactive time in forest areas and buffer zones. Boxplots illustrate the distribution of GPS points, with the box representing the interquartile range (IQR, the middle 50% of the data), the horizontal line inside the box indicating the median (50th percentile), and the vertical lines (whiskers) extending to the smallest and largest values within 1.5 times the IQR. All individual data points are shown, with those beyond the whiskers representing potential outliers. The *x*-axis represents individual leopard cats (ID) and minor horizontal spreading (jittering) is applied to avoid overlap and improve visibility. These plots provide insights into the variability of activity levels across habitats and activity states.

satellite technology to understand the ecology of the leopard cat using fine-scale spatial data. The use of satellite GPS technology in this study provided accurate, continuous, high-resolution spatial data coupled with ACC, offering real-time temporal insights on leopard cat movements (Cagnacci et al., 2010; Hebblewhite &

TABLE 4 Previous telemetry studies done on leopard cats in other localities with the average locations per collaring day and total locational points accumulated in different periods.

Collar type	Collared individuals	Average ± (SE) number of locations per collaring day	Total locations fixed	Tracking period	Locality	Reference
GPS	*4*	*22.60 ± 0.3*	*13,206*	*4–7 months*	*Kinabatangan floodplain, Sabah, Malaysia*	*Current study*
VHF	4	—	292	1–9 months	Kaeng Krachan, National Park, Thailand	(Grassman, 2000)
VHF	11	—	3509	2–36 months	Iriomote Island, Japan	(Schmidt et al., 2003)
VHF	25	—	7260	1–22 months	Phu Khieo Wildlife Sanctuary, Thailand	(Haines et al., 2004)
VHF	25	1	1681	3–20 months	Phu Khieo Wildlife Sanctuary, Thailand	(Grassman et al., 2005b)
VHF	10	—	818	11 months	Tabin Wildlife Reserve, Sabah, Malaysia	(Rajaratnam et al., 2007)
VHF	5	0.56 ± 0.08	146	2–11 months	Korea	(Choi & Park, 2009)
VHF	1	—	495	4 months	Tsushima Island, Japan	(Oh et al., 2010)
VHF	6	0.44 ± 0.05	356	1–12 months	Taiwan	(Chen et al., 2016)
VHF	11	Min. 4	2031	44 months	Central Kalimantan, Indonesia	(Silmi et al., 2021)

Note: While these studies involve more individuals, our study, despite fewer subjects, provides the most consistent frequency and accuracy of data on leopard cat movements using improved tracking technology and methodology.
Abbreviations: GPS, Global Positioning System; VHF, very high frequency.

Haydon, 2010). This approach enabled a more precise and comprehensive analysis of habitat use and activity patterns while overcoming logistical constraints by capturing movement across diverse habitats, including complex terrains (Recio et al., 2011), without disturbing the animal's natural behavior. However, several limitations of this study include the reliance on male-only samples, which could affect our findings, as behaviors and spatial patterns may differ by sex. Additionally, we retained a small sample size of only four male individuals compared to similar studies (i.e., Rajaratnam et al., 2007; Silmi et al., 2021). Nonetheless, despite this smaller sample size, our study benefits from the volume and resolution of the data collected, which ultimately reflects a more accurate representation of movement patterns for male leopard cats. However, it is important to interpret these results with caution, as the data were derived from only two plantations, which may limit the generalizability of the findings to other plantation landscapes.

