

Mapping the current and past distribution of Asian elephants (*Elephas maximus*) and human-elephant-conflict (HEC) in human-occupied-landscapes of Peninsular Malaysia.

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Statement of originality.

I hereby declare that all work within this dissertation is entirely my own and am aware of the University's policy on plagiarism.

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Abstract

Conservation planning of Asian elephants (*Elephas maximus*) requires the understanding of their basic spatial distribution and habitat associations to monitor changes in elephants' range, which can be used as a proxy for population trends. Elephants in Peninsular Malaysia persist in fragmented landscapes having been extirpated from most of their former geographical ranges due to habitat loss and fragmentation. The current distribution and factors driving distribution patterns of elephants in Peninsular Malaysia are poorly studied and not accurately known. Therefore, this study aims to (1) map the current and past distribution of wild elephants and human-elephant-conflict (HEC) in human-occupied-landscapes of Peninsular Malaysia using a relatively fast and cost-effective approach; (2) understand the temporal changes of elephant and HEC distribution in the past 40 years; and (3) identify what ecological factors influence elephant distribution and habitat use. This study is the first to produce a distribution map of elephants and HEC in Peninsular Malaysia focusing in human-occupied landscapes using systematic semi-structured interview surveys. The study area was the human-occupied-landscapes in Peninsular Malaysia. The structured questionnaires were haphazardly administered to residents via face-to-face interview over a 5x5 km cell grid to gather baseline quantitative information on the distribution of elephants, HEC and temporal changes in both. The survey yielded a total of 5,585 interviews or 2,230 grids encompassing an area of approximately ca. 55,750 km². Elephants were detected in only 12.9% (289 grids) out of the total grids surveyed. Up to 40 years ago, elephants were still detected in 616 grids, having lost 68% of their detected range. HEC was reported in 68.5% (198 grids) of all the grids with elephant detection and crop damage was the most common form of HEC. The occupancy model showed that the main determinant of elephant's area of use is proportion of forest cover within 225 km² indicating elephant's occurrence and HEC incidences are spatial phenomena and occur on entire landscapes. The human density factor was also an important determinant of elephant's area of use. Elephants could tolerate areas with low human density but avoid these after a threshold was achieved. Contrastingly, elephants in Peninsular Malaysia do not seem to thrive outside forests and protected areas stressing the need to retain large contiguous forest

blocks and protected areas in addition to improving connectivity to facilitate elephants' movement in human-occupied-landscapes. Additionally, HEC mitigation efforts such as erecting electric fences should be in place for areas with high HEC incidence to reduce impacts and loss caused by HEC. Finally, the use of questionnaire surveys has proven to be a relatively fast and effective way to obtain information about elephant and HEC presence and this study could be repeated after five or ten years to monitor changes in distribution of elephants and HEC.

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1. Introduction

The Asian elephant (*Elephas maximus*) is an animal revered by many around the world (Gupta 1983, Sukumar 1992, Fernando et al. 2011). In India and many parts of the world, a deity known as Lord Ganesha with an elephant head is worshipped (Choudhury 2004). Elephants are also used in important celebrations (perahera) in Sri Lanka and are a symbol of royalty in Thailand (Sanford 1991). Beyond their cultural and symbolism roles, elephants play many important ecological roles (Campos-Arceiz and Blake 2011). Being the largest terrestrial animal, they are essentially the mega-gardeners of the forest as well as a keystone species (Shoshani 1993). Elephants are important seed dispersers, moving seeds of a wide range of plant species over long distances (Campos-Arceiz and Blake 2011). They mobilize and facilitate nutrient cycling for plants and are also ecological filters, vital for tree recruitment processes (Owen 1980, Terborgh et al. 2015).

Elephants do not have natural predators (Sinclair 2003). Yet they are being extirpated from most of their former geographical ranges (Sukumar 1989). Currently, Asian elephants are listed as “Endangered” in the IUCN Red List (IUCN 2015). Asian elephants used to roam an area of 9 million km² (Olivier 1978, Santiapillai and Jackson 1990, Sukumar 2003). As to date, Asian elephants only occur in fragmented landscapes within 13 countries with an estimated range of 486,800 km² (Sukumar 2003, Blake and Hedges 2004). These countries include India, Sri Lanka, China (Xishuangbanna), Indonesia (Sumatera and Kalimantan), Malaysia (Peninsular Malaysia and Sabah), Lao PDR, Myanmar, Thailand and Vietnam (Olivier 1978, Sukumar 1989, Choudhury et al. 2008). Till today, the decline in numbers and range of these large charismatic animals continue unabated (Kemf and Santiapillai 2000).

Asian and African elephants (*Loxodonta spp.*) are generalist herbivores, bulk-feeders and highly adaptable to thrive in varied environmental conditions (Cumming et al. 1997, de Silva and Wittemyer 2012, Roever et al. 2012). Asian elephants require between 100 kg to 300 kg of food or more for each adult individual daily (Sukumar 2003, Douglas-Hamilton 2005). Due to their dietary requirements, Asian elephants are highly dependent on large areas of suitable

habitat, most notably with abundant forage. For example, in Sri Lanka, elephants prefer disturbed habitat especially cultivated areas resulting from slash and burn cultivation (Weerakoon et al. 2004). Regardless of their specific habitat preference, as deforestation rate continues unabated across Southeast Asia, the availability of suitable habitat for elephants in this region is being compromised (Leimgruber et al. 2003). Large tracts of forests are increasingly being encroached by humans and most of the lowland areas are now being converted to small and large scale agriculture and developments (Santiapillai and Jackson 1990, Hansen et al. 2009). As elephants' natural habitat continue to shrink, their home range often extends and overlaps with human settlements and cultivated areas. Indeed, approximately 70% of Asian elephants are estimated to live in human-dominated-landscapes (Leimgruber et al. 2003, Blanc et al. 2007). Inevitably, this leads to intense competition for the same resources and land space resulting in escalation of human-elephant-conflicts (HEC) globally (Pimm et al. 1995, Hoare 1999, Balmford et al. 2001, Sukumar 2003, Choudhury 2004, Di Fonzo 2007).

HEC has been recognized as the most significant threat to Asian elephants' survival as global growth of human population demands for more food, resources and land to sustain the population (Hoare 1999, Sitati et al. 2003, Thirgood et al. 2005, Siebert 2006, Hedges 2007, Fernando et al. 2008). A common source of conflict arises when elephants raid crops, destroy properties and agriculture land as well as injuring or killing people and/or elephants (Sukumar 1994, Inskip and Zimmermann 2009). According to Santiapillai et al. (2010), 100 farmers suffered losses amounting to USD 200 annually in various parts of Sri Lanka due to crop damage by elephants. Meanwhile, farmers in six villages in Thailand (Na Yao, Na Isan, LumTha Sang, Tha Ten, Na Ngam and KlongToey) lost approximately 25% of their annual income due to HEC (Jarungrattanapong and Sajjand 2011). As reported by Choudhury (2004), it was estimated that between 1980 and 2003, more than 1,150 humans and 370 elephants have died as a result of HEC in Northeast India alone. In Sri Lanka, on average 100 to 120 elephants are killed annually by farmers due to conflict (Kemf and Santiapillai 2000). Therefore, the issue and consequences pertaining to HEC are not only confined to the conservation of the species but of a much broader scale concerning major socio-economic and political issues (Fernando et al. 2008). As

such, reducing the impacts of HEC is of major concern and has become the highest priority for elephant conservation in Asian elephant ranging countries.

1.1 Asian elephants and economic development in Peninsular Malaysia

In the 19th century, elephants occurred throughout the whole of Peninsular Malaysia except on Penang Island (Olivier 1978, Khan 1992). By the 1940s, there were almost no elephants roaming in Perlis, mainland Penang, Melaka and Selangor states except for some pocketed herds (Foенander 1952). Over the years, elephant distribution has seen a progressive retreat from its former ranges, most evident on the west and south of Peninsular Malaysia (Department of Wildlife and National Parks Peninsular Malaysia 2013). Consequently, as to date, these animals can be found widely but fragmentally in 6 out of the 11 states, according to the current official figures by Department of Wildlife and National Parks Peninsular Malaysia (DWNP) (2013): Kedah, Perak, Pahang, Kelantan, Terengganu and Johor. Since 2011, Perlis, Selangor and Negeri Sembilan have lost their last few elephants as a result of land clearance and translocation by DWNP (DWNP 2013). Translocation is a HEC mitigation technique that involves the capture and relocation of elephants from conflict areas to a suitable (Saaban et al. 2011).

In the past 100 years, Peninsular Malaysia as other developing countries, has undergone a rapid urban growth and transformation (Masron et al. 2012). As of 2010, it is estimated that more than 70% (22.5 million) of Malaysians live in Peninsular Malaysia (Population Household and Living Quarters 2010) making it the fourth most populous country amongst Southeast Asian countries with elephant ranges after Indonesia, Vietnam and Thailand (World Population Prospects 2015). Since Malaysia gained independence in 1957, in tandem with urbanization growth in the west coast of Peninsular Malaysia, road construction and expansion has since been intensified (Leinbach 1975). Under various five-year Malaysia Plan from 1966 to 2005, road development connecting major cities was regarded as one of the most important elements to support the growth of human population, economic and social development in Peninsular Malaysia (FAO Corporate Document Repository 2002). As to date, Malaysia has constructed a total of 144,403 km of paved roads and is the third country with the longest road

network (after Indonesia and Thailand) amongst elephant ranging countries in Southeast Asia (Southeast Asian Economic Outlook 2013).

