B-CONNECTED Phase I

Annual Report

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The DodoBase

Danau Girang • Field Centre •

ELEPHANT FAMILY

Protecting Asian elephants and their habitat

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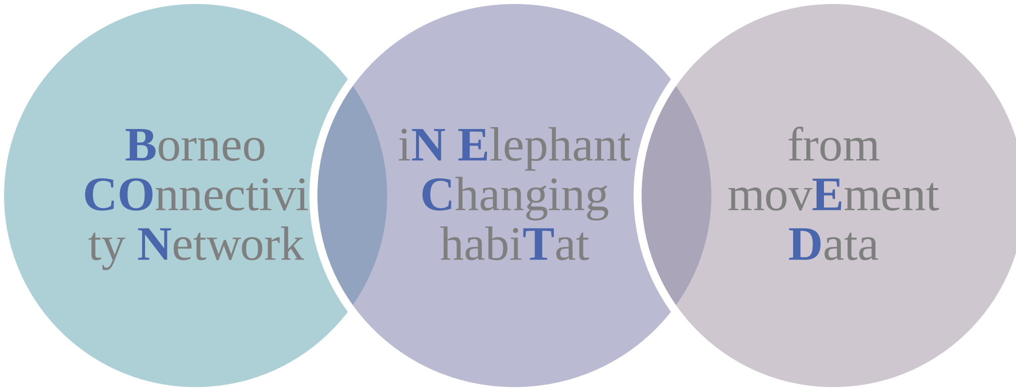


EXECUTIVE SUMMARY

The Bornean elephant (*Elephas maximus borneensis*) is one of the four sub-species of Asian elephants and can be found only in Sabah, Malaysia. Recent estimates assessed the total population of Bornean elephants as being around 2040 individuals (range: 1184 to 3652), making this the most endangered elephant species in Asia (currently listed as *Endangered*, IUCN Red List). The continuous changes in landscape, the constant pressure by oil palm plantations and the subsequent creation of plantations, roads and villages, contribute to decrease the Asian elephant habitat, cutting elephant pathways, isolating elephant populations and exacerbating the situation regarding human-elephant conflicts (HECs). A recent study further shows that achieving a balance between economic development and biodiversity protection will require a whole-landscape approach to land-use planning that has the potential for Borneo economy to save over US$43 billion. In this context, the WWF Malaysia and the Sabah Wildlife Department in 2015 highlighted the need for conservationists, managers and stakeholders to have decision-making tools and guidelines for forest elephants in Borneo.

Project B-CONNECTED responds to a **dual global conservation** need: the absolute necessity of

- ✓ **valorizing** the huge amount of field data collected by conservation projects and yet often not analyzed to their full potential and
- ✓ **improving** local capacity building by passing on knowledge and analytical know how. In Sabah (Borneo), this is especially needed to optimize landscape connectivity threatened by anthropogenic pressure in order to, on one hand, prevent costly human-wildlife conflicts and on the other hand, protect habitat and biodiversity.

Over the past eight years, the Danau Girang Field Centre (DGFC) has been satellite-tracking more than 30 elephants and translocating problematic animals found in oil palm plantations into more elephant-friendly areas to help reduce HECs in collaboration with local stakeholders, students and organizations. Using available and new data on elephant movements, HECs occurrence and local stakeholder perceptions, this project focuses on answering the “where/when/why do elephants move?” questions by:

- ✓ **mapping corridors** and dispersal constraints;
- ✓ developing and **validating a connectivity framework** to predict movements in a changing landscape;
- ✓ **identifying HEC** hotspots and their potential causes;
- ✓ **building capacity** of young scientists and conservationists in Sabah;
- ✓ developing a **toolkit, guidelines** and recommendations for managers and stakeholders for better decision-making in securing corridors, managing elephant forest habitat and improving translocation site selection.

> *Project B-CONNECTED is meant to contribute to elephant and forest conservation while improving human-elephant interactions and co-existence through science-based policy and management.*

INTRODUCTION

Re-connecting or keeping connected heterogeneous landscapes has become a necessity in conservation where habitat fragmentation has become the primary driver of species extinction (Pimm and Raven, 2000). A functional connectivity requires that individuals can move between habitat fragments so that connectivity is not measured solely in terms of physical features of the landscape but also based on the dispersal characteristics of the species (Calabrese and Fagan, 2004; Clobert *et al.*, 2012). Connectivity should be treated as a function of the response of individual dispersers to landscape structure: for instance, the ability of a species to move between patches of habitat can be constrained by anthropogenic modifications of the landscape, *e.g.*, roads, or habitat cues (Ball and Goldingay, 2008; Fletcher, 2006). Therefore an understanding of species movement behavior and dispersal abilities, *i.e*., answering the “Where do animals move? When? Why?” questions, is crucial for connectivity assessments and to improve the accuracy of predictions of potential connectivity, particularly in changing landscapes (Hudgens *et al.*, 2012; McIntire *et al.*, 2007). Recent reviews however indicate that **animal movement behavior data are not used in most connectivity assessments** (Sawyer *et al.*, 2011; Vasudev *et al.*, 2015; Zeller *et al.*, 2012).

Landscape connectivity. In Borneo, the continuous changes in landscape, the constant pressure by the oil palm industry and the subsequent creation of plantations, roads and villages, contribute to decrease and fragment the Asian elephant habitat (*e.g.*, the state of Sabah lost 40% of its forest during the 20th century (Estes *et al.*, 2012)), cutting elephant pathways, isolating elephant populations (see Goossens *et al.*, 2016), increasing densities locally and exacerbating the situation regarding human-elephant conflicts (HEC). Preserving elephant movement within a matrix of protected and unprotected lands in Borneo not only has scientific and conservation importance but **the management and social need to retain traditional values of tolerance towards elephants has the potential for Borneo economy to save over US$43 billion** (Runting *et al.*, 2015; Singh and Kumar, 2014). Promoting coexistence between people and elephants to achieve a balance between economic development and biodiversity protection will require a whole-landscape approach to land-use planning through pro-active and innovative measures.

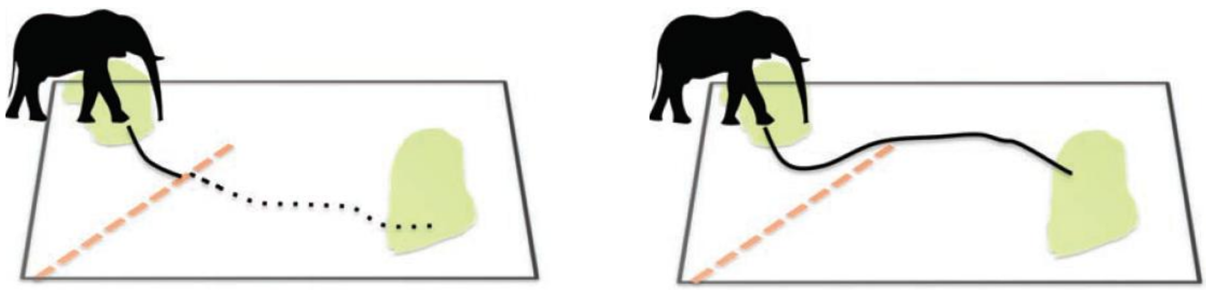


Figure 1 - Movement path modification between two patches of forest with the installation of a fence (orange dashed line): ancestral route (left) versus new route (right). Mortality effects at fences are caused by electrocution or persecution by humans while behavioral effects occur when individual elephants modify their path on perceiving the threat posed by wildlife fences (Vasudev *et al.*, 2015).

Conservation need. Recognizing the current paucity of local trained scientists and of in-depth analyses of available data about elephant ecology in changing landscapes which impair the development of appropriate management strategies at the landscape level to support elephant conservation, the project responds locally to a dual global conservation need:

- ✓ **valorizing the field data** collected since 2008 in Sabah on elephant movement by DGFC and partners by incorporating species movement behavior data to maintain functional connectivity to, on one hand, protect habitat and biodiversity threatened by anthropogenic pressure (Eggert *et al.*, 2013) and on the other hand, prevent costly human-wildlife conflicts and

- ✓ **building capacity** of local scientists and **facilitating decision-making** through guidelines and analytical tools.

Managed Elephant Ranges. In 2012, in Sabah (Borneo, Malaysia), as part of the Sabah Elephant Action Plan (2012-2016) (that was evaluated by the PI and other stakeholders in a workshop in November 2016 and will be revised in 2017 for another 10 years) four 'Managed Elephant Ranges' (MERs) were declared: Lower Kinabatangan Range, North Kinabatangan Range, Tabin Range and Central Forest Range. In the 1990 Action plan for Asian Elephant Conservation, a MER was defined as a matrix of protected areas (*i.e.,* sanctuaries) and unprotected areas where the priority was given to the requirements of elephants, but compatible human activities were permitted, *e.g.*, sustained-yield forestry, rotation shifting cultivation, controlled livestock grazing, and subsistence hunting (Santiapillai and Jackson, 1990). However, as changes in landscape increase around and within MERs, the incidences of HECs increased, as well as the number of elephants that were poisoned or killed illegally.