Our findings showed that the average home range size of male leopard cats in the Kinabatangan floodplain (mean: 8.60 km^2 ± 1.98, 95% MCP) was larger than reported in most studies. Home range estimation derived using a similar technique (refer to Table 5) ranged from 0.78 km^2 [100% MCP] in Tsushima island (Oh et al., 2010), 3.54 km^2 [95% MCP] in Korea (Choi & Park, 2009), 4.07 km^2 [100% MCP] in Thailand (Grassman, 2000), to 4.94 km^2 [100% MCP] in Iriomote island (Schmidt et al., 2003). Studies conducted in the oil palm–forest interface in Indonesia (1.94 km^2, 100% MCP; Silmi et al., 2021) and Tabin Wildlife Reserve in eastern Sabah (3.49 km^2, 95% MCP) (Rajaratnam et al., 2007) reported smaller averages of home range size for male cats. The closest estimate was from a study in Taiwan (8.0 km^2, 100% MCP) which was carried out in a mixed-habitat landscape of forest and grasslands (62%) and man-made habitats (38%) (Chen et al., 2016). The variability in the size of home ranging areas among individual cats in our study (3.60–11.84 km^2, 95% MCP, $n = 4$) is likely influenced by habitat type. In our study, males that utilized a higher proportion of homogenous anthropogenic landscapes (i.e., oil palm plantations) tended to have larger home ranges (6–8 km^2 based on 95% a-LoCoH), while the individual with greater use of secondary forest habitats had the smallest range (2.20 km^2). Our results suggest a tendency that greater landscape heterogeneity may be associated with smaller core areas in leopard cats. Although a negative relationship was observed between home range size and habitat diversity, it was not statistically significant, likely due to the small sample size.

TABLE 5 Home range areas of leopard cats estimated using Minimum Convex Polygon in different localities based on previous studies.

Average home range size (km^2)		Average core area size (km^2)				
MCP (100%)	**MCP (95%)**	**MCP (50%)**	**Sex**	***n***	**Locality**	**References**
4.07	—	—	M	3	Kaeng Krachan, National Park, Thailand	(Grassman, 2000)
2.50	—	—	F	1		
4.94	—	—	M	5	Iriomote island, Japan	(Schmidt et al., 2003)
2.11	—	—	F	6		
18.50	12.40	2.20	M	14	Phu Khieo Wildlife Sanctuary, Thailand	(Grassman et al., 2005b)
17.40	14.00	1.80	F	6		
—	3.49	—	M	4	Tabin Wildlife Reserve, Sabah, Malaysia	(Rajaratnam et al., 2007)
—	2.09	—	F	2		
2.99	3.54	—	M	2	Korea	(Choi & Park, 2009)
3.25	2.51	—	F	1		
0.78	—	—	M	1	Tsushima Island, Japan	(Oh et al., 2010)
8.00	—	1.05	M	2	Tongsiao Township, Miaoli County in northwestern Taiwan	(Chen et al., 2016)
1.90	—	0.35	F	2		
1.94	—	—	M	7	Central Kalimantan, Indonesia	(Silmi et al., 2021)
1.36	—	—	F	4		

Mammals often exhibit smaller home ranges in more heterogeneous habitats, due to concentrated resources and reduced dispersion (Van Moorter et al., 2016; Walter et al., 2018; Lauer et al., 2023). In anthropogenic landscapes, fragmentation and human disturbance can shape habitat selection and space use for large carnivores across various ecosystems (Crooks et al., 2011; Cruz et al., 2018). Large carnivores like leopards' (*Panthera pardus*), jaguars' (*Panthera onca*) and bobcats (*Lynx rufus*) show positive correlations between home range size and human density (Morato et al., 2016; Snider et al., 2021). Whereas mesocarnivores like coyotes (*Canis latrans*) may adjust their habitat use at finer spatial scales rather than expanding their home ranges, highlighting species-specific strategies in response to fragmentation (Gorman et al., 2024). In highly fragmented landscapes, where habitats are broken into isolated patches, animals may need to traverse larger areas to access key resources to meet their ecological needs, as observed in pumas (Azevedo et al., 2021). Similarly, mammalian carnivores in disturbed landscapes, such as European wildcats, Eurasian lynx, and kodkod cat (*Leopardus guigna*), exhibited larger home ranges due to resource scarcity and habitat fragmentation (Herfindal et al., 2005; Ruiz-Villar et al., 2022; Šálek et al., 2015; Schüttler et al., 2017). Hence, larger home ranges can be attributed to the uneven distribution of resources in time and space (Buchmann et al., 2012; Péron, 2019; Rémy et al., 2013; Viana et al., 2018). Critical resources (i.e., food, water, shelter) are often clumped as a result of patchy arrangements of habitats in a fragmented landscape (Trevail et al., 2021; Ziv & Davidowitz, 2019).