Forest clearance and fragmentation are some of the main causes of shrinking elephant distribution and population decline in Peninsular Malaysia (Olivier 1978, Santiapillai 1990, Leimgruber et al. 2003, DWNP 2013). In addition, governments often regard logged over forests as degraded forests unsuitable as wildlife habitat and thus forests were often clear felled for large-scale agriculture (Casson 2000, McMorrow and Talip 2001). In Malaysia, there is two-tier governmental structure; federal and state government (Awang 2008). The Federal Constitution of Malaysia 1957 stipulates that land is a state matter and therefore the state government has the jurisdiction to legislate, manage and develop the lands without approval from the federal government (Harding 2012). For instance, in the late 1970's, Endau Rompin National Park (ERNP) was extensively logged by concessionaires whereby logging licenses were given by the state government of Pahang (Yusof 1989). The logging activities were then contrary with the Third Malaysia Plan national plan which declared ERNP as a forest reserve and limited logging to certain designated areas only; the federal government however had no power to stop logging as land is a state matter (Hussain 1979). Therefore, land conflicts often occur when different sets of development plans contravene. More often, the economic development will be given prioritization over environmental matters (Awang 2008).

With the reduction in natural forest cover, commercial plantation of oil palm increased dramatically since the 1990s (Murphy 2014). In order to meet local and global demand of palm oil due to its versatility, oil palm plantations in Malaysia have grown from less than 3.5 km² in 1910 to approximately 50,000 km² in 2011 (Malaysian Oil Palm Statistics 2011). Between 1990 and 2005 alone, 55–59% of these oil palm plantations originated from the clearance of natural forests (Koh and Wilcove 2008). In line with the federal government's objective of reducing the poverty rate of the nation, farmers were given lands to plant oil palm or rubber resulting in large tracts of forest clearance in the past 40 years (Bahrin 1977, Brown and Jacobson 2005). Consequently, forest clearance and the shrinking habitat of elephants indirectly led to the escalation of HEC. Blair et al. (1979) reported that the Federal Land Development Authority

(FELDA) suffered losses amounting to USD 20 million per year due to HEC. Meanwhile, DWNP recorded 10,759 HEC complaints between 1998 and 2010 including 9 human deaths due to HEC between 2001 and 2011 (Saaban et al. 2011). Although elephants were not the most common crop-raider in comparison with wild boar and macaques, the extent of their damage on cash-crops and/or property destruction as well as the fear of being injured and killed by the large herbivore often places elephants as the most feared, destructive animal and generally less tolerated (Naughton-Treves et al. 2000, Hoare 2001, DWNP 2013).

1.2 Studying elephant distribution

Elephants in Peninsular Malaysia persist in fragmented landscapes, but little is known about their distribution and habitat use across their entire range (DWNP 2013). The information of habitat transformation and their effects on elephant distribution are essential to monitor, as well as identify threats and prioritize conservation of the remaining habitat for elephant's long-term survival. Furthermore, this information is valuable to improve and inform elephant conservation and management actions (Leimgruber et al. 2003, Gaucherel et al. 2010).

Despite the abundant research on the behavior and ecology of Asian elephants (mostly in India and Sri Lanka), the lack of information on the current distribution of elephants could be attributed to logistic and funding constraints (Balmford and Whitten 2003, Carwardine et al. 2008). One of the common methods of determining elephant distribution and abundance include conventional dung counts or elephant sign surveys along a transect (Barnes et al. 1997, Fernando 2000, Barnes 2001, Blake and Hedges 2004, Hedges et al. 2005). Besides that, non-invasive DNA-based capture-mark-recapture methods are also used to estimate elephant population size (Eggert et al. 2003, Hedges et al. 2013). In recent years, camera traps have become popular for wildlife population studies including elephants (Silveira et al. 2003, Grassman et al. 2005, Varma et al. 2006). Despite recent advancements of the mentioned non-invasive tools, not all methods can be efficiently applied across all elephant ranges and most notably in Peninsular Malaysia. For example, the huge cost of deploying camera traps across the whole of Peninsular Malaysia is a major limiting factor because it is impractical, expensive and very time-consuming (Magoun et al. 2007, Karanth et al. 2011). Due to Malaysia's thick

rainforest vegetation, despite their large size, elephants are difficult to visually detect and photograph unlike what is commonly done in Sri Lanka and some parts in Africa, mainly in savannah landscapes (Santiapillai et al. 1984, Wittemyer et al. 2007, De Silva and Wittemyer 2012). Furthermore, considering the steep, dense and mountainous landscape, direct observations and dung count surveys are an extremely time and resource consuming to undertake. Meanwhile, DNA based capture-mark-recapture survey method is logistically challenging and expensive when implemented over a large study area i.e. whole of Peninsular Malaysia (Hedges et al. 2013).

Therefore, so far the estimation of elephant distribution in Peninsular Malaysia by DWNP has been based on the use of reported cases of HEC as proxy and wildlife inventories based on sign surveys (DWNP 2013). These reports are based on individuals proactively reporting to DWNP, capturing only biased information, which led to overlooking areas where elephants live in undisturbed habitat and do not cause conflicts (DWNP 2013). Additionally, according to Daim (2002), the wildlife inventories are badly designed dung count surveys; therefore the estimate provided should be taken as conservative figures. As reported by Saaban et al. (2011), it is speculated that the results of dung-count surveys previously conducted in three areas in Peninsular Malaysia (Gua Musang, Taman Negara and Endau Rompin) might underestimate the total elephant numbers.

In the study of the abundance and distribution of elephants or other wildlife species, detection/non-detection data are widely collected and used in various analyses of wildlife–habitat relationships including occupancy estimation (Gu and Swihart 2004). Occupancy is the proportion of sites occupied by a species of interest (Mackenzie et al. 2002). Occupancy modeling is useful in determining the species distribution and identifying important habitat characteristics associated with elephants' occurrence (Peterman et al. 2013). Consequently, a number of studies have examined the relationship between elephant occupancy and environmental or anthropogenic covariates (Buij et al. 2007, Martin et al. 2010, Nielsen et al. 2010, Gopaldaswamy et al. 2012, Jathanna et al. 2015). A more recent approach has seen a number of researches also incorporating questionnaire survey information into occupancy modeling for assessing wildlife distribution and habitat use (Karanth et al. 2009, Karanth et al.

2011, Zellar et al. 2011). Estimation of wildlife habitat use, particularly elephants in this study, requires information on environmental covariates as elephant occupancy and probability of detecting elephants can be influenced by ecological variables (Nupp and Swihart 1996, Odell and Knight 2001). Studying elephant habitat association requires various environmental variables such as topological information (slope or elevation), habitat associations (vegetation measurement, forest or plantation presence) and human presence or disturbance (human density). Additionally, spatial autocorrelation within explanatory variables should be incorporated in the occupancy modelling to enhance precision of elephant occupancy estimation (Gu et al. 2001, Klute et al. 2002).

It is however difficult to distinguish true absence from non-detection (false absence) of elephants within any study area (Hedges 2012). Ignoring this fact will reflect poorly on estimates of habitat models resulting in inaccurate distribution of elephants when the data is uncorrected for non-detection (Mackenzie et al. 2003, Tyre et al. 2003). Moilanen (2002) and Karanth et al. (2009) reported that false absences posed a greater source of bias than false presence records for unknown habitat areas. Imperfect detection or non-detection of any studied species is a common occurrence, likely to surface due to the (1) behavior of the species, (2) sampling efforts/design, and (3) other related parameters such as observer error; which influence species detection even when they are present (Mackenzie et al. 2002, Kellner and Swihart 2014). Not surprisingly, Kellner and Swihart (2014) reported that only 23% of the 537 ecological journals published in the past 5 decades incorporated imperfect detection. It is therefore critical to account for imperfect detection in occupancy modelling to be able to make reliable inferences about the distribution of elephant's occurrence (Mackenzie 2006).

1.3 Questionnaire survey as a systematic method to collect distribution data

Many natural science researchers are highly skeptical of the accuracy and reliability of information obtained through interview based surveys (Latour 2000). Besides that, many practitioners consider that social science surveys do not fulfill the rigorous and robust scientific requirements normally practiced in conventional conservation research (Meijaard et al. 2011). However, interview surveys are increasingly being practiced in conservation as a tool for data

collection (Sheil and Lawrence 2004, White et al. 2005, Jones et al. 2008, St John et al. 2011). Despite common suspicion on the reliability or robustness of questionnaire surveys, these can be applied to study the distribution and/or abundance of wildlife species when the area of concern is enormous and could not be surveyed by field teams (Meijaard et al. 2011). Meijaard et al. (2011) also proved that when surveys were conducted by trained personnel and with careful implementation in the field, they possess great potential as a robust and cost-effective tool in gathering information. In essence, humans are better predictors than ecological variables in determining elephant occurrence where elephants are present (de Boer et al. 2013). Besides, the use of questionnaire surveys makes it possible to obtain information on underlying complex socio-cultural factors such as perception and attitudes of villagers, stakeholders and government officials which are equally helpful in conservation and management of the studied species (Meijaard et al. 2011).

1.4 Aims of study

Conservation planning of Asian elephants in Peninsular Malaysia requires the understanding of their basic spatial distribution and habitat associations (Sukumar 2003, Guisan et al. 2013). Therefore in this study, my objectives are:

- 1) To identify the current and past distribution of wild elephants and HEC in human-dominated-landscapes of Peninsular Malaysia using a relatively fast and cost-effective approach;
- 2) To understand the temporal changes of elephant and HEC distribution in Peninsular Malaysia in the past 40 years;
- 3) Based on the information gathered, I aim to generate country-wide occupancy maps of elephant distribution (in human-dominated-landscapes).
- 4) Finally, I aim to identify what ecological factors influence elephant distribution and occupancy.