> *The density of elephants is particularly elevated in the MERs where we will concentrate our efforts (Tabin Reserve, Central Sabah, North and Lower Kinabatangan MERs) due to the reduced available habitats (Figure 2).*

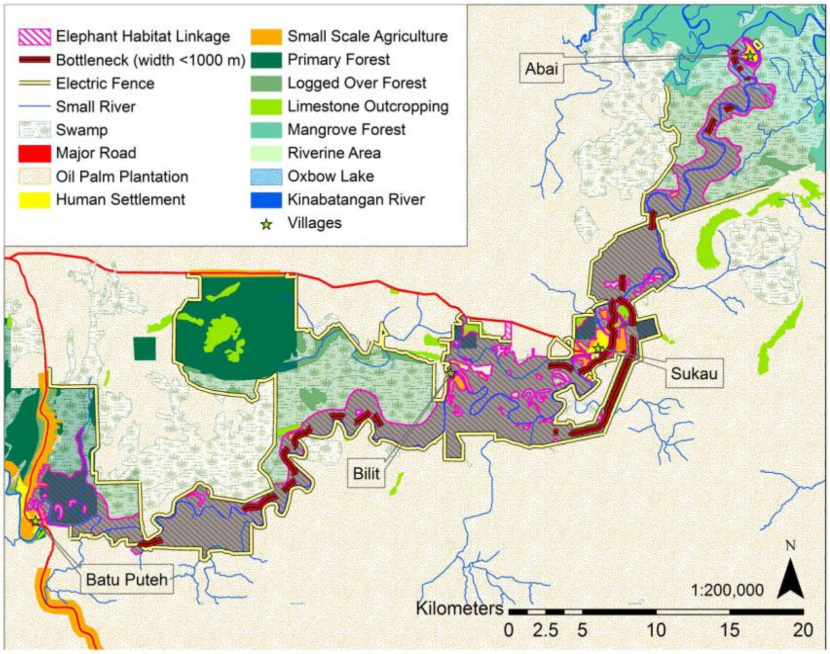


Figure 2- Map of remaining connectivity (Elephant Habitat Linkage) in the Lower Kinabatangan MER (see also the map of the project area below) where the available suitable elephant habitat was estimated at 184 km^2 before 2012 (for an elephant density of 1.62 km^{-2} (95% CI: 0.83–3.15)), hence 54% smaller than the Lower Kinabatangan MER habitat estimate (400 km^2) and 47% smaller than the visual connectivity estimate (from Estes *et al.*, 2012).

Project scope. In 2015 the Sabah Wildlife Department and the WWF Malaysia identified the need for conservationists, managers and stakeholders to have decision-making tools and guidelines for elephants in Borneo (Jayasinghe, 2015). Responding to this need, this project builds on the on-going work carried out by the **Danau Girang Field Centre** (DGFC) and partners over the past eight years and will focus on understanding elephant behavior in a changing landscape and identifying connectivity corridors to ensure the long-term preservation of elephant movement and beyond that, of biodiversity in Borneo.

Project background. Established in 2007 and operational since 2008, DGFC, a collaborative research and training facility managed by Cardiff University and Sabah Wildlife Department, has been working strenuously within the Lower Kinabatangan Wildlife Sanctuary (LKWS) in Sabah, Malaysia, to increase our knowledge of the behavioral ecology of the Asian elephant and reduce human-elephant conflicts in the area. Since 2008, DGFC has been collaborating with partners to better understand elephant movements in a changing landscape by collaring elephants (n = 35) and to elucidate other aspects of their biology and ecology, including genetic studies (Goossens *et al.*, 2016).

DGFC has been very active in finding solutions for HEC mitigation, especially in the Telupid complex (North Kinabatangan MER). Several attempts of translocation were engaged to move forward the troublesome elephants (n = 7) but those have so far always find the way back to the conflicting area. An analysis of structural connectivity was undertaken in 2012 providing a snapshot of the quantity and location of available elephant habitat in the Lower Kinabatangan (Estes *et al.*, 2012). This study also highlighted that **current methods** used by managers to quantify available habitat **tend to overestimate the size of suitable habitat** by not accounting for functional connectivity (*e.g.*, by including, in their estimation, patches that might be suitable but are unreachable, hence are unavailable to elephants, (Goossens *et al.* unpublished data). Moreover, recognizing the need for valorizing the available data in the Lower Kinabatangan MER, a Malaysian PhD student (Nurzhafarina Binti Othman) registered at Cardiff University and supervised by the PI, is currently studying home range and movement behavior of 10 elephants (PhD submission scheduled for October 2017).

Focus. The present report aims at **identifying gaps in the available data and set priorities for data** collection and analysis for the development of a science-based connectivity management framework. This exploratory first phase, funded by Elephant Family, aims at exploring data and characterizing elephant routes to **better understand dispersal patterns and habitat use** in different parts of Sabah. Questionnaires were conducted with representatives of palm oil companies and NGOs to understand their perceptions of elephants and conflicts and their aspirations for an improved management strategy. The present report assesses the current knowledge gaps and future research needed to be addressed by the B-CONNECTED project for which additional funding has been seek from the USFW Asian Elephant Conservation Fund.

CURRENT KNOWLEDGE ON ELEPHANTS IN BORNEO, SABAH

Distribution, range & abundance. Four sub-species of Asian elephants have been identified and genetics analyses concluded that there were one mainland-Asia sub-species and 3 isolated sub-species: the Sumatran, the Sri Lankan and the Bornean species. *Elephas maximus borneensis* only occurs in the north-eastern part of Borneo, mainly in Sabah extending over to a small area across the international boundary between Malaysian Sabah and Indonesian Kalimantan (Figure 3). In 2007-2008, a survey to estimate elephant abundance was conducted using a systematic line transect survey method and long term monitoring of dung decay rates. Results of this survey suggested a population of 1,184-3,652 inhabiting the five MERs (Figure 4). In 2012, the new Action Plan presented a less optimistic figure with **1,127-1,623 elephants** thought to be present in Sabah (Ambu *et al.*, 2012).

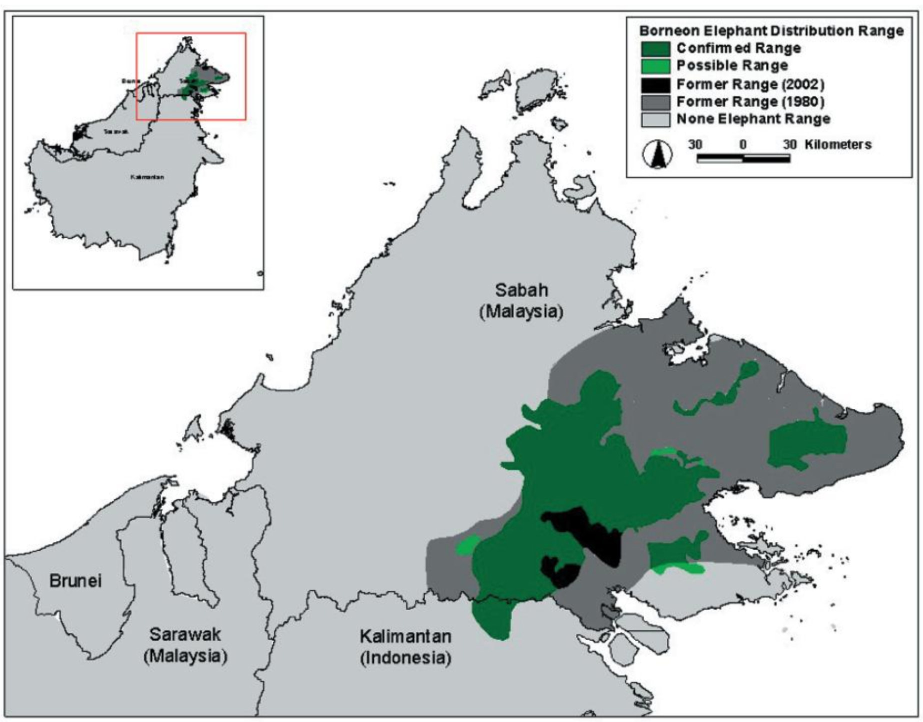


Figure 3- Past and current distribution of Bornean elephant in Sabah (Alfred *et al.* 2010)

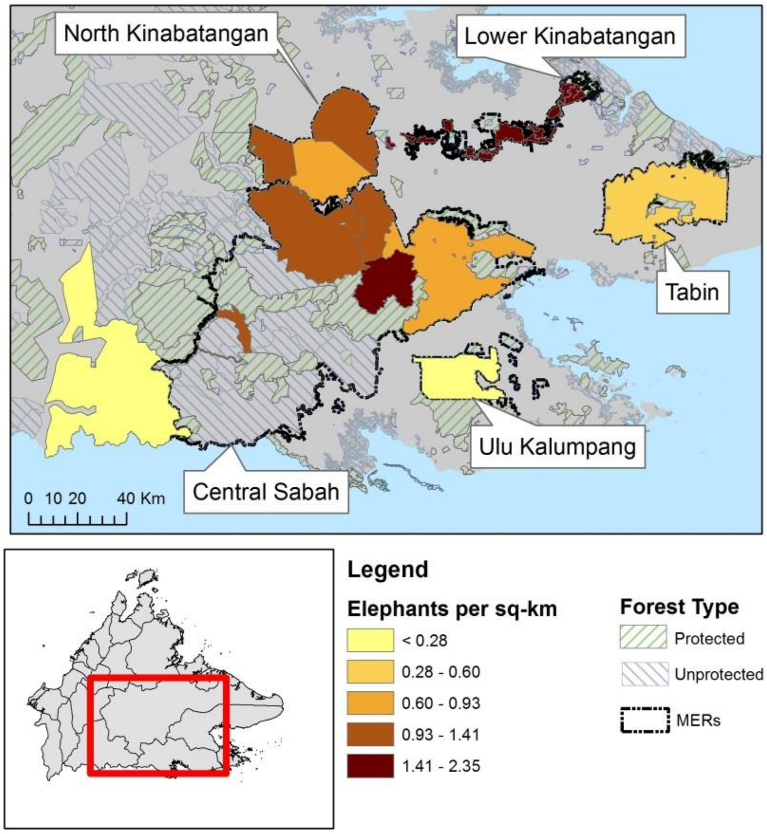


Figure 4- Elephant densities in Sabah: in the 5 MERs (North and Lower Kinabatangan, Central Sabah and Ulu Kalumpang Ranges and Tabin Reserve) and in isolated forests from the 2012 Action Plan (Ambu *et al.*, 2012).