Core areas were smaller than overall home ranges, suggesting that leopard cats concentrated their activity in specific parts of their range. Core size exhibited a strong negative correlation with habitat diversity (SDI), suggesting that larger core areas were associated with lower habitat heterogeneity. While overall home range may not be strongly influenced by habitat heterogeneity, core range sizes tend to be larger in simpler, less diverse habitats. This suggests that core extent depends on habitat composition rather than the overall variety of habitat. There is a notable proportion of buffer zones such as HCV forest patches in Pontian Hillco, while Pontian Pendirosa contains only a small proportion of these patches (Figure 2). Forest patches can serve as crucial refuges, providing wildlife with cover and safety from predators such as feral dogs or human activities in plantations (Assefa & Chelmala, 2019; Bernard et al., 2013; Bjørneraas et al., 2012; Lema & Magige, 2018; McLoughlen & Ferguson, 2000; Quinn & Whisson, 2005). In agricultural landscapes, the combination of an open structure and extensive road networks likely enhances prey catchability for generalist carnivores (Bernard et al., 2013; Chua et al., 2016; Mohamed et al., 2013; Rajaratnam et al., 2007), which may explain leopard cats' affinity for oil palm plantations, despite prey availability being similar in both oil palm and forest habitats in our study area

(Guerrero-Sanchez et al., 2022). However, as core areas become more isolated, species may need to cover greater distances and cross gaps to access resources, which can result in larger home ranges, as shown by Gardiner et al. (2019), who found that fragmentation increases home range size for mobile species capable of navigating these gaps.

The larger home range size estimated in our study could also be attributed to the use of GPS telemetry, as documented in studies of various other species (e.g., Girard et al., 2002; Kochanny et al., 2009; Peris et al., 2020; Skupien et al., 2016). The higher locational accuracy and increased volume of data provided by this method allowed us to capture habitat-driven variations in movement and space use more precisely. Unlike radiotelemetry, GPS collars enabled continuous nocturnal tracking and rapid stabilization of sampling curves, with the minimum number of locational fixes (>300) obtained in less than a month, supporting robust home range estimation. Additionally, the higher average daily fixes recorded could be linked to the open canopy, which improves the overall GPS fix success (Hofman et al., 2019; Tomkiewicz et al., 2010). However, this observation is descriptive and based on a small sample size ($n = 4$), so it should be interpreted with caution.

Despite the small sample size, we observed an overlap in home range (7%–28%) of male cats in this study, suggesting some degree of tolerance in shared spaces within the broader landscape. Habitat heterogeneity can influence space use by shaping resource availability and distribution, which in turn may affect interactions among individuals (Buchmann et al., 2012; Viana et al., 2018). In some carnivore species, resource clumping has been linked to reduced range overlap among same-sex individuals due to increased competition, as individuals defend key resources within their territories (Hidalgo-Mihart et al., 2004; Quinn & Whisson, 2005). However, in fragmented landscapes where resources are unevenly distributed, some overlap may still occur if the benefits of accessing these areas outweigh the costs of direct competition (Elbroch et al., 2016; Karanth et al., 2017). Territorial animals can mitigate conflicts by adopting spatial time-sharing strategies or encounter avoidance, allowing for some degree of home range overlap (Getty, 1981; Isbell et al., 2021). In our study, core ranges were predominantly exclusive, suggesting that strong territoriality is maintained in these critical areas despite the overlap in overall home ranges (Almasieh et al., 2022; Facka & Powell, 2021; Persson et al., 2010; Viana et al., 2018). Territoriality over essential resources has been documented in other wild felids, such as pumas (Elbroch et al., 2016), lions (*Panthera leo*) (Packer et al., 2005), and Eurasian lynx (Schmidt et al., 1997).