2. Methodology

2.1 Study area

My study area was the human-occupied-landscapes in Peninsular Malaysia. Peninsular Malaysia, also known as the West Malaysia, lies between the latitudes 1°27' - 6°69' N and longitudes 100°09' - 104°27' E, comprises an area of 130,598 km², and borders with Thailand to the north and Singapore to the south. The topography of Peninsular Malaysia is dominated by mountain ranges, lowland and flat coastal plains (Whitmore 1988). On the northern regions is the backbone of Peninsular Malaysia, a mountain range known as Banjaran Titiwangsa which runs from the Thai border across the central spine down to Negeri Sembilan, Gunung Tahan is its highest peak (Moore 1988). On the contrary, the southern regions are relatively flat (Moore 1988). Peninsular Malaysia has a diversity of forest types covering approximately 58,300 km² or 44% of total land area (Forestry Department Peninsular Malaysia 2015). These forest types include mangroves, peat swamps, lowland dipterocarp, hill dipterocarp, upper-dipterocarp, montane-oak and montane-ericaceous forests.



Figure 1. Map of research area, Peninsular Malaysia.

Generally, Peninsular Malaysia's climate is characterized by a high humidity (monthly average: 70% to 90%) with fairly uniform temperatures (monthly average: 21°C to 32°C) and copious rainfalls (average 2,500 mm per annum). The amount of rainfall received varies according to seasonal monsoon (north-east monsoon from November till March and south-west monsoon from May till September (Jamaludin and Jemain 2007). As a result of the topographic configuration combined with copious rainfalls, there are generally many free-flowing rivers originating from the mountain ranges across Peninsular Malaysia (Rainboth 1996).

In the last 100 years, Peninsular Malaysia has undergone a rapid urban growth and transformation (Masron et al. 2012). Due to its topography, Peninsular Malaysia is generally divided into the west and east coast. The east coast comprises of the states of Kelantan, Pahang

and Terengganu facing the South China Sea. Meanwhile, the west coast refers to states facing the Straits of Malacca i.e. of Perlis, Kedah, Penang and Perak (northern region), Selangor (central region), and Negeri Sembilan, Malacca and Johor (southern region) (Chan and Parker 1996).

2.2 Data collection

I used a questionnaire-based survey as a rapid method to gather baseline quantitative information on the distribution of elephants, human-elephant conflict, and temporal changes in both. Similar approaches have been successfully used in the study of various mammals (see Meijaard et al. 2011, Zeller et al. 2011, Abram et al. 2015).

2.2.1 Ethics statement

The methods and questionnaire were reviewed and approved by the University of Nottingham Malaysia Campus' ethical committee. At the start of each interview, signed informed consent was obtained from most of the respondents (approximately 73 % of total respondents) after the objectives of the study were clearly explained. I was unable to obtain the remaining signed consent forms due to respondent's unwillingness to sign the form despite assurance that their name will be strictly confidential and used only for the purpose of this research. Alternatively, I obtained their verbal consent and made sure they are comfortable with the interview before starting. Respondents were also informed of the option to withdraw from the interview at any time without giving any explanation. Furthermore, demographic details (e.g. gender, age and occupation), social status and ethnic group information were not collected to ensure anonymity. Finally, all respondents were ensured of their confidentiality and anonymity during the analysis of the data.

2.2.2 Questionnaire design

The questionnaire comprised of 3 primary and 10 secondary questions to gather data on the current and past presence of elephants and HEC, elephant demography, seasonality of elephant presence and HEC occurrence, levels and types of HEC experienced, and human or elephant related deaths. Prior to conducting the full survey, a pilot study was conducted in November 2012. A total of 68 respondents were interviewed within the state of Negeri Sembilan.

Subsequently, minor changes were made and the questionnaire was translated to the national language, Bahasa Malaysia (Appendix 1). Additionally, a 'plantation questionnaire' was also developed with slight modifications of wordings to make it more appropriate to interview plantation managers (Appendix 2).

2.2.3 Sampling strategy and respondent selection

The study area was divided into pre-defined grids of 5 km x 5 km size (25 km²) using ArcGIS 10.0 (ESRI 2011). This sampling grid size was chosen based on previous approximate known Asian elephant home ranges of more than 100 km² (Olivier 1978, Sukumar 1989, Fernando et al. 2008). This grid size enables the collection of data on a scale about one order of magnitude finer than the elephant home range area. Because this is a questionnaire-based survey, sampling took place only in grids with human presence (i.e. human-occupied landscapes). Grids which were inaccessible and without human presence, such as plantations, forests, water bodies etc. were marked as "no interviewees" and not included in the study. Within each grid cell, a maximum of 3 respondents (1 to 2 km apart) were selected haphazardly, defined as a non-statistical technique used to approximate random sampling by selecting sample items without any conscious bias and without any specific reason for including or excluding items (American Institute of Certified Public Accountants 2012). In this context, true random sampling was difficult to achieve and would have required huge amounts of effort and time, making it unpractical. Therefore, I chose haphazard sampling as the most appropriate sampling strategy for this study.

2.2.4 Semi-structured interview

I used the structured questionnaire to conduct face-to-face semi-structured interviews. I started each interview providing some general information and the objectives of the survey. Subsequently, I inquired whether elephants are present within the grid area (25 km²). If the resulting answer was "No", I asked about the number of years the respondent has been living in the area. In order to meet the criteria to be included in the survey, respondents must have lived in the sampling grid for more than 30 years. This resulted in the selection of respondents who

presumably have a better (and long-term) knowledge of the occurrence of elephants and HEC within the surrounding area. Additionally, respondents who are working outdoors for example farmers, hunters and non-timber-forest-products were also targeted.

All interviews were conducted between November 2012 and July 2015. Malaysia being a diverse and culturally rich country requires the interview to be conducted in various languages (English, Bahasa Malaysia, Mandarin and Cantonese dialects) depending on respondent's mother language, with great care taken to ensure the construct and meaning of the questions were consistent throughout. Each interview lasted between 2 to 15 minutes. Upon completion of the survey period, all responses were typed into Excel and revised to identify and correct typing errors.

2.2.5 Efforts in reducing bias

Bias can occur in various stages including data collection period; from questionnaire design, interview process to analysis (Davis et al. 2009, Meijaard et al. 2011). Therefore, in this study efforts were made to reduce sources of errors and bias throughout the interview period. For example, I reduced interviewer bias (Davis et al. 2009) by having only one interviewer (myself) conducting all the interviews. All respondents were interviewed independently and separately from other respondents, family members, or friends to reduce audience-effect bias whereby input from a third party might influence the response of the respondent (Newing 2010). Since the presence of elephants is generally not a sensitive issue (unlike hunting), the potential effect of social desirability bias (Fischer 1993, Meijaard et al. 2011) was ignored. Interviews that ended prematurely were not included in the analyses. Differential recall or respondent bias arises due to the inability to recall memory after a period of time leading to inaccurate or conflicting responses (Meijaard et al. 2011). Therefore, during each interview, if respondent mentioned there were elephants here in the past but could not recall in which year, I would ask them to relate to major and well-known incidents which occurred within the same time frame for example Malayan Emergency, were they in primary or high school, etc. Additionally, asking respondents to provide binary responses (Yes or No) rather than frequency of occurrence may result in less uncertainty and more resilience towards differential recall bias (White et al. 2005).

Finally, all respondents were treated as reliable assuming no “false positives” because elephant signs are conspicuous (especially presence of dung and footprints) and easily differentiated from other animals such as wild boar or macaques (Pillay et al. 2011).

2.3 Data analysis

Data from the full survey was entered manually into an Excel spreadsheet. The responses obtained from the pilot study were not included in the final analysis. All analysis was conducted using R statistical environment (R Development Core Team 2015).

2.3.1 Descriptive mapping of current and past elephant distribution

The main dataset for mapping elephant’s presence included all villagers and plantation respondents. All detection/non-detection of elephants were binary coded; detection as “1” while non-detection as “0”. Grids with more than one elephant or HEC detection were classified as “elephant/HEC detection” to map descriptive current, past elephant and HEC distribution.

2.3.2 Covariates selection and *a priori* hypothesis

Occupancy and detection probabilities may vary according to temporal, environmental and site-specific characteristics (Mackenzie et al. 2002). To address this issue, I chose natural environmental and anthropogenic-influenced covariates which are ecologically relevant and known to influence elephant distribution (Table 1).

Land-use information (forests and plantation) were obtained from DWNP. In ArcGIS 10.0 (ESRI 2011), I overlaid pre-defined grids onto Peninsular Malaysia map to extract information on the count (presence/absence) and proportion of forest or plantation areas within each defined 25 km² grid. Subsequently, I used neighbourhood analysis under “Spatial Statistic Tools” to extract information from neighbouring grids (9 grids in total) for count (presence/absence) and proportion of forest or plantation. Although the information obtained from DWNP dates back to 2006 and inevitably there have been considerable amount of changes to land cover since then, it is by far the most comprehensive map with extensive land use information and other environmental data available for the whole of Peninsular Malaysia. I obtained the elevation and slope raster layers from WorldClim (Hijmans et al. 2005)

(<http://www.worldclim.org>) and subsequently overlaid with the pre-defined grid layer (25 km²) to extract average slope and elevation for each grid. Human population density raster layer was obtained from World Population (ESRI) (<http://www.worldpop.org.uk/>) and human density was calculated by obtaining sum of human within each 25 km² grid. Although roads are known to affect elephant distribution (Barnes et al. 1991, Newmark et al. 1996), they were not included in this study due to lack of detailed road information.

Table 1. Summary of the covariates selected for occupancy model analysis and abbreviation.