Managed Elephant Ranges (MERs). The 1990 Action Plan for the Asian elephant conservation (Santiappillai and Jackson, 1990) stated that elephants can only be conserved by ensuring the integrity of their forest habitats. As such, countries were invited to develop a network of protected areas of sufficient size and ecological diversity. It was highlighted that maintaining a **Minimum Viable Population (MVP) was not sufficient** and the objective was the creation of protected areas at least double the MVP that would be part of larger areas: the Managed Elephant Ranges (MERs). In MER, **priority was set for elephants requirements** in terms of habitat but did not exclude human activities so long as these were compatible: examples of sustained-yield forestry, slow-rotation shifting cultivation, controlled livestock grazing and subsistence hunting were given in the 1990 Action Plan. The current set up of MERs in Sabah and evidence from collared elephants suggest that two MERs (**Lower Kinabatangan and Tabin Reserve) are completely isolated**. North Kinabatangan, Central Sabah and Ulu Kalumpang appear connected and will be considered as one area: the **super MER**.

Status of elephant corridors. Between 1990 and 2005, it was estimated that 55-59% of Malaysia's oil palm extent replaced forests with a likelihood for ongoing expansion in the eastern floodplains of Sabah that have a very high yield potential (Abram *et al.*, 2014). In 2002, in the Kinabatangan basin under threat by large scale conversion to palm oil, the project for the **Kinabatangan-Corridor of Life** (K-CoL) emerged as an alternative for sustainable development.

The K-CoL project intended to create a river corridor where reforestation initiatives, sustainable agriculture, tourism and local community engagement along with patrolling and monitoring teams would unite to conserve and manage the floodplain in harmony.

In 2012, the WWF-Malaysia exited the Kinabatangan but some initiatives remained such as reforestation. The Borneo Conservation Trust (BCT) seems to have taken over launching a similar project in its **Sabah Mega Biodiversity Corridor Programme**, A Green Corridor to reconnect the MERs and avoid population isolation of elephants, rhinos, orang utans among others. From the Wildlife Department, a memorandum of understanding was also initiated to promote an action plan for the re-establishment of ecological corridor to connect forest patches.

Human-Elephant Conflict in Sabah. In Borneo, HEC occurrences are increasing as oil palm plantations are reducing elephant habitat. It is estimated that 300-500 ha of oil palm would be destroyed by elephants each month while 10-16 elephants and 1-2 humans would be killed every year (Alfred *et al.*, 2011) as a consequence of HECs. However, it is impossible to quantify HECs occurrence as no database or standardized data collection protocol exist. These conflicts also generate a **negative attitude towards wildlife and conservation**. Electric fences, culling and translocations are currently the methods used to mitigate HEC in Sabah.

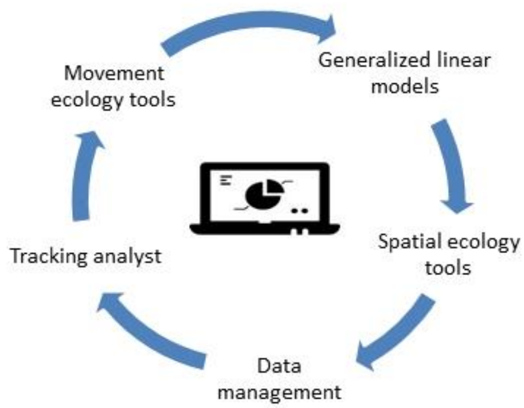
Figure 5- Elephant culled in Tawau in November 2016 (left) – Damages in a village after elephant raiding (right).

STRATEGIC OBJECTIVES

RESEARCH ON LANDSCAPE AND ELEPHANT MOVEMENT

Focus. The aim of this first phase of data analysis was to study elephant movement on a broad scale and link it to landscape characteristics and human disturbances. Data were compiled and elephant daily distances and speed were calculated:

- ✓ for comparison between MERs and
- ✓ to study impacts of landscape features and human disturbances on elephant movement.



Methodology. We used spatial and quantitative approaches and built models in R and ArcGIS to analyse elephant movements. We organised the data to get one position every 2 hours for each elephant and used ArcGIS to measure the distances between successive locations. Two variables were then extracted: the daily distance (the sum of all distances traveled in 24hrs) and speed (Appendix 1).

MAIN FINDINGS

PRELIMINARY OVERALL RESULTS. Looking at the GPS locations and overall movement range (Figure 6), different landscape features shape the mobility of elephant. In particular, **elephant movement range** appears to be **restricted** in the Lower Kinabatangan by **human-built features**: westward by a main road and along the river by electric fences on both sides (Figure 6). On the other hand, in Tabin Reserve and Central Sabah, movements seem to follow clearly defined pathways. In terms of connectivity, Tabin Reserve and Lower Kinabatangan MERs seem isolated while **Central Sabah, North Kinabatangan and Ulu Kalumpang ranges appear connected**.

Overall, the MERs present **very different terrain** in terms of slope and elevation likely to shape elephant movement by imposing considerable energetic costs on travel (*e.g.*, Wall *et al.*, 2006):

- ✓ the **Lower Kinabatangan** is a **floodplain** characterized by an overall low elevation and limited slope,
- ✓ the **Tabin** Reserve is a balanced **mixture** of low and high elevation and slope areas,
- ✓ the **super MER** offers a habitat with **high elevation and slope** in most part of its range

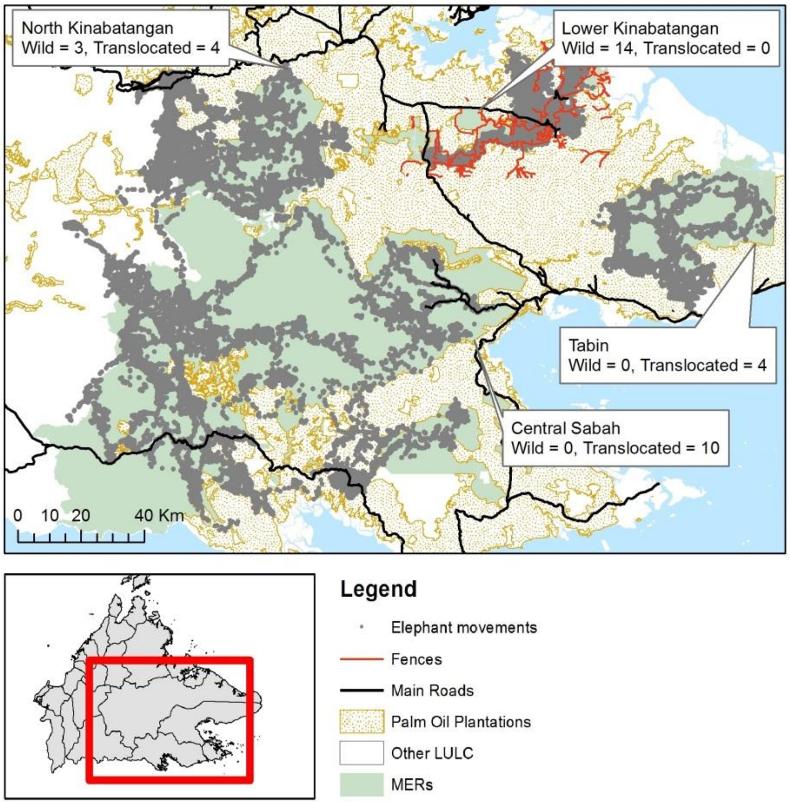


Figure 6- Number of wild and translocated elephants and their movements within and between the MERs with location of main roads and electric fences (only available for the Lower Kinabatangan MER).

ELEPHANT MOVEMENT LINKED TO LANDSCAPE FEATURES. Linking elephant movement to underlying landscape features is key to identify factors motivating and shaping elephant spatial behavior. In each MER, we investigated, using generalized linear models, the impact of different landscape features likely to shape elephant movement:

- ✓ **Elevation** and **slope** impose considerable **energetic costs** on travel (*e.g.*, Wall *et al.*, 2006) and induced significantly- slower movement in all MERs. These factors are likely to **restrict elephant** propensity to use most part of the **Central Sabah and Ulu Kalumpang** MERs (Figure 7).

- ✓ Land cover categories "**palm oil**" induced significantly-**slower movement** in the **super MER** while "plantation" led to more rapid movement. In the **Lower Kinabatangan**, the "**palm oil**" seems to lead to significantly **more rapid movement** and "**cleared forest**" to **slower movement**. This illustrates the fact that human agricultural activities (palm oil, plantation…) as an habitat can induce a **dual response** of the elephants, most likely linked to nearby human disturbances, especially villages, fences, persecution and poaching activities.