Previous camera-trapping studies have shown low sightings of leopard cats in forests compared to sympatric felids (e.g., marbled cats [*Pardofelis marmorata*] and Sunda clouded leopard [*Neofelis diardi*]) (Mohamed et al., 2013; McCarthy et al., 2015; Ross et al., 2010). As smaller mesopredators with broader prey specialization, leopard cats may be more inclined to exploit agricultural landscapes where prey is abundant and interspecific competition is less intense (Grassman et al., 2005a; Kamler et al., 2020; Parab & Lyngdoh, 2024). Male cats in our study showed that leopard cats spend 80.89% of their home range in oil palm plantations and minimal time in forests (0.11%). However, frequent human activity associated with oil palm plantations can influence their space use and behavior (Pardo et al., 2021). In Taiwan and Japan, leopard cats have been observed adjusting their home ranges and resting site selection to avoid areas of intense human activity, showing a preference for vegetated or forested patches within the human-dominated landscape (Oh et al., 2010; van der Meer et al., 2023). Our study demonstrates how remnant habitats contribute to structural heterogeneity within oil palm landscapes. These patches may provide important resting opportunities as evidenced by use during inactive periods, offering shelter and reducing exposure to anthropogenic threats. In the fragmented landscapes of Sabah, such remnant habitats can also buffer the effects of disturbance, potentially supporting key behaviors such as resting, denning, and accessing secondary prey (Rajaratnam et al., 2007).

In addition to these sheltering patches, leopard cats benefit from the abundance of prey in agricultural landscapes (Silmi et al., 2021). Oil palm plantations provide a unique foraging landscape, offering stable rodent prey populations year-round (Hood et al., 2019). Rodent densities in these plantations can reach up to 600 individuals per hectare, primarily due to the continuous availability of food sources like crop residues and loose fruits (Wood & Chung, 2003). As a result, plantations accumulate large rodent populations, particularly *Rattus* spp., which contribute to production losses of 5%–10%. Since leopard cats primarily feed on rodents, they are commonly associated with agricultural landscapes, such as sugarcane, coffee, and oil palm plantations, due to the abundance of prey and the ease of prey catchability in these habitats (Chua et al., 2016; Lorica & Heaney, 2013; Rajaratnam et al., 2007). Studies in the Lower Kinabatangan suggest that prey abundance is similar in both forest and plantation habitats, making prey catchability, enhanced by the open structure of plantations and the presence of plantation roads, a more significant factor that drives leopard cat association with oil palm plantations (Chua et al., 2016; Guerrero-Sanchez et al., 2022; Rajaratnam et al., 2007). Whereas, prey diversity is significantly lower in plantations compared to adjacent forest patches, which support a broader range of prey species, including small rodents, reptiles, amphibians, insects, and ground-nesting birds (Chua et al., 2016; Guerrero-sanchez et al., 2022; Majewski, 2017).

In oil palm plantations, prey movement is influenced by understory vegetation and human activities, adding complexity to predator space use (Hood et al., 2019). This may increase energetic expenditure, affecting overall fitness (Gehr et al., 2017; Wang et al., 2017). As leopard cats remain in closer proximity to human activity, they face risks of encountering humans, vehicles, or machinery, increasing the likelihood of injuries or fatalities (Hui et al., 2021; Laton et al., 2017). Additional threats include cross-transmission of disease from domestic animals (Guerrero-Sánchez et al., 2021), hunting activities (Azhar et al., 2013) and attack by feral dogs (Marshall et al., 2022). Additionally, the use of pest control methods, particularly rodent poisoning and pesticides, is common in plantation management (Verwilghen, 2015). The use of rodenticides in plantations also poses a risk, with poisoned prey potentially causing secondary poisoning in leopard cats (Ravindran et al., 2022). These combined challenges highlight the precarious balance leopard cats must navigate in intensively managed landscapes.