Covariate	Variable	Abbreviation
a) Forest	• Percentage of forest cover within grid	fr
	• Squared value of percentage of forest cover within grid	fr2
	• Percentage of forest cover within 9 neighboring grids	fr.nb
	• Squared value of percentage of forest cover within 9 neighboring grids	fr.nb2
b) Plantation (oil palm and rubber)	• Percentage of plantation cover within grid	pl
	• Squared value of percentage of plantation cover within grid	pl2
	• Percentage of plantation cover within 9 neighboring grids	pl.nb
	• Squared value of percentage of plantation cover within 9 neighboring grids	pl.nb2
c) Topography	• Average elevation within grid	elev
	• Average slope within grid	slope
d) Human density	• Log value of human density within grid	hmn.den
e) Length of stay	• Respondent's length of stay within grid	yr

As I was unsure of which spatial scale best describe elephant distribution, I included 4 different scales for forest and plantation covariates which will be tested using univariate analysis (based on individual covariate categories as described in Table 1) to explore the relationship between site-specific covariates and elephant distribution. Additionally, I also included quadratic functions for forest and plantation which were expected to exhibit non-linear responses to variation of the covariates. Elephants benefit from small disturbances which increase food availability. However, as the intensity of disturbance increases, the habitat

becomes less suitable and elephants can no inhabit them. Hence, the relationship with forest cover, human density, etc, is not necessarily linear. All covariates were scaled and standardized. In the univariate analysis, all the top ranked covariates (for each category) were chosen to test for collinearity, computed using parametric Pearson’s rank-order-correlation (r_s) tests. If two or more variables were found to be highly correlated ($r_s > 0.8$), only one was included in any model for occupancy analysis to enable discrimination of models between correlated variables.

Elephants are generalist feeders and require extensive habitat areas due to their large home ranges (Olivier 1978, Sukumar 1989, Fernando et al. 2008). Therefore, forest cover within neighbouring grids was predicted to have a positive correlation with elephant occupancy (Leimgruber et al. 2003). Elephant’s presence in human-occupied areas is predominantly determined by human’s presence (Graham et al. 2009). To test for these effects, human density was predicted to have a negative relationship with occupancy estimate while respondent’s length of stay was hypothesized to be positively associated with elephant detection. Additionally, plantation cover within neighboring grids was predicted to be negatively associated with elephant occupancy. Slope was thought to be negatively affect elephant distribution (Rood et al. 2010). A set of *a priori* candidate models were constructed (Table 2) based on previous known knowledge of Asian elephant ecology and behavior.

Table 2. List of *a priori* candidate models. Please see Table 1 for description of covariates.

<i>A priori</i> candidate models
$\Psi(\text{elev} + \text{slope} + \text{fr.nb} + \text{fr.nb}^2)\text{p}(\text{year})$
$\Psi(\text{elev} + \text{slope} + \text{fr.nb} + \text{fr.nb}^2 + \text{pl.nb} + \text{pl.nb}^2)\text{p}(\text{year})$
$\Psi(\text{elev} + \text{slope} + \text{fr.nb} + \text{fr.nb}^2 + \text{pl.nb} + \text{pl.nb}^2 + \text{hmn.den})\text{p}(\text{year})$
$\Psi(\text{elev} + \text{slope} + \text{fr.nb} + \text{fr.nb}^2 + \text{hmn.den})\text{p}(\text{year})$
$\Psi(\text{fr.nb} + \text{fr.nb}^2 + \text{hmn.den})\text{p}(\text{year})$
$\Psi(\text{fr.nb} + \text{fr.nb}^2)\text{p}(\text{year})$
$\Psi(\text{pl.nb} + \text{pl.nb}^2)\text{p}(\text{year})$

2.3.3 Missing observations

Due to logistic and practicality reasons, there were grids which I was not able to haphazardly sample 3 respondents in total. For example, in many villages I visited there were no suitable villagers for me to conduct the interview. This issue will be addressed in the occupancy model developed by Mackenzie et al. (2002). The model accepts and incorporates missing observations with respect to different sampling intensity assigned to each grid.

2.3.4 Occupancy analysis and model selection

All occupancy analyses were conducted using *unmarked* package in R (Fiske and Chandler 2011). The recorded values from multiple interviews (maximum of 3) were treated as separate spatial replicates (detection histories) for the computation in statistical occupancy analysis. The replicates were used to address and reliably estimate both detection probability and occupancy estimate in the possibility of failing to detect presence of elephants where most of the case detection probability is less than 1 (Mackenzie et al. 2002).

One of the few assumptions of Mackenzie et al. (2002) occupancy model is population closure during the survey period. As this survey was conducted in the period of 2 years, I was unable to fully meet the closure assumption. According to Mackenzie and Nichols (2004), the relaxation of this closure assumption therefore changes the interpretation of occupancy of this study from “proportion of area occupied” to “proportion of area used” by elephants.

I used single-season occupancy model to estimate occupancy and detection probability following MacKenzie et al. (2002) using maximum likelihood estimation method in a two-step approach. The global model i.e. the model with additive effects of all considered covariates for the detectability parameter was held constant. In the second step, covariate effects on occupancy parameter was explored based on the *a priori* candidate models (Table 3). Subsequently, I chose the highest ranking model based on parsimony, Akaike’s information Criterion (AIC: Burnham and Anderson 2002, Mackenzie et al. 2002) and ΔAIC to assess covariates’ influence

on occupancy. To account for spatial autocorrelation in estimating occupancy of elephant over large extent, the highest ranked model was used to estimate occupancy following Johnson et al. (2013).

2.3.5 Occupancy mapping output

The occupancy estimates obtained following Johnson et al. (2013) was then used to map out the predicted distribution map of elephants in Peninsular Malaysia.

3. Results

3.1 Survey effort

The survey yielded a total of 5,585 interviews (villagers and plantations) encompassing an area of approximately ca. 55,750 km² (39.3% or 2,230 grids from a total of 5,673 grids covering the whole of Peninsular Malaysia). From the total number surveyed grids, 18.6% (415 grids) had one interview, 12.3% (275 grids) had two interviews while the remaining 69.1% (1,540 grids) had three interviews.

As this survey was conducted in human-occupied landscapes only, I was unable to survey approximately 60.7% of the total grids (3,443 grids or ca. 86,075 km²) which encompasses 65% (2,233 grids) forests, 26% (924 grids) plantation, 7% (228 grids) water bodies and 2% (58 grids) cleared land (Figure 2).

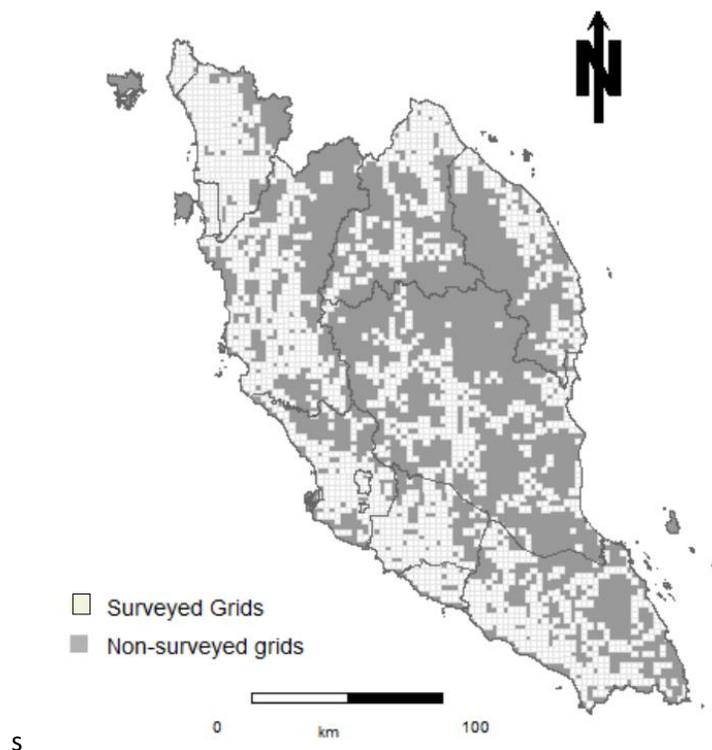


Figure 2. Peninsular Malaysia map displaying surveyed and non-surveyed grids.

3.2 Descriptive mapping of elephant and HEC distribution

3.2.1 Current elephant distribution

Overall, elephant's detection was reported in only 12.9% (289 grids) out of the total grids surveyed (Figure 3). There was no elephant detection in most of the entire west coast of Peninsular Malaysia; an area with high human, roads and crops density. Currently, elephants are only detected fragmentedly in the north (Kedah, Perak and Kelantan), central (Pahang and Terengganu) and south-east (Johor) of Peninsular Malaysia detected mostly at settlements near forest or plantation edges (Figure 3).

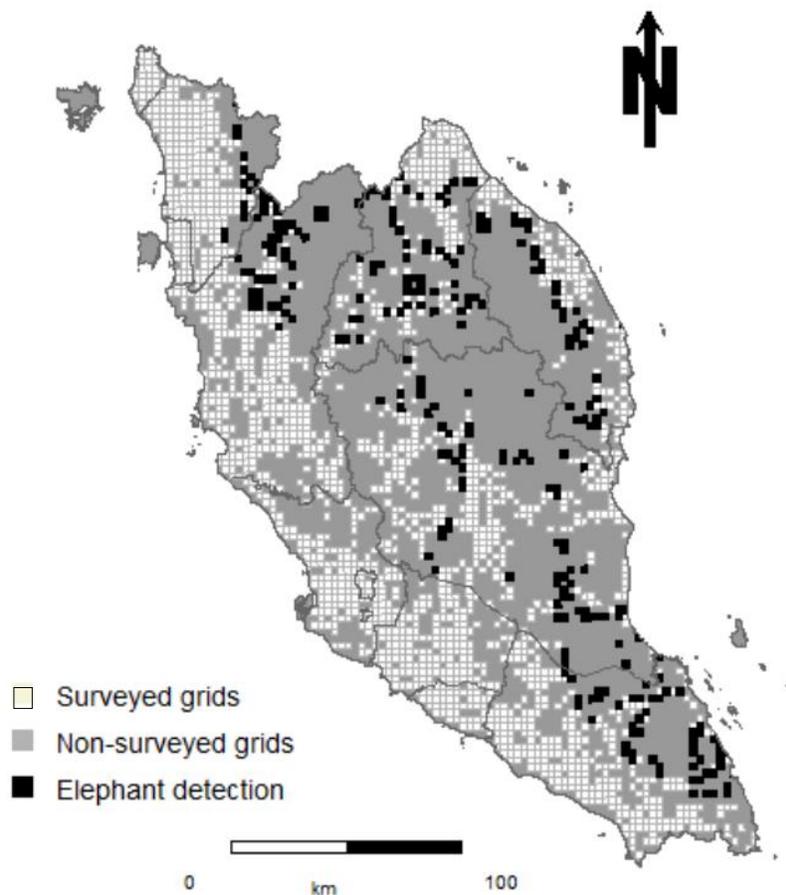


Figure 3. Map of Peninsular Malaysia showing grids where elephants were reportedly detected.

Besides gathering information on elephant's occurrence, I also obtained information on seasonality and demography of elephant's presence (Figure 4). Most of the grids reported remarkably high irregular detection (n=107) of elephants and most of these occurrences were herds with young (n=112).

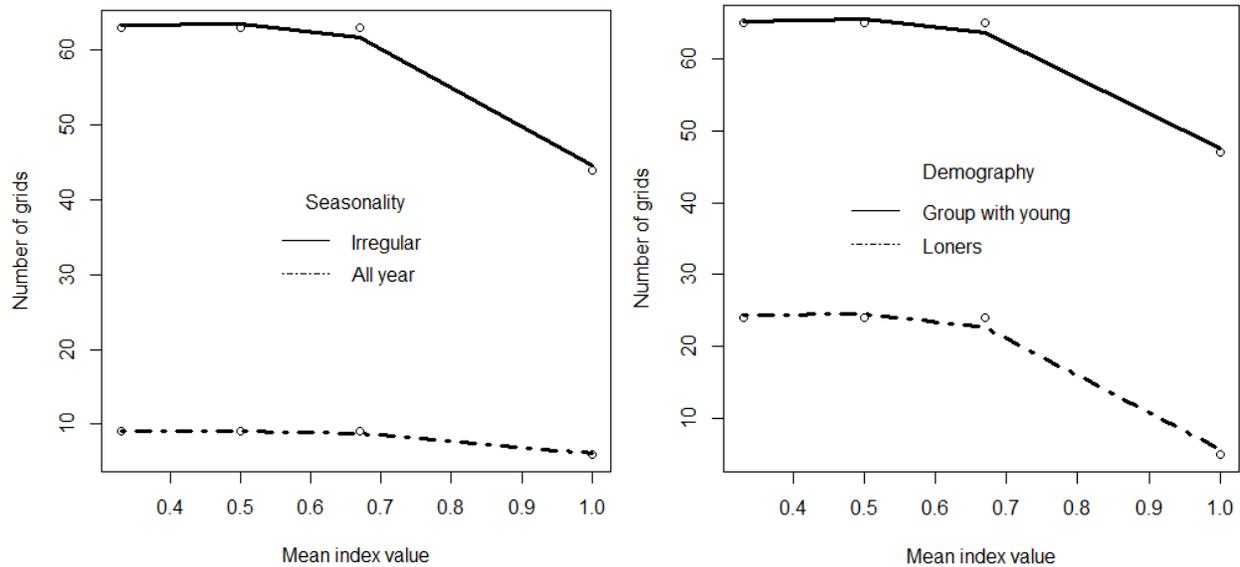


Figure 4: Seasonality and demography of elephants in grids with elephant's detections. Mean index value was obtained by averaging presence (1) or absence (0) values with number of respondents within each grid. These data were collected from secondary questions in grids with elephant's detection.

3.2.2 Past elephant distribution

Up to 40 years ago, elephants were still detected in 616 grids (Figure 5), having lost 68% of their detected range. In this period, elephants were no longer reported present in various states in the north (Perlis) and west (south of Perak, Selangor, Negeri Sembilan, Melaka and west of Johor). Elephant distribution shrank mainly from the edges of forests and plantation areas.

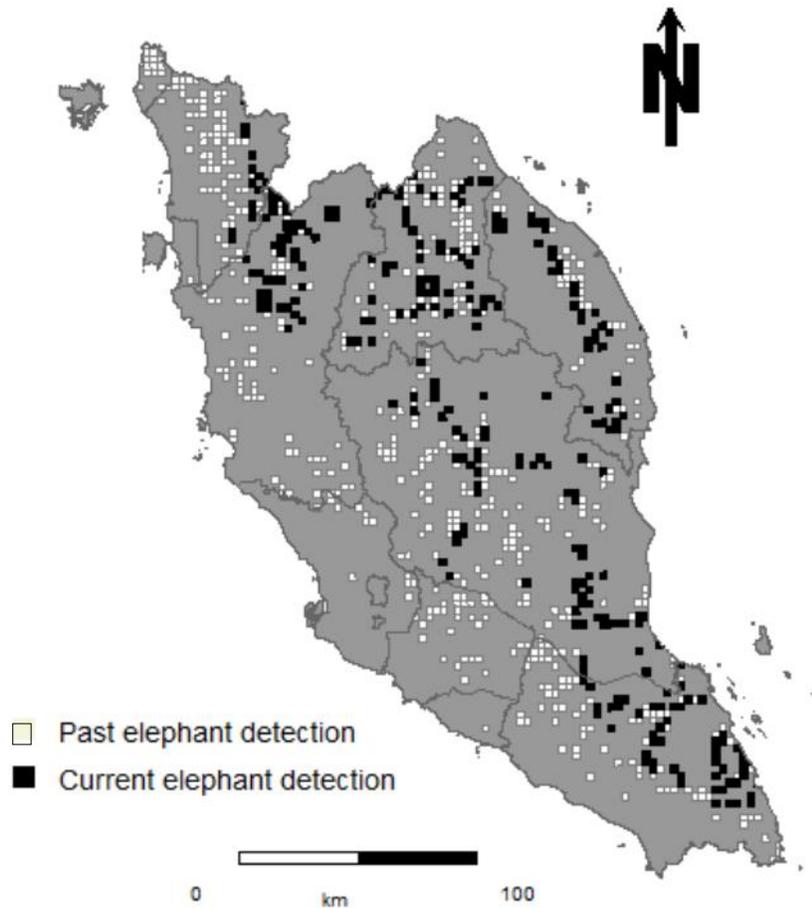


Figure 5. Map of Peninsular Malaysia denoting the grids where elephants were reportedly not detected since 40 years ago.

3.2.3 Human-elephant-conflict (HEC) distribution

HEC was reported in 68.5% (198 grids) of the grids with elephant detection (Figure 6). Of all the grids with HEC detection, 61% (n=120) reported major form of conflicts while the remaining 26% (n= 52) and 13% (n= 26) reported medium and minor levels of HEC, respectively (Figure 7). When asked about the trends of HEC, generally HEC incidences were decreasing in 43% of the grids (n= 85), 23% were stable (n= 46) while 34% were increasing (n= 67) (Figure 7). Crop raiding was reported as the most common form of HEC with 86% (n=170) followed by property damage 8% (n=16) and safety 7% (n= 12) (Figure8).

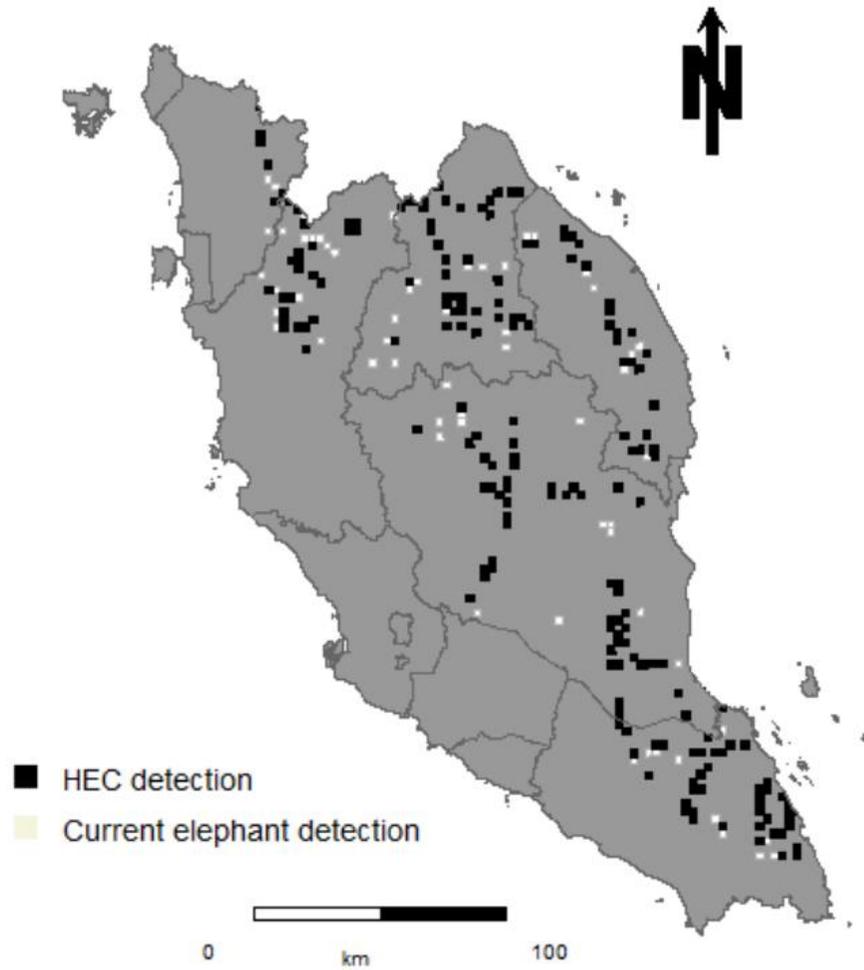


Figure 6. Peninsular Malaysia map showing grids where HEC were reportedly present.

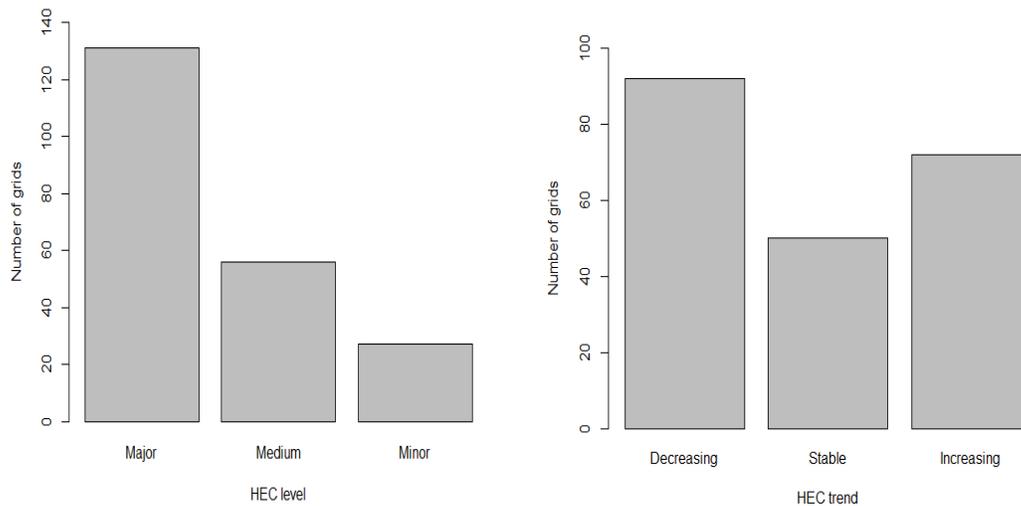


Figure 7. HEC levels and trends in grids with HEC detection.

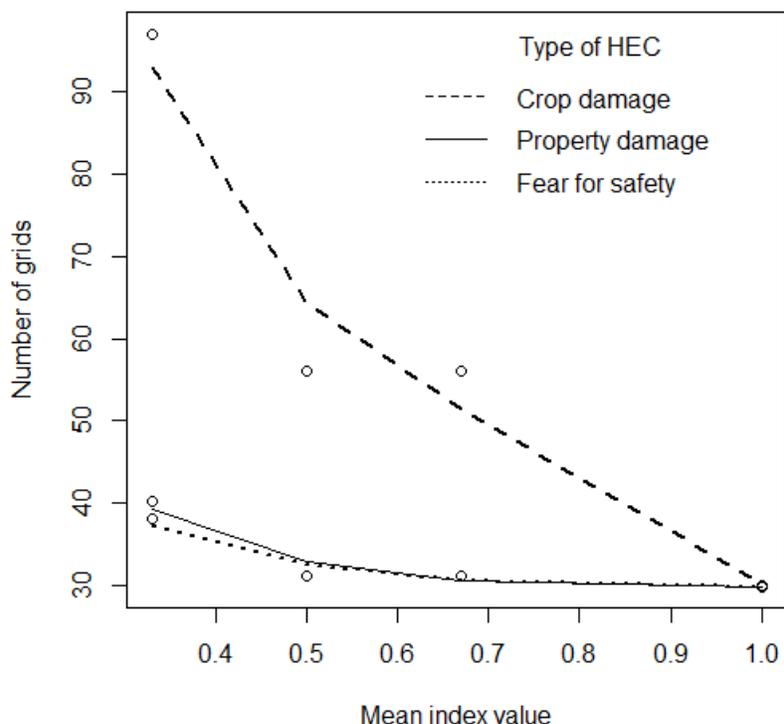


Figure 8. Types of HEC reported in grids with HEC detection. Mean index value was obtained by averaging presence (1) or absence (0) values of each HEC type with number of respondents within each grid. These data were collected from secondary questions in grids with HEC detection.

Table 3. Results of individual univariate analysis

Category	Covariate	nParsimony	AIC	Δ AIC	AICweight	cumltvWt
a) Forest	fr.nb + fr.nb2	3	2137.85	0.00	1.0e+00	1.00
	fr + fr2	3	2245.71	107.86	3.8e-24	1.00
b) Plantation	pl.nb + pl.nb2	3	2389.40	0.00	1.0e+00	1.00
	pl.nb + pl.nb2	3	2416.66	27.26	1.2e-06	1.00
c) Topography	slope	3	2375.65	0.00	1.0e+00	1.00
	elev	3	2401.77	26.12	2.1e-06	1.00

3.4 Pearson correlation and univariate analysis

Univariate analyses (Table 3) were conducted for each covariate category (for forest, plantation and topography only) and the covariates chosen for further analysis were slope, elevation, fr.nb

with fr.nb2, pl.nb and pl.cnt.nb2, in addition to year and human density. I subsequently assessed collinearity of the chosen covariates using Pearson’s correlation coefficients. Although slope and elevation were highly correlated with each other, I chose both of the covariates to investigate the possibility of highly correlated but opposite effect between each other.

Table 4. Pearson correlation significance testing for all covariates.

	yr	elev	slope	hmn.den	fr.nb	fr.nb2	pl.nb	pl.nb2
yr	1.0000	-0.0197	-0.0262	0.1732	-0.0895	0.0365	-0.1046	0.0111
elev		1.0000	0.8139	-0.3231	0.6954	0.6694	-0.3449	0.1378
slope			1.0000	-0.3149	0.7189	0.5585	-0.3546	-0.0151
hmn.den				1.0000	-0.5029	-0.3197	-0.0222	0.0350
fr.nb					1.0000	0.7233	-0.4373	-0.0596
fr.nb2						1.0000	-0.4525	0.3131
pl.nb							1.0000	0.0251
pl.nb2								1.0000

3.5 Occupancy analysis with covariates

The naïve occupancy estimate (assuming detectability=1) was 0.139 which means 13.9% of the surveyed grids were used by elephants. Occupancy (0.153) and detectability (0.682) estimates obtained from single season occupancy model without the incorporation of any site-specific covariates yielded a slightly higher value (Table 5).

Table 5. Detectability (p) and occupancy (ψ) estimates for elephants using fixed model with no covariate effect.

	Estimate	Standard Error
p	0.689	0.0209
ψ	0.143	0.008

Using a two-step approach, the effect of covariates on detectability was first tested while holding occupancy probability constant with year covariate (the only covariate which influence probability of detecting elephants given that they were present in the grid). To limit the number of models, I used the candidate models in the *a priori* hypothesis (Table 2) to

identify the best model which affect elephant occupancy. The analysis yielded the top ranked model (AIC weight = 0.49) with additive functions of *elev + fr.nb + fr.nb2 + hmn.den* (Table 6).

Table 6. Top three ranked models for occupancy (ψ) as a function of covariates structure for detectability (p) using candidate in Table 2.

Model	nParsimony	AIC	Δ AIC	AIC weight	Cumu.weight
ψ (slp + elev + fr.nb + fr.nb2 + hmn) p(year)	8	1928.65	0.00	8.6 e-01	0.86
ψ (elev + fr.nb + fr.nb2 + hmn + pl.nb + pl.nb2) p(year)	10	1932.29	3.64	1.4 e-01	1.00

Table 7. Summary of top ranked additive models with untransformed covariates coefficient estimates for detection probability and occupancy with standard error (SE) in parentheses.

Covariate	ψ (slp + elev + fr.nb + fr.nb2 + hmn) p(year)	ψ (elev + fr.nb + fr.nb2 + hmn + pl.nb + pl.nb2) p(year)
Occupancy		
Intercept	-2.5388 (0.1306)	-2.5481 (0.1540)
Slope	0.0236 (0.1270)	0.0307 (0.1290)
Elevation	-0.5728 (0.1577)	-0.5758 (0.1600)
Human	-1.3624 (0.1428)	-1.3788 (0.1470)
Fr.nb	1.5967 (0.1619)	1.5872 (0.1970)
Fr.nb2	-0.3469 (0.0782)	-0.3178 (0.1090)
Pl.nb		0.0710 (0.1330)
Pl.nb2		-0.0316 (0.1340)
Detection		
Intercept	0.7507 (0.1027)	0.7509 (0.1026)
Year	-0.0169 (0.0811)	-0.0156 (0.0812)

The top model in Table 7 showed that forest presence in neighboring grid (fr.nb) was the most positively associated covariate with elephant's area of use. As predicted, elephant occupancy is positively associated with forest cover in neighboring grids but negative when expressed in quadratic form. Meanwhile, human density (hmn.den), quadratic term for presence of neighboring forest (fr.nb2) and elevation were negatively associated with elephant's area of use. There is strong evidence (Δ AIC = 3.64) suggesting that occupancy was

also highly influenced by the second model suggesting plantation cover in neighbouring grids, with its quadratic form were also an important predictor for elephant’s area of use.

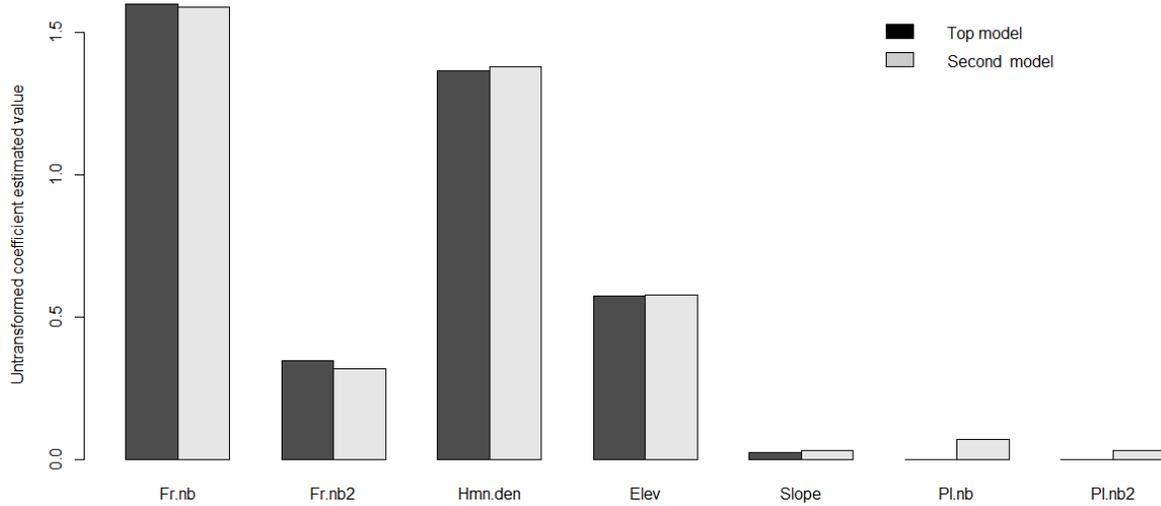


Figure 9. Covariates’ ranking for top two additive models based on untransformed coefficient estimates for occupancy. The top model contains all covariates except *pl.nb* and *pl.nb2*.

Therefore, I used model averaging as described by Buckland et al. (1997) and Burnham and Anderson (2002) to estimate all the parameters within the top two models and plotted the map of area used by elephants (Figure 10) following Chandler (2015). The map indicates that elephant’s use is concentrated in the north (Perak, Kelantan), center (Pahang) and south (Johor) of Peninsular Malaysia.

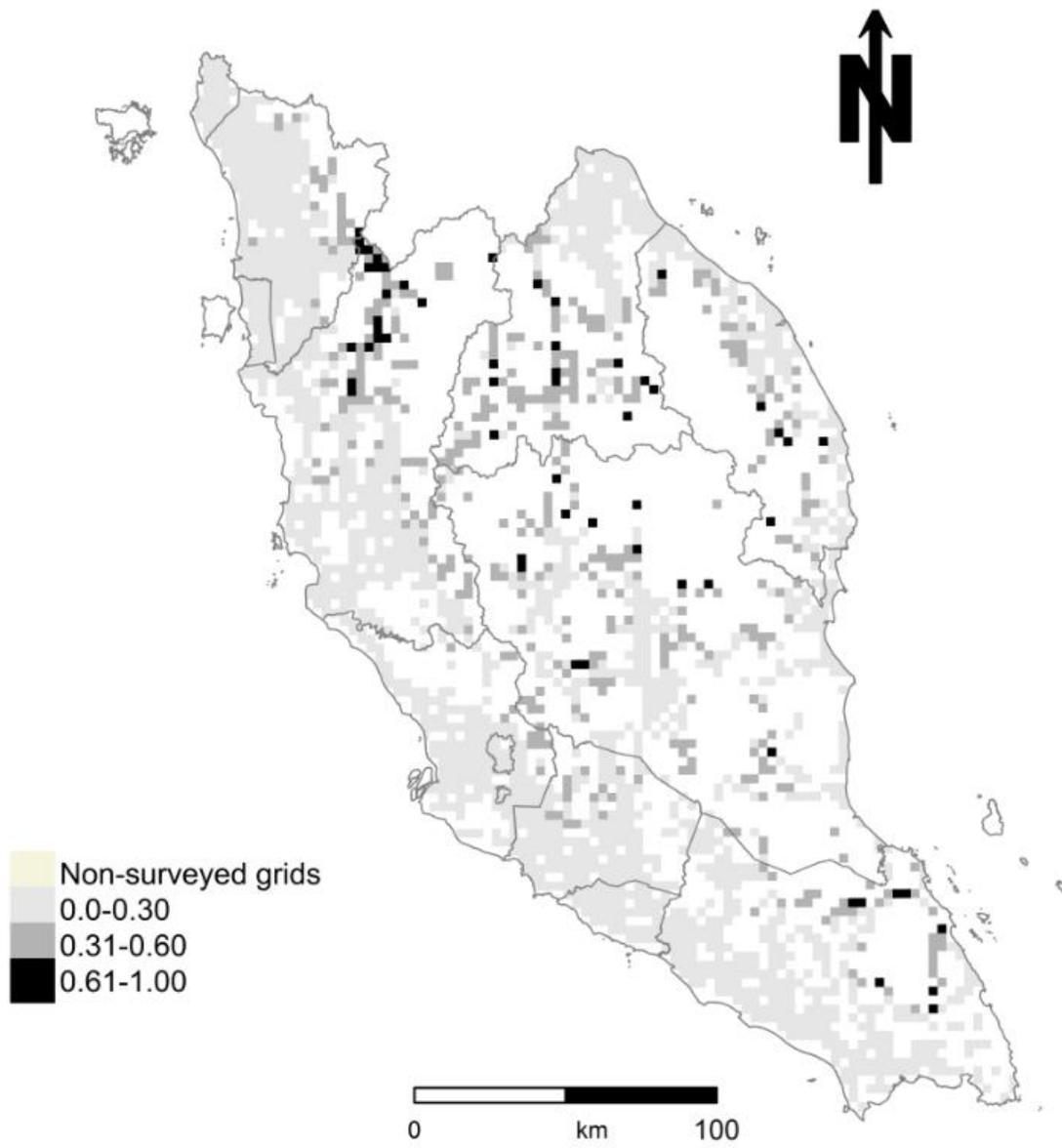


Figure 10. Map of elephant's use in Peninsular Malaysia based on estimates from top ranked model following Johnson et al. (2013).

4. Discussion

Asian elephants have lost 68% (within the last 40 years) of their range within the areas we surveyed. This alarming decline is largely attributed to habitat loss, fragmentation and intense conflict with people (DWNP 2013). The geographic separation created by the mountainous main range between the peninsula's east and west coasts has created an imbalanced human population distribution; resulting in higher population on the western regions (Rostam 2000). This ultimately creates a pressure in urban areas with the need to expand for inclusion of more spaces for houses, employment, roads, agribusiness opportunities and others resulting in lowland forest clearance mainly on the west coast (Masron et al. 2012). Consequently, most of the former lowland elephant habitats have been converted to large scale agriculture plantations (rubber and oil palm) and various infrastructure developments such as dams, highways and new settlements (Daim 2002). As a result, elephants retreated from the populous states of Peninsular Malaysia most notably on the west coast (Selangor, Melaka Negeri Sembilan, Perlis, Penang and Kedah) and south (Johor). Furthermore, elephants have been translocated from various conflict areas and released to protected areas such as Royal Belum State Park, Taman Negara and Endau Rompin sites in the north and east of Peninsular Malaysia. Translocation of elephants has resulted in the removal of elephants from various areas in Selangor, Melaka and most recently in Negeri Sembilan, where DWNP believe they might have translocated the last elephant to Taman Negara in 2011 (Saaban et al. 2011).

Crop-raiding was the most common type of HEC recorded in the surveyed areas, consistent with previous studies from other elephant ranging countries such as India (Sukumar 1990, Williams et al. 2001), Sri Lanka (Bandara and Tisdell 2002, Fernando et al. 2005, Campos-Arceiz et al. 2009), Africa (Hoare 1999, Sitati et al. 2003, Chiyo et al. 2005, Lee and Graham 2006) and South China (Zhang and Wang 2003). Sukumar (1989) has well explained the attraction of elephants to cash crops at any given growing stage due to their palatability, nutrition and lower secondary metabolites in comparison with wild forage. Within Peninsular Malaysia, oil palms being our largest cultivated cash crops nationwide are high in fat and vitamin contents (oil palm shoots and fruits) making them even more attractive to elephants

(Sundram et al. 2003). Besides oil palms, rubber saplings are also prone to crop raiding by elephants due to mineral deficiency in their diets (Blair et al. 1979, Chen et al. 2013).

Many crop raiding incidents across the elephant ranging countries were seasonal and strongly influenced by rainfall pattern (Hoare 1999, Sitati et al. 2003, Osborn 2004, Sitati et al. 2005, Campos-Arceiz et al. 2009). In this study however, most of the respondents reported irregular raiding patterns. The fact that Peninsular Malaysia experiences relatively high average monthly rainfall between 115 to 314 mm all year round, there is no pronounced dry season which might reduce the quality of natural forage and influence crop-raiding pattern (Chiyo et al. 2005, Wong et al. 2009). Farmers in Peninsular Malaysia are able to cultivate perennial crops such as banana, cassava, oil palm rubber etc. all year round making crop-raiding pattern harder to predict within the studied area. Even in the presence of abundant natural forage, elephants might prefer to raid crops (Campos–Arceiz 2013) because besides having more nutritional value, cultivated crops are more spatially predictable and occur at higher densities (Sukumar 1989, Naughton-Treves et al. 1998). It is however interesting to note that plantations are more prone to elephant raiding during replanting season (replacing mature oil palm or rubber trees with saplings aged less than 2 years old). As the data collected from the respondents pertaining to crop-raiding pattern was very coarse, it cannot be used to predict such patterns.

Previous studies have reported that male elephants exhibit higher tendency to raid crops (five times higher than females) due to male's strategy in maximizing reproductive success in male-male competition by being larger through better nutrition (Sukumar and Gadgil 1988, Sukumar 1990, Sukumar 1991, Hoare 1999). However, my results indicate that crops were raided more by elephant groups with young as compared to loners. A similar phenomenon was also reported by Fernando et al. (2005) in Sri Lanka and Balasubramanian et al. (1995) in India. Williams et al. (2001) found that in Rajaji National Park, females were equally responsible for crop raiding. Fernando et al. (2005) further elaborated that where elephant populations are restricted to living in small but highly fragmented habitat, limited resources has an effect on the elephants which will likely influence female groups to raid crops as well.

Another possible explanation on the prevalence of crop raiding by elephant groups is that elephants perceive crop raiding as a low risk activity in Peninsular Malaysia. Most crop planting in Sri Lanka are planted in home gardens cultivated at high density within varying sizes (between 0.4 to 2.0 hectares) (Jacob and Elles 1987). These lands are often fenced using physical barriers such as electric fences to discourage elephants from entering their farm lands or villages (Perera 2009). Furthermore, crops are also guarded by farmers and when elephants approach, they are usually driven away with loud noises created by villagers. This brings the elephants to be in greater conflict with people – “a high risk- high gain” strategy in order to obtain nutritious and palatable crops (Sukumar 1991). In contrast, rubber and oil palm plantations cultivated by villagers in Peninsular Malaysia are generally located few kilometers from their home. When elephant’s home range overlaps with small or large scale but low density (for example 143 oil palm trees per hectare as suggested by FAO Corporate Document Repository 1990) agricultural plantation, they might perceive these lands as forests. Thus elephant groups or loners may not perceive raiding crops (or simply walk through the plantation) as a high risk incident.

HEC was recorded in 68.5% of grids with elephants’ detection. A possible explanation could be the low tolerance of people towards elephant raiding. This is consistent with findings by Ponnusamy et al. (2015), reporting findings of low tolerance towards presence of elephants in 8 settlements living in conflict areas and with construction of electric fences by DWNP across Peninsular Malaysia. However, it is important to note that this might not be the only reason explaining this scenario. As HEC is a complex issue involving other factors such as human perception, economic impacts, lives and livelihoods and others, more information are required to tease apart and explain the high record of HEC detection within this study area (Fernando et al. 2005, Thirgood et al. 2005).

Surprisingly, in my results, 43% of the grids with elephant’s presence reported a decreasing trend of HEC. This trend was also recorded by DWNP where HEC complaints decreased between the years 1998 to 2001, but subsequently increased annually until 2009. Previous research has shown that HEC has become more widespread but not necessarily more

intense than in the past which may be the case for Peninsular Malaysia (Hoare 1999, O'Connell-Rodwell et al. 2000). Another possible explanation could be the declining elephant number in Peninsular Malaysia as a result of their shrinking distribution (mentioned earlier) and globally (Leimgruber et al. 2003, Sukumar 2006, Pillay et al. 2010). Also possible, the mitigation technique employed by DWNP by erecting electric fence could be effective in reducing HEC. Electric fences are widely used in mitigating and reducing impact of HEC across all elephant range countries (Fernando et al. 2008, Lenin and Sukumar 2008). Since 2009, DWNP has constructed 17 electric fences totaling more than 100 km in areas with high HEC intensity across Peninsular Malaysia (Saaban et al. 2011, Ponnusamy et al. 2015). Electric fences have been found to be successful with many privately owned fences in India (Nath et al. 1998). In Sri Lanka, well designed, implemented and maintained fences along with community support could help in reducing and mitigating HEC (Gunaratne and Premarathne 2006, Fernando et al. 2011). Meanwhile, Sukumar (2003) also reported effectiveness of electric fences used by oil palm and rubber plantations in Malaysia. Most recently, Ponnusamy et al. (2015) reported 80% of villagers living near electric fences felt that the fences were effective in reducing HEC which might contribute to the decreasing trend.

4.1 Distribution of elephants and HEC

The current distribution and factors driving distribution patterns of Asian elephants in Peninsular Malaysia are poorly studied and not accurately known (DWNP 2013). Understanding factors that confound elephant spatial distribution patterns is critical to prioritize habitat/elephant conservation and inform management actions. This study is the first systematically designed grid-based approach to determine elephant and HEC distribution in Peninsular Malaysia. The occupancy estimates (proportion of area used by elephants) can be used as a baseline whereby future surveys on changes of elephant distribution can be measured against.

The occupancy modelling indicates that human presence (measured in the form of human density) has the strongest negative influence on elephant's area of use. This finding is broadly consistent with many studies conducted in both Africa and Asia (Parker and Graham

1989, Barnes et al. 1991, Hoare 1999, Sitati et al. 2003, Blom et al. 2005). Buij et al. (2007) developed a model where human activity was the major determinant of elephant distribution patterns in Gabon in comparison of other ecological features i.e. wetlands. Meanwhile Hoare and du Toit (1999) carried out a similar study in Zimbabwe and concluded that elephant density and human density were indeed negatively correlated. They further explain that both variables have a non-linear relationship because human activity does not represent a single continuous variable, but comprises a number of variables such as road density etc. and that elephant density is unrelated to human density until a threshold is reached (non-linear relationship) at about 15.6 persons/km². This translates to approximately 40–50% of transformation due to human activities, point at which elephants vanish.

Whereas in Asia, not surprisingly, Sodhi et al. (2010) correlated human population density with species endangerment in Southeast Asia. Rood et al. (2010) found that elephants avoid areas with high road densities (indirect measurements of human encroachment) resulting in lower elephant occupancy in human-dominated areas. Similarly, this response was also reported by Lin et al. (2008) and Goswami et al. (2014) where elephants avoid human disturbance in Mengyang, China and India respectively. This pattern is consistent with my findings of higher proportion of elephant usage at settlements near forest or plantation edges where presumably grids further away from forests have higher human density and thus lower estimates on areas of elephant use.

As predicted, percentage of forest cover within neighbouring grid was a strong positive influence in estimating elephant habitat use. The covariate *fr.nb* reflects the proportion of forest cover within 225 km². The availability of forest cover within a larger landscape increases the probability of elephant use of that area. This phenomenon is similar to findings in Sumatera where elephant distribution was positively correlated with forest cover (Rood et al. 2010). Additionally, Mathur et al. (2011) found that elephant abundance was highly associated with the protected area at Dudwa National Park in India. Maintenance of remaining forest areas, reforestation, and the creation of habitat corridors are strategies that could help prevent further expansion of conflict.

One of the leading causes of habitat loss and fragmentation in Peninsular Malaysia is due to agricultural expansion (DWNP 2013). Although plantation covariates were only included in the second model, nonetheless there is evidence that these covariates were important in estimating the proportion of elephant's use. The results indicate that *pl.nb* positively influences elephants' use until a certain threshold (*pl.nb2*) is achieved. In initial stages of forest clearance, the cleared area can be a very attractive place for the elephants (Barnes et al. 1991, Dudley et al. 1992). For example, the clearance of forest for oil palm and rubber plantations is accompanied by an abundant growth of grasses. It will then be followed by planting of oil palm or rubber saplings, creating a mosaic of attractive crops for elephants and other crop raiders as explained by Sukumar (1989).

Elephants' occurrence and HEC incidence are spatial phenomena and occur on entire landscapes rather than few habitat patches (Leimgruber et al. 2003). This is consistent with my finding of neighbourhood spatial scale which has more influence on estimating elephant's use of an area for both forest and plantation covariates. Elephants have large home ranges with high fidelity (Fernando et al. 2008). Therefore, occurrence of elephants and HEC are not confined to a particular grid only, but beyond much larger spatial scale. In areas with high HEC incidences, it is important that developments and land use planning take into consideration its impact on neighbouring areas as well.

4.2 Challenges in questionnaire survey

There were some challenges encountered with the use of questionnaire interview for data collection. When asking the question on past elephants' detection, I am assuming the respondents are telling the truth. However, there is also a big possibility that the respondent might be mistaken owing to failing memory to precisely remember elephant's presence (Hedges 2007). For this particular reason, a validation study which requires re-interviewing certain proportion of respondents to cross check with original responses could be done (Tourangeau 2007). Due to limited resources and time, I was unable to conduct this study but should be considered in future interview surveys. Furthermore, as noted by Naughton-Treves and Treves (2005), farmers have a tendency to exaggerate when discussing about HEC. Unlike

other common crop raiders like wild boars and macaques which often cumulatively cause more total damage than elephants, a single event of crop-raiding by elephant could potentially destroy an entire cultivated area including risk of injuring or killing humans (Woodroffe et al. 2005, Hedges 2007). This may distort the perception of conflict creating a hostile impression regardless of occurrence of conflict (Thouless 1994, Inskip and Zimmermann 2009). Such factors can contribute to a distorted perception of conflict (Inskip and Zimmermann 2009). In a study by Chartier et al. (2011), attempts were made to conduct interviews during the lowest conflict season in hope to gain more objective responses. However, as discussed earlier, there is no particular season on the presence of elephants detected and therefore I was not able to attempt similar methods as Chartier et al. (2011) during data collection.

4.3 Suggestions for future work

This study of elephant occupancy should be expanded to nonhuman-occupied-landscapes although it would require of course using a different methodological approach i.e. dung count surveys. This information would be useful in identifying core elephant areas and corridors vital for their continuous movements. The study could also be expanded to look specifically into areas with high HEC intensity to obtain more definite spatial and temporal factors affecting elephant distribution and HEC. Additionally, other information captured in the questionnaire (eg. elephant presence seasonality, types of crop-raiding, crop-raiding seasonality, elephant demography, human or elephant deaths, HEC trends etc.) could be potentially explored further in future surveys to better understand the spatial and temporal trends of elephant presence and HEC.

4.4 Implications for elephant conservation

Various studies have shown the importance of forest fragments in holding considerable conservation value of biodiversity (Mudappa et al. 2007, Sridhar et al. 2008). The importance of forest availability would indicate the need to retain large forests and improve connectivity