> *We considered North Kinabatangan, Central Sabah and Ulu Kalumpang ranges as one super MER in the generalized linear models given their apparent connection.*

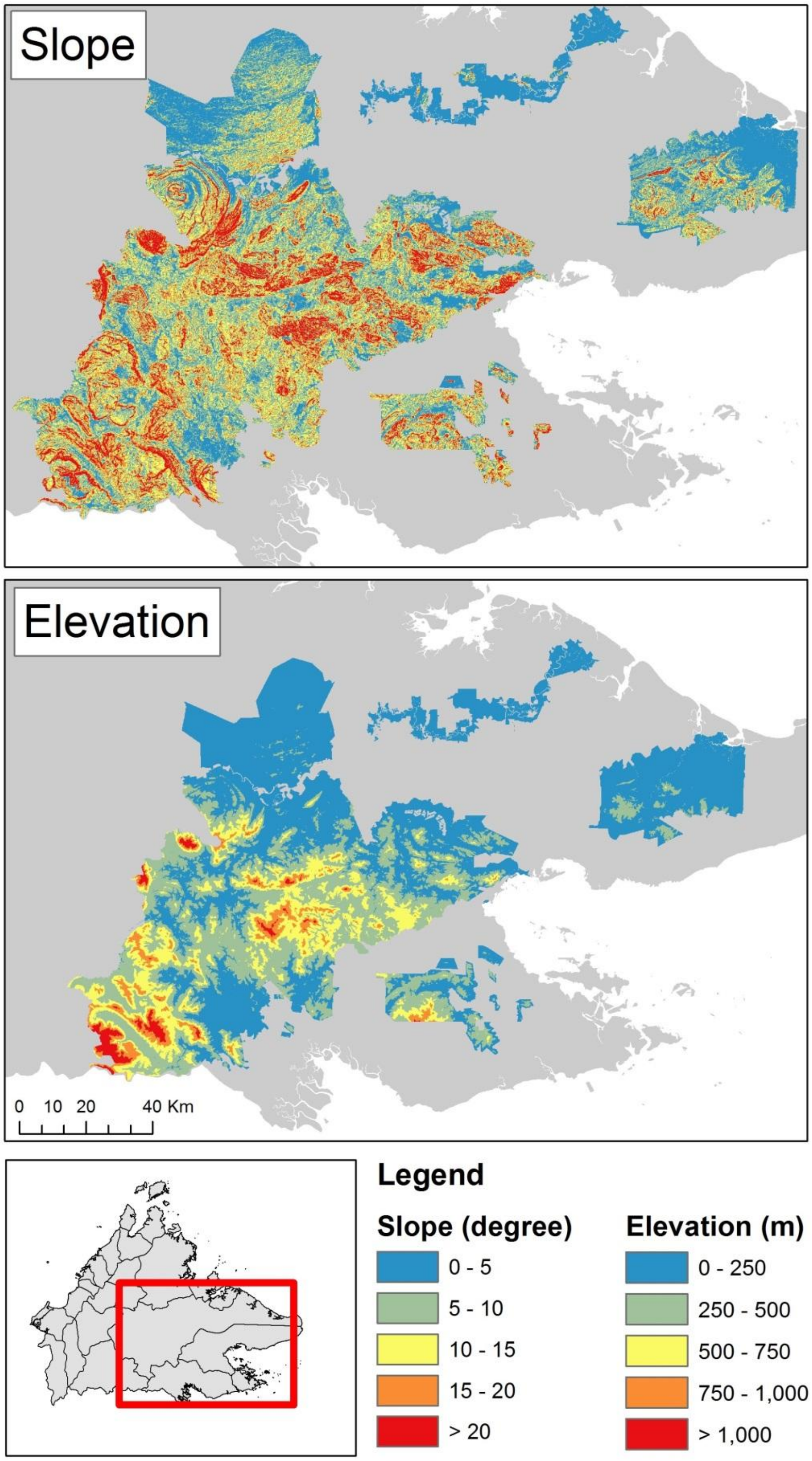
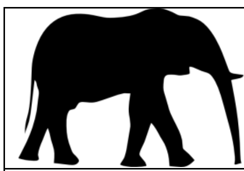


Figure 7- Elevation and slope characterizing the MERs.

ELEPHANT MOVEMENT LINKED TO HUMAN DISTURBANCES. Understanding the way elephants persist in human-dominated landscapes is critical for their conservation, both to preserve elephant populations by managing movement and to avoid human-wildlife conflicts. **Human disturbance** was also illustrated previously with the land cover parameter. Here we focused on human-built disturbances that are likely to impact movements by inducing further **fragmentation** in the habitat and acting either as a **movement constraint or as a facilitator**. We studied at a broad scale, human impact on elephant movement using **roads (main and gravel) and villages**. Results are summarized in Table 1. Main roads systematically induced a significant behavioural change with elephant adopting **higher velocity close to the main roads** while gravel roads had the opposite effect in all MERs. In Sabah, given the road traffic and induced noise, it is not surprising that we found a negative association with main roads. However, in the MERs, elephants appear to seek out **secondary/gravel roads** with significant less traffic, either for **ease of travel** and because they are attracted to **secondary growth**.

Table 1 Summary of elephant behavior in response to human disturbances: palm oil plantations, gravel and main roads, villages and fences (for Lower Kinabatangan only).

	Low movement closer to	Rapid Movement closer to
Lower Kinabatangan		
Super MER		
Tabin Reserve		

Fragmentation has a major impact on elephants including mortality, behavioral changes, reduced dispersal capacity, impediment to gene flow… We based the fragmentation classes of Figure 8 on the Alfred et al. (2012) study. We also used the landscape metrics "**effective mesh size**" which is the average size of an area that an elephant will be able to access without crossing barriers: $m_{eff}(j) = \frac{1}{A_{ij}} \sum_{i=1}^{n} A_{ij}^2$ where n is the number of unfragmented patches in unit j, A_{ij} the size of patch *i* and A_{ij} the total area of unit j**. Rivers, major roads and palm oil plantations** were the barrier elements used to fragment the landscape in patches within each MER. ArcGIS tools were then used to calculate the area A_{ij} of each patch.

Lower Kinabatangan displays the **highest degree of fragmentation** with the size of unfragmented habitat being no bigger than **67 km^2 (Figure 8)**. Remember that elephant **home range** was estimated between **250 and 400 km^2** in an unfragmented landscape!

ELEPHANT MOVEMENT IN THE LOWER KINABATANGAN. The analysis showed that elephant movement significantly differs between the MERs but the Lower Kinabatangan MER case was striking. **Elephants moved significantly at a greater pace in Lower Kinabatangan** than in any other MERs. This higher movement rate in Lower Kinabatangan could be:

- ✓ linked to **restricted food availability** forcing elephant to move more to feed,
- ✓ linked to **habitat fragmentation**: the Lower Kinabatangan exhibits the highest level of fragmentation (Figure 8) and Alfred et al. (2012) showed that the home range is bigger in fragmented landscape (600km^2 as opposed to 250-400km^2 in an unfragmented habitat),
- ✓ **stressed-induced** by human presence (Douglas-Hamilton *et al*., 2005): villages are on average not more than 4,5 km away from the elephants (as compared to 12-22 km in other MERs).

So not surprisingly, models showed that elephants travel at a significantly-**greater speed** when **closer to the fences and human settlements** in the Lower Kinabatangan MER.

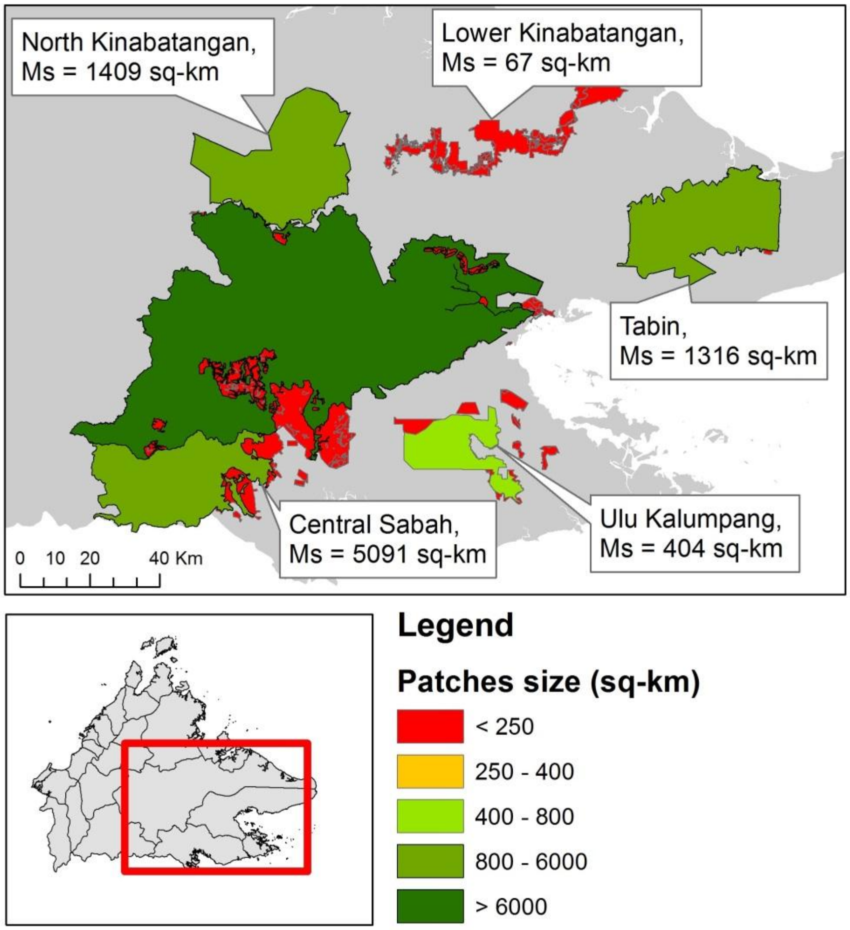


Figure 8- Fragmentation level in the MERs and value of the effective mesh size “Ms”.

ELEPHANT MOVEMENT LINKED TO SEASON. Distribution and elephant movement are also likely shaped by meteorological and food-productivity factors. In other studies, elephants have been shown to aggregate in wetlands bordering rivers for high-quality browse (Blake, 2002) in low-productivity seasons. We observed similar patterns in the MERs, especially in the floodplain of the Lower Kinabatangan MER with elephants **concentrated along the river** during the **dry season** and moving away from the river and settling **in palm oil plantations** with significantly-slower movements during the **wet season** (Figure 9). Flooding reduces the area available to elephants and forces them to move to reach non-flooded area, where they can find food and security. As the palm-oil plantations are preferably set up on areas less vulnerable to flooding and fenced, there is little space along the river for the animals to reach a safer place during the wet season (Estes *et al.*, 2012). However, data on primary productivity and further analyses are required to explain the differential habitat utilization highlighted in Figures 9, 10, 11.

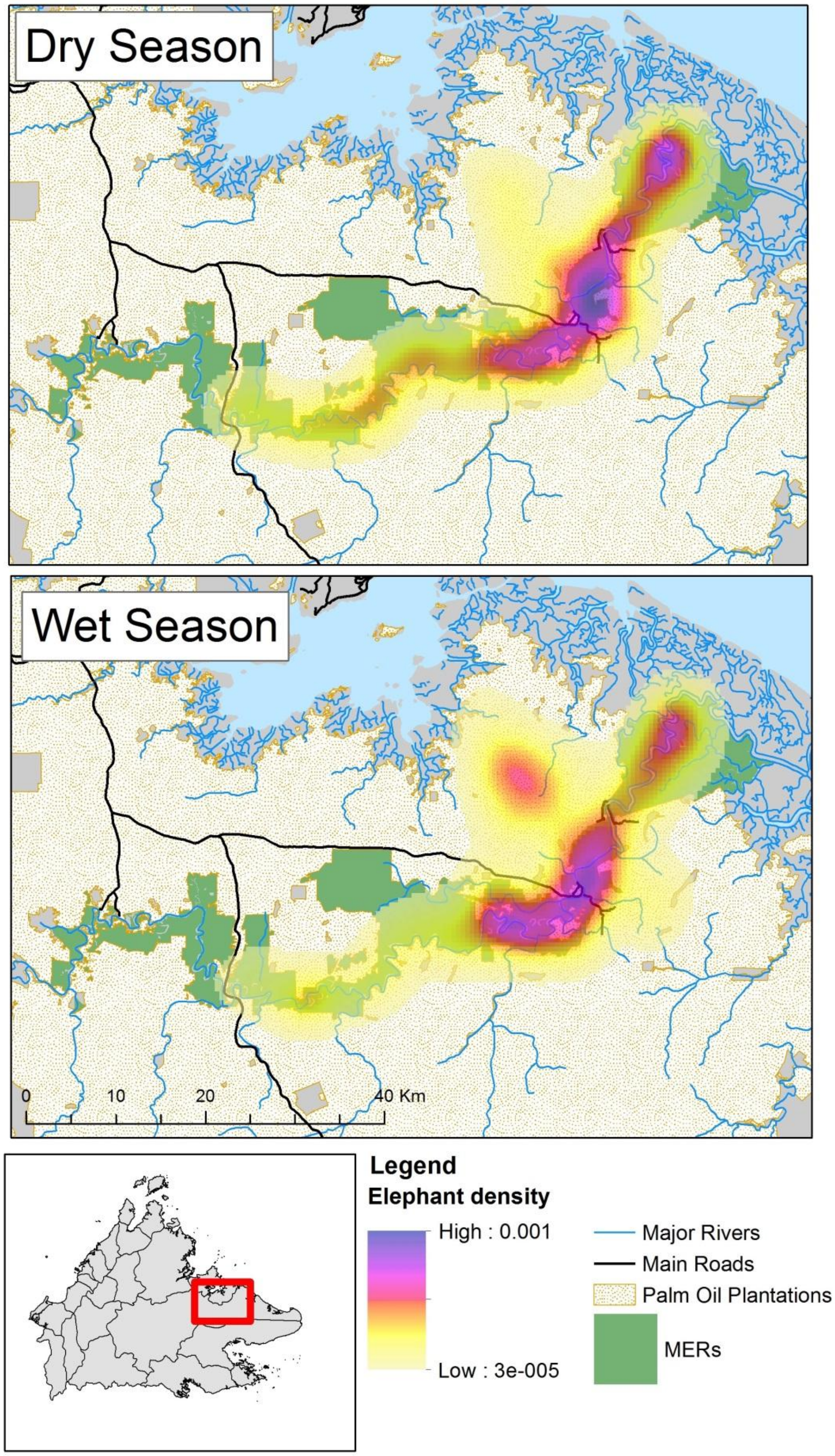


Figure 9- Seasonal habitat utilization by elephants collared in the Lower Kinabatangan MER.

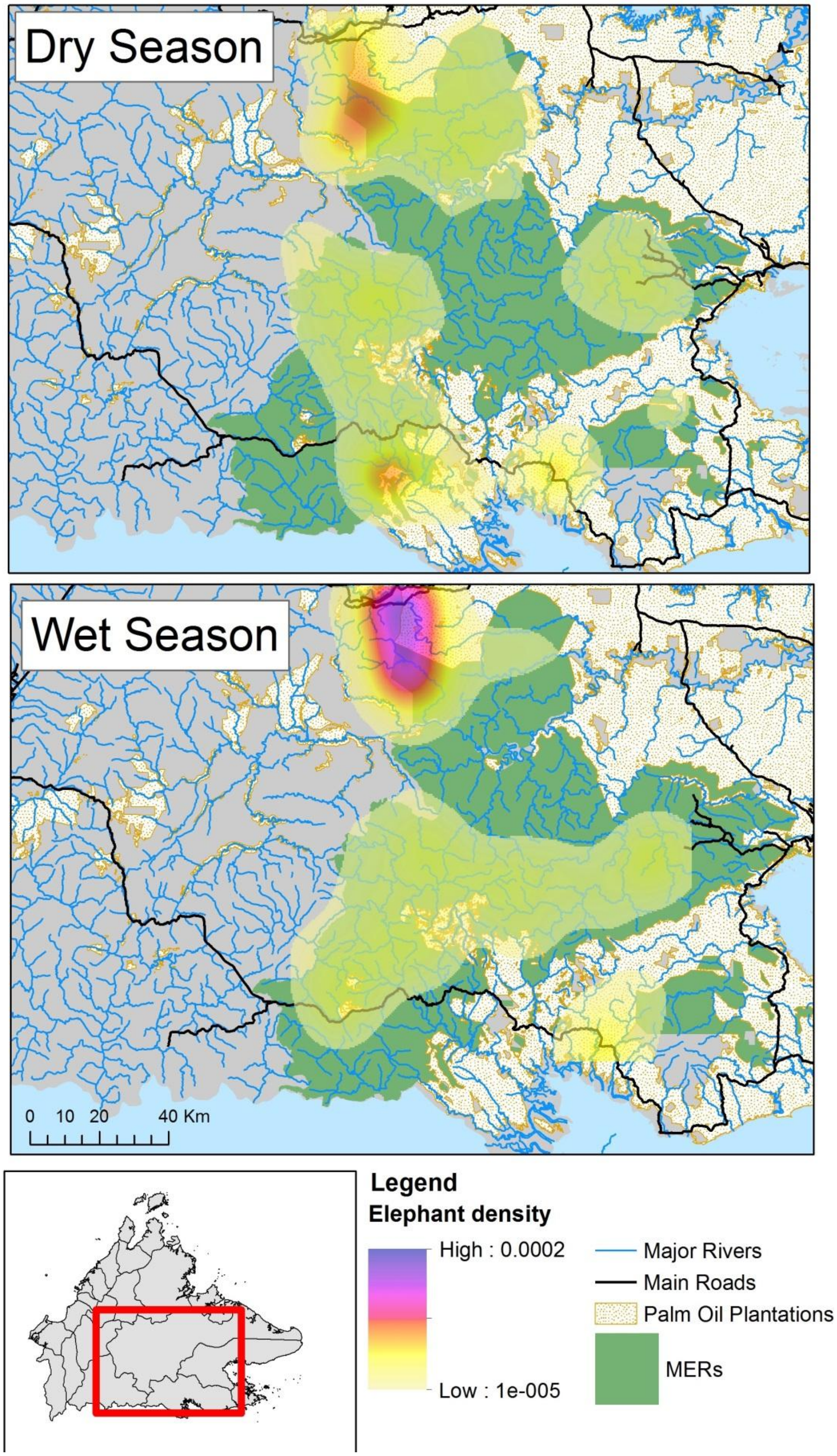


Figure 10- Seasonal habitat utilization by elephants collared in the super MER.

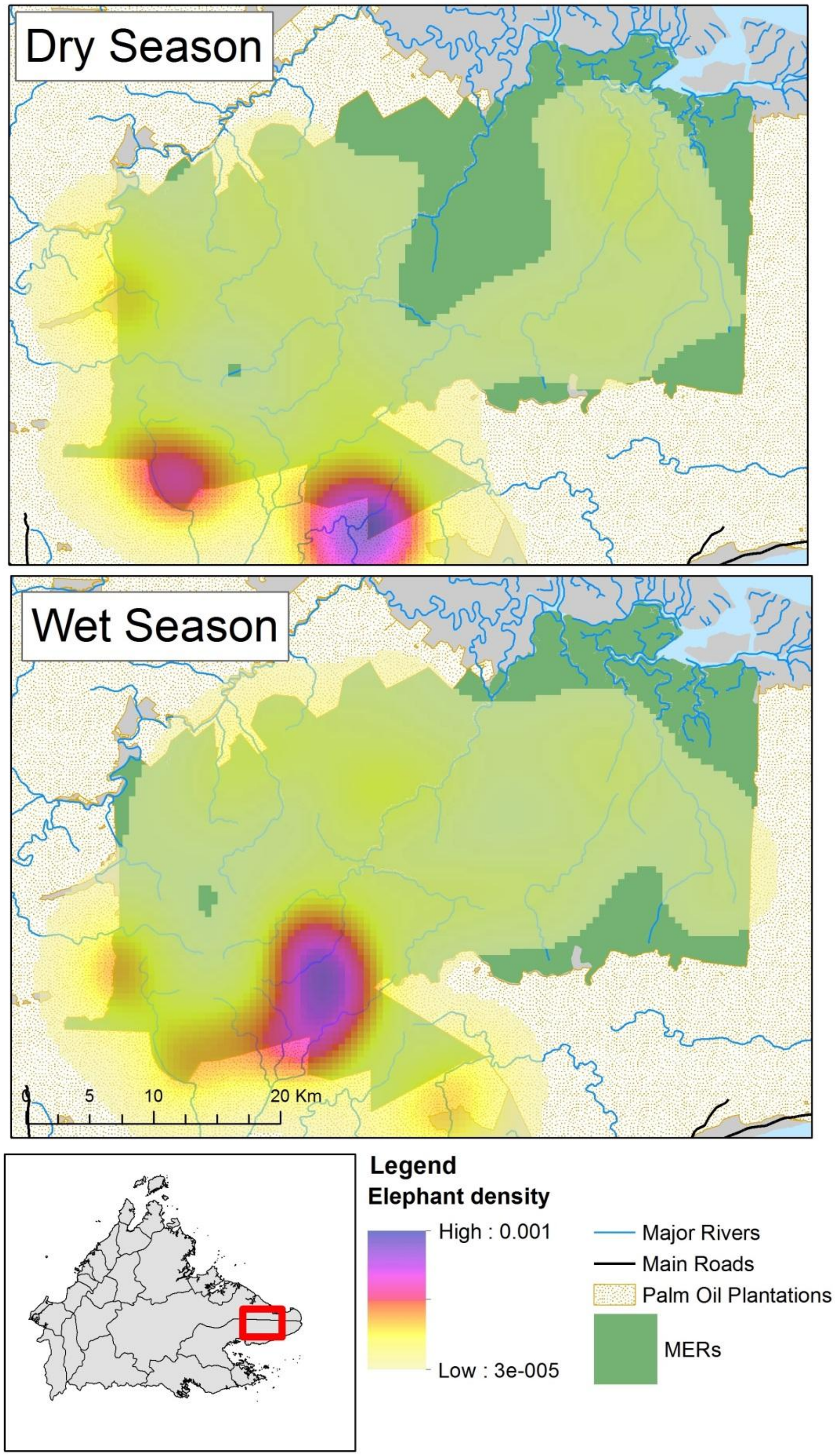


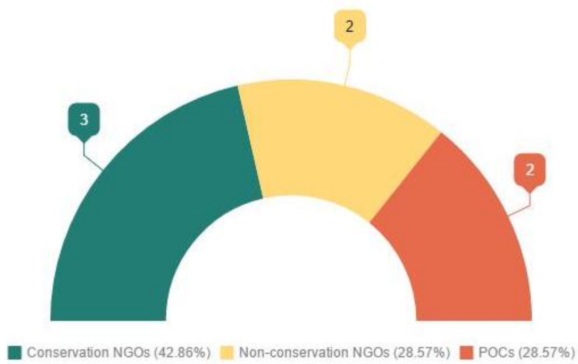
Figure 11- Seasonal habitat utilization by elephants collared in the Tabin Reserve MER.

SURVEYS. Open ended surveys were conducted to:

1- **Understand perceptions** and attitudes towards elephants;
2- **Evaluate the knowledge** on elephant behavior and HEC causes;
3- **Assess the expectations** of stakeholders from a management plan.

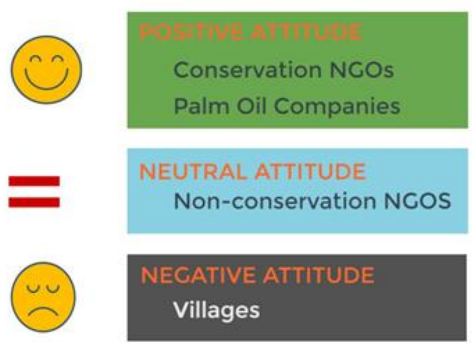
Respondent profile. The questionnaire targeted three groups:

1- **NGOs**: **three wildlife conservation** NGO representatives were surveyed; and **two NGOs (non conservation) focusing on promoting sustainable palm oil production,**
2- **Palm oil companies** (**POCs**): **two** representatives were surveyed,
3- **Villagers** were not interviewed directly; however some of their attitudes and perceptions were reported by representatives of conservation NGOs.



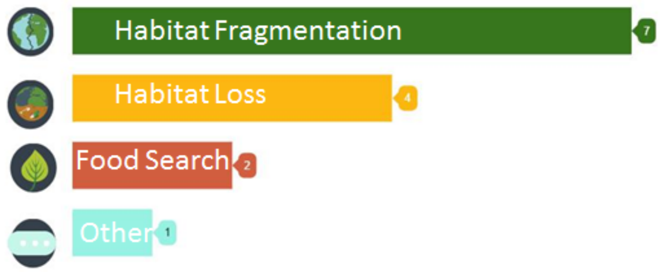
Results. Questions covered different areas in relation to **attitude and experience towards elephants** as well as **costs and benefits** of having elephants and **knowledge and anticipated management measures** to prevent HECs (Appendix 2).

Attitude- Do you see the elephants as a problem or as a resource?

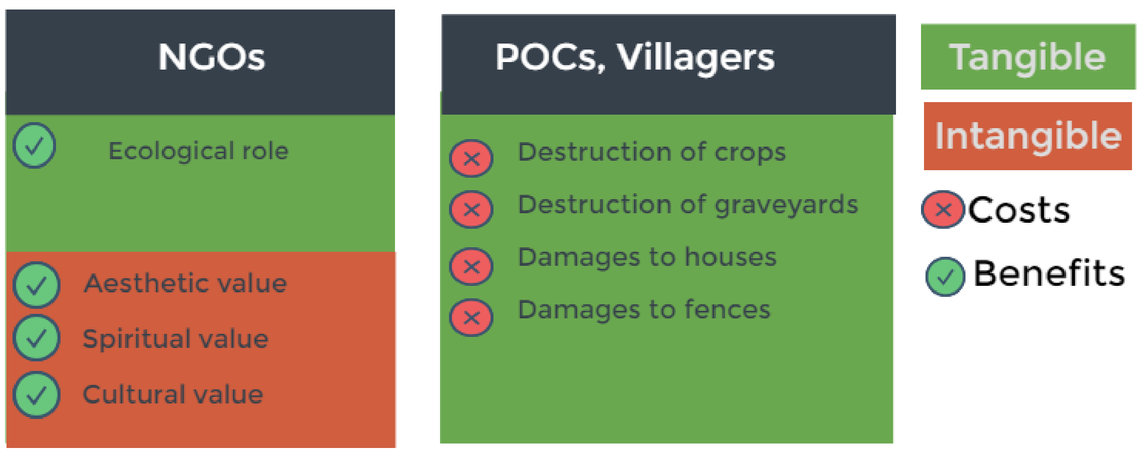


Experience- Have you ever had to deal with elephants?

Knowledge- What do you think is the root cause for problems with elephants?



Benefits & Costs- Have you ever benefited in any way or experienced any damages from elephants?



Management Measures- What measures do you think should be included in a management plan?

IN SHORT-

1. **Critical situation of the Lower Kinabatangan MER-** signs of **stress** displayed by elephants, the highest density of elephants, the smallest area, its complete **isolation**, the **highest degree of fragmentation** with the size of unfragmented habitat being no bigger than **67 km^2** (Figure 8). Remember that elephant **home range** was estimated between **250 and 400 km^2** in an unfragmented landscape!

2. **Slope and elevation-** likely to restrict elephant propensity to use most part of the Central Sabah and Ulu Kalumpang MERs.

3. **Human disturbances-** Fences, villages and main roads **cause elephant to increase their velocity** (change their behavior) except gravel roads that appear to have the opposite effect.

4. **Rainy season- decreases further the available habitat** available for elephants, especially in the Lower Kinabatangan MER.

5. **Perception**- Elephants are not believed to provide monetary benefits according to major NGOs and palm oil companies.

RECOMMANDATIONS AND NEXT STEP

CONNECTIVITY FRAMEWORK- Re-connecting or keeping connected heterogeneous landscapes should be a priority for elephant conservation in Sabah. After these overall analyses on elephant broad movements, we have identified some spatial and external constraints (S and E, Figure 12) to elephant movement. For example, we have established that main roads are a constraint but that gravel roads do not seem to be. We now need data and analyses at a finer scale to understand and identify all the limiting factors for successful elephant movements. Building a **SEI framework would be an asset** for conservation, management and decision-making because **fully accounting for dispersal abilities of elephants will define the effectiveness of corridors** facilitating connectivity between habitat fragments (Vasudev *et al.* 2015). We need to intersect **three types of constraints** for an effective SEI framework (Figure 12):

1- **Spatial** constraints (**S**) corresponding to the locations of landscape elements limiting movement, *e.g.*, main roads, fences. We identified that to follow up on spatial constraints, we need more data in particular on main and secondary roads and electric fences.

2- **External** environmental factors (**E**) corresponding for example, to climatic factors and terrain (here we have established that the rainy season, slope and elevation can be a limiting factor for movement) but also to biotic factors such as resources and vegetation structure. We would need additional data on vegetation and productivity.

3- **Intrinsic** constraints (**I**) corresponding to the movement mode pertaining to traits of individual dispersers. For example, we know that females with calves will be less likely to use narrow corridors along the Kinabatangan River, especially during the rainy season, while single males might use these paths, *e.g.*, dispersal trap for some categories. This would require more observations on the ground (*e.g.*, camera traps or field surveys) and improving the data form used during capture and collaring.

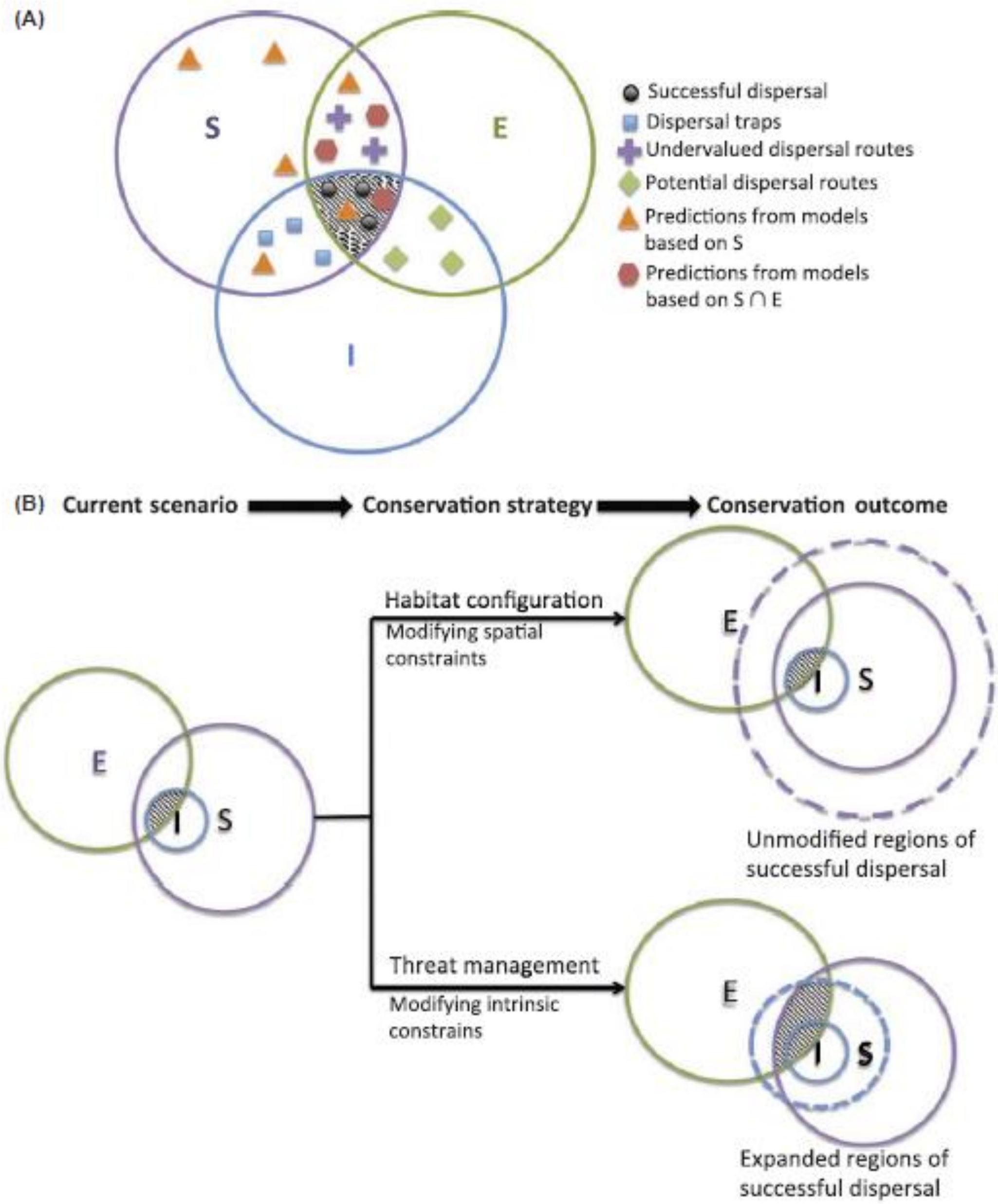


Figure 12- (A) Spatial-Environmental-Intrinsic (SEI) framework to facilitate the identification of constraints limiting successful dispersal (diagonally shaded).We illustrate that dispersal models based on spatial constraints may over-predict regions of successful dispersal. (B) Results of conservation actions are represented as dashed circles: conservation actions focusing on the most limiting factor (I) may result in facilitating dispersal while those focusing on non-limiting factors (e.g., S) may not facilitate dispersal (Vasudev *et al.* 2015)

LOCAL STAKEHOLDERS- It is well understood and accepted that conservation and management measures can only work if supported by local stakeholders. This study showed that **NGOs are willing to support management measures** that insure better co-existence of people and elephants. **Palm Oil Companies** that are seeking 'sustainability' labels are willing to **support management measures** and provide part of their lands to create connectivity corridors. NGOs reported that **most villagers still see elephants as pests** that destroy their crops further affecting their frail economy.

HEC AND PERCEPTION- HECs are on the rise in Sabah due to habitat fragmentation, human population growth, and reduced habitat availability. While some measures to reduce HEC occurrence have been implemented (*e.g.*, use of electric fences and elephant translocations), a more effective strategy is lacking. This study revealed that there is no system in place allowing for standardized collection and reporting of HECs occurrence. Opportunistic data are collected by the Sabah Wildlife Department, however most HECs are unreported. The basic understanding of when, where, how and why a conflict occurs is a fundamental requirement for the implementation of successful mitigation strategies. Another requirement for effective HECs management strategies is the identification of shared objectives between wildlife conservation organizations and local livelihoods and the implementation of monitoring strategies to measure the success of conflict reduction actions.

In this study, we focused on the perceptions and attitudes that major stakeholders have towards elephant conservation and while the need for an effective HEC management strategy was generally acknowledged by all interviewees, it became apparent that elephants are mostly seen as a source of problems and never as a source of monetary benefits. Nevertheless, examples of successful ecotourism initiatives benefiting both the community and conservation exist in Sabah but are still scarce. Reproducibility of successful ecotourism projects should be assessed and people's willingness, attitude and adaptability to alternative economic activities that would promote conservation of elephants should be evaluated.

> *Promoting coexistence between people and elephants to achieve a balance between economic development and biodiversity protection will require a whole-landscape approach to land-use planning through pro-active and innovative measures.*

CAPACITY BUILDING AND OUTREACH- Recognizing the current paucity of local trained scientists and of in-depth analyses of available data about elephant ecology in changing landscapes which impair the development of appropriate management strategies at the landscape level to support elephant conservation, this project identified the need of building capacity of local scientists in order to facilitate on the ground decision-making processes. Furthermore, this study pointed out that elephants are usually associated with negative reputation and are seen mostly as pests. On-the-ground-awareness initiatives are needed in order to provide villagers in particular, with important information on the role that elephants play to maintain a balanced ecosystem and the potential role they can play in the local economy.

MANAGEMENT PRIORITIES

- ✓ **The Lower Kinabatangan MER** needs **urgent management measures** aimed at increasing the area available for elephants during both the wet and dry seasons. The Lower Kinabatangan is completely isolated from the other MERs and the already limited available area for elephants is further reduced during flooding events. The Lower Kinabatangan is further at risk due to the plan of building a bridge in the Sukau area that will further shrink the range available for elephants, likely increasing the incidence of human-elephant conflicts. The elephants are showing signs of stress (higher pace and higher movement rate compared to other MERs) related to human disturbance within the MER (electric fences, main roads, villages), the high degree of fragmentation and the high elephant density (the highest in all MERs).

- ✓ A need to **re-think** how **connectivity** corridors and reserves for elephants are designed:

    - Managers currently use methods that tend to **overestimate the size of suitable habitats** for elephants by not accounting for functional connectivity (*e.g.*, by including patches that might be suitable but are unreachable, hence are unavailable to elephants because of environmental or intrinsic constraints not taken into account) and fragmentation (Figure 12). In-depth analyses of the degree of habitat fragmentation need to be conducted to evaluate the need for **connectivity within and between the MERs**.

- ✓ **Involving stakeholders** in identifying effective management measures:

    - Understanding villagers' perceptions and attitudes towards elephants and their conservation are a priority in order to implement effective management measures.

    - Working with Palm Oil Companies to identify suitable corridors is a priority in order to establish effective functional connectivity all year round.

B-CONNECTED PHASE II

Developing and validating a connectivity framework to predict elephant movements in a changing landscape:

- ✓ In order to achieve this goal, **more spatial data** are needed to allow for **fine-scale movement** analyses per each collared elephants. Data such as fences location, road location and type, changes in vegetation/land use, and productivity are necessary in order to identify dispersal constraints. If most of the needed spatial data are available and free online, some might be missing (*e.g.*, location of fences) and could need to be collected on the ground.

Compiling HEC data in a database and implementing an online reporting system in order to assess occurrence, causes and damages:

- ✓ At present there is no system in place to collect and report on HECs occurrences. It is therefore necessary to work with all stakeholders to implement a system that allows for collection and sharing of **where, when and how HECs occur**. This system will provide a more comprehensive database to better understand the root causes of HECs.

Conducting surveys with local villagers to understand their **perception and attitudes towards elephants** but also to identify aspirations and potential alternative livelihood opportunities:

- ✓ A better understanding of people's views on elephants and HECs and a deeper knowledge of their aspirations will permit the identification of alternative livelihood opportunities for local villagers.

Developing a tool- kit and guidelines for managers and stakeholders for **better decision-making** in securing corridors, including:

- ✓ An analytic mapping toolkit to secure landscape connectivity and to manage essential movement corridors for improved decision-making on land-use planning;

- ✓ A set of guidelines and recommendations for managers and stakeholders on landscape management and prevention of HEC.

Promoting and supporting capacity building on the ground through intensive programs for young scientists and conservationists in Sabah, including:

- ✓ Training programs on movement ecology and landscape connectivity, including advanced spatial and statistical analysis.

BIBLIOGRAPHY

Alfred, R., Ahmad, A.H., Payne, J., Williams, C. & Ambu, L. (2010) Density and Population Estimation of the Bornean Elephants (*Elephas maximus borneensis*) in Sabah. *OnLine Journal of Biological Sciences,* 10, 92-102.

Alfred, R., Ambu, L., Nathan, S.K.S.S. & Goossens, B. (2011) Current Status of Asian Elephants in Borneo. *Gajah,* 35, 29-35.

Alfred, R., Ahmad, A.H., Payne, J., Williams, C., Ambu, L.N., How, P.M. & Goossens, B. (2012) Home range and ranging behaviour of Bornean elephant (*Elephas maximus borneensis*) females. *PLoS One,* 7, e31400.

Abram, N.K., Xofis, P., Tzanopoulos, J., MacMillan, D.C., Ancrenaz, M., Chung, R., Peter, L., Ong, R., Lackman, I., Goossens, B., Ambu, L. & Knight, A.T. (2014) Synergies for improving oil palm production and forest conservation in floodplain landscapes. *PLoS One,* 9, e95388.

Ambu, L., Andua, P.M., Nathan, S., Tuuga, A., Jensen, S.M., Cox, R., Alfred, R. & Payne, J. (2012) Asian Elephant Action Plan Sabah (Malaysia).

Ball, T.M. and Goldingay, R.L. (2008) Can wooden poles be used to reconnect habitat for a gliding mammal? *Landscape and Urban Planning* 87: 140-146.

Blake, S. (2002) The Ecology of Forest Elephant Distribution and Its Implications for Conservation. PhD, University of Edinburgh.

Calabrese, J. M. and Fagan, W. F. (2004) A comparison-shopper's guide to connectivity metrics. *Frontiers in Ecology and the Environment* 2: 529-536.

Clobert, J. et al. (2012) Dispersal Ecology and Evolution. Oxford University Press, Oxford, UK.

Douglas-Hamilton, I., Krink, T. & Vollrath, F. (2005) Movements and corridors of African elephants in relation to protected areas. *Naturwissenschaften,* 92, 158-163.

Estes, J.G., Othman, N., Ismail, S., Ancrenaz, M., Goossens, B., Ambu, L.N., Estes, A.B. & Palmiotto, P.A. (2012) Quantity and configuration of available elephant habitat and related conservation concerns in the Lower Kinabatangan floodplain of Sabah, Malaysia. *PLoS One,* 7, e44601.

Fletcher, R.J. (2006) Emergent properties of conspecific attraction in fragmented landscapes. *American Naturalist* 168: 207-219.

Goossens, B. et al. (2016) Habitat fragmentation and genetic diversity in natural populations of the Bornean elephant: implications for conservation. *Biological Conservation* 196: 80-92.

Hudgens, B.R. et al. (2012) How complex do models need to be to predict dispersal of threatened species through matrix habitats? *Ecological Applications* 22: 1701-1710.

McIntire, E.J.B. et al. (2007) Designing a network for butterfly habitat restoration: where individuals, populations and landscapes interact. *Journal of Applied Ecology* 44: 725-736.

Pimm, S. L. and Raven P. (2000) Biodiversity: extinction by numbers". *Nature* 403(6772): 843-845.

Runting, R.K., Meijaard, E., Abram, N.K., Wells, J.A., Gaveau, D.L., Ancrenaz, M., Posssingham, H.P., Wich, S.A., Ardiansyah, F., Gumal, M.T., Ambu, L.N. & Wilson, K.A. (2015) Alternative futures for Borneo show the value of integrating economic and conservation targets across borders. *Nat Commun,* 6, 6819.

Santiappillai, C. & Jackson, P. (1990) The Asian Elephant, An Action Plan for its Conservation.

Sawyer, S.C., Epps, C.W. & Brashares, J.S. (2011) Placing linkages among fragmented habitats: do least-cost models reflect how animals use landscapes? *Journal of Applied Ecology,* 48, 668-678.

Singh, M. and Kumar, M. A. (2014) Our backyard wildlife: challenges in coexisting with uneasy neighbours. *Current Science* 106:1463-1464.

Treves, A., Wallace, R. B., Naughton-Treves, L., & Morales, A. (2006) Co-managing human–wildlife conflicts: a review. *Human Dimensions of Wildlife*, *11*(6), 383-396.

Vasudev, D. & Fletcher, R.J. (2015a) Incorporating movement behavior into conservation prioritization in fragmented landscapes: An example of western hoolock gibbons in Garo Hills, India. *Biological Conservation,* 181, 124-132.

Vasudev, D., Fletcher, R.J., Goswami, V.R. & Krishnadas, M. (2015b) From dispersal constraints to landscape connectivity: lessons from species distribution modeling. *Ecography,* 38, 967-978.

Wall, J., Douglas-Hamilton, I. & Vollrath, F. (2006) Elephants avoid costly mountaineering. *Current Biology,* 16.

Zeller, K.A., McGarigal, K. & Whiteley, A.R. (2012) Estimating landscape resistance to movement: a review. *Landscape Ecology,* 27, 777-797.

APPENDIX 1- SUMMARY OF THE SATELLITE TRACKING DATA

Summary of the satellite tracking data as elephant mean daily distance ("Distance" in meter/day) and mean daily speed ("Speed" in km/hour) and associated 95% confidence interval (CI) limits (CIL: lower/CIU: upper); MER: NK = North Kinabatangan, LK = Lower Kinabatangan, CS = Central Sabah, Ta = Tabin Reserve; eleType = elephant type as either wild or translocated ("Trans").

Elephant	tracking days	Distance	CIL	CIU	Speed	CIL	CIU	MER	eleType	sex
Abaw	503	**1385.5**	1293.1	1477.9	**0.06**	0.06	0.07	NK	wild	female
Aqeela	907	**3757.2**	3604.5	3909.9	**0.16**	0.16	0.17	LK	wild	female
Benina	125	**2475.5**	2035.7	2915.3	**0.08**	0.06	0.09	LK	wild	female
Bikang 1	175	**1587.3**	1373.1	1801.6	**0.07**	0.06	0.08	Ta	Trans	female
Bikang 2	142	**2087.0**	1757.2	2416.7	**0.09**	0.08	0.11	Ta	Trans	female
Bodtai	130	**2713.4**	2229.9	3197.0	**0.07**	0.06	0.09	LK	wild	female
Daisom	44	**5067.2**	3948.0	6186.4	**0.22**	0.16	0.29	CS	Trans	male
Dara	574	**2262.7**	2086.6	2438.8	**0.10**	0.09	0.11	CS	Trans	female
Gading	315	**3075.8**	2699.4	3452.2	**0.12**	0.11	0.13	LK	wild	male
Guli	469	**4774.3**	4512.6	5035.9	**0.20**	0.19	0.22	NK	Trans	male
Ij	14	**6255.7**	5355.4	7156.0	**0.25**	0.16	0.34	NK	Trans	female
Ita	414	**3499.9**	3265.2	3734.6	**0.15**	0.14	0.17	LK	wild	male
Jasmine	164	**3515.5**	3197.9	3833.0	**0.14**	0.12	0.15	LK	wild	female
Jasper	515	**3233.1**	3021.2	3445.0	**0.14**	0.13	0.15	CS	Trans	male
Jati	78	**4209.6**	3680.7	4738.5	**0.19**	0.16	0.22	CS	Trans	male
Kasih	817	**3784.4**	3641.3	3927.5	**0.16**	0.15	0.17	LK	wild	female
Koyah	86	**4505.4**	3892.6	5118.2	**0.19**	0.16	0.22	LK	wild	female
Kuma	71	**4336.3**	3753.0	4919.5	**0.19**	0.16	0.21	CS	Trans	female
Liningkung	169	**2062.8**	1720.2	2405.4	**0.09**	0.08	0.11	CS	Trans	female
Liun	698	**3467.5**	3239.7	3695.3	**0.16**	0.15	0.17	LK	wild	female
Maliau	449	**4584.4**	3953.8	5215.0	**0.19**	0.17	0.20	NK	wild	female
Merotai	528	**4968.1**	4700.3	5235.9	**0.21**	0.20	0.23	CS	Trans	male
Perdana	444	**2860.0**	2261.3	3458.8	**0.11**	0.10	0.12	NK	Trans	male
Puteri	1224	**4016.5**	3877.7	4155.4	**0.17**	0.16	0.18	LK	wild	female
Putut	260	**3142.6**	2831.8	3453.5	**0.13**	0.12	0.15	LK	wild	female
Sandi	787	**3890.1**	3748.7	4031.5	**0.17**	0.16	0.17	LK	wild	female
Sejati	147	**6184.3**	5743.3	6625.2	**0.27**	0.25	0.29	LK	wild	male
Seri	328	**3190.4**	2942.0	3438.8	**0.13**	0.12	0.15	Ta	Trans	male
Tambisan	304	**4677.0**	4342.4	5011.5	**0.21**	0.19	0.23	Ta	Trans	male
Tangki	128	**1982.2**	1664.2	2300.3	**0.09**	0.08	0.11	CS	Trans	female
Tuah	47	**2454.6**	1920.8	2988.3	**0.11**	0.08	0.14	LK	wild	male
Tulid	896	**4181.0**	3990.7	4371.3	**0.18**	0.17	0.19	NK	wild	female
Tunglap	707	**2928.7**	2732.1	3125.2	**0.13**	0.12	0.13	NK	Trans	female
Umas	252	**4686.8**	4248.5	5125.1	**0.20**	0.18	0.22	CS	Trans	male
WinWin	922	**2410.3**	2293.3	2527.4	**0.10**	0.10	0.11	CS	Trans	female

APPENDIX 2- DEFINITION OF VARIABLES ADDRESSED DURING THE SURVEYS

Variable	Definition	Categories
Experience	The extent to which a person or a stakeholder group is exposed and interacts with elephants.	Experience can be: ○ Positive ○ Negative ○ *Nil*
Knowledge	The information a person or a group has about elephant behaviour that could cause HECs.	Knowledge can be about feeding behaviour, movements and migrations, habitat use.
Attitude	The disposition of a person or a stakeholder group to regard the elephants favourably, unfavourably or with indifference.	Attitude can be: ○ Positive ○ Negative ○ Neutral
Benefits	The perception of receiving positive outcomes from elephants.	Benefits can be: ○ Tangible, usually when there is a monetary gain directly (i.e., wildlife tourism) or indirectly (i.e., compensatory scheme) ○ Intangible, including aesthetic, cultural and spiritual values
Costs	The perception of receiving negative outcomes from elephants.	Costs can be: ○ Tangible, usually when there is a monetary loss as a consequence of HEC ○ Intangible, usually the indirect perceived costs related to the danger, fear and risk that elephants represent
Management measures	The methods used or needed to prevent HECs.	We identified the following categories: ○ Obstacles to MM ○ Form/content of MM ○ Enforcement and legal institutions