Despite these challenges, male cats in our study spent the majority of their time in oil palm plantations, regardless of activity state emphasizing how well adapted they are to life in plantations (Mohamed et al., 2013; Silmi et al., 2021). Our results suggest that activity levels of leopard cats may vary across habitat types, with certain habitats being more associated with either active or inactive states. Male cats were predominantly found in plantations, where they were generally more active, although a notable amount of inactivity was also observed there. Inactivity was observed less frequently in buffer zones, suggesting that plantations serve both as foraging and resting areas. The presence of understory vegetation such as dense oil palm fronds and bushes that may provide sufficient cover for resting or sleeping, a pattern similarly observed in common palm civets, which selected dense vegetation within plantations as day-bed sites (Hood et al., 2019; Nakashima et al., 2013; Silmi et al., 2021). The use of buffer zones for inactivity, although less frequent, may indicate their supplemental role as lower-disturbance refuge areas within the landscape. Similar reports were recorded in Taiwan, where different habitat types might serve different purposes in fulfilling the cats' ecological needs (van der Meer et al., 2023). The use of buffer zones indicates that these areas serve as refuge sites, which is particularly relevant in a landscape dominated by industrial oil palm plantations, that are often fragmented and lack substantial areas of natural habitat (Bernard et al., 2014).

The remaining degraded forest areas in oil palm plantations are isolated into islands or narrow strips of corridors, typically designated as buffer zones. These forest patches can offer important ecological functions to generalist species that go beyond mere shelter, such as denning sites, human avoidance, and access to secondary prey (Bernard et al., 2013; Knowlton et al., 2019; Rajaratnam et al., 2007; Ross et al., 2010; Selwood & Zimmer, 2020; van der Meer et al., 2023). This highlights the importance of HCV buffers in boosting landscape connectivity and providing refugia for such species within oil palm areas (Furumo et al., 2019; HCV Malaysia Toolkit Steering Committee, 2018). Due to its ecological plasticity, the leopard cat can adapt to a range of habitats, including human-modified landscapes like oil palm plantations, where it can exploit available resources despite the challenges posed by these environments. With the projected increase in replanting of oil palms over the coming years, it presents both challenges and opportunities for farmers (Ashton-Butt et al., 2019; Murphy et al., 2021; Petri et al., 2023). Although replanting efforts can exacerbate environmental issues, it also offers an opportunity to redesign plantation landscapes to increase sustainability and promote nature-based solutions (Ayompe et al., 2021; Bicknell et al., 2023).

5 | CONCLUSION

In conclusion, male leopard cats in our study retained a large home range area in oil palm plantation, suggesting that these cats are adapting to altered landscapes to access sufficient resources. This highlights the complex dynamics of habitat use in human-modified environments and underscores the importance of understanding the spatial requirements of leopard cats in such areas. This adaptation highlights their capacity to persist in such environments, emphasizing the importance of management practices that mitigate risks and enhance habitat connectivity to ensure their long-term survival. A long-term monitoring of their adaptive potential and behavioral patterns in disturbed habitats could be useful in understanding how to better manage these agricultural landscapes to enhance long-term persistence in shared landscapes. Implementing wildlife-friendly practices, such as adopting sustainable farming and maintaining accessible refuge areas, will be essential in balancing agricultural productivity with biodiversity conservation to ensure the continued presence of native carnivore populations.

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CONFLICTS OF INTEREST

The authors declare no competing financial and/or non-financial interests in relation to the work described.

DATA AVAILABILITY STATEMENT

Data in support of the findings of this study and the codes generated for this study are available from the corresponding author by reasonable request.

CONSENT FOR PARTICIPATION

All authors agreed to participate in this study and co-authorship.

CONSENT FOR PUBLICATION

All authors agreed with the content and that all gave explicit consent to submit.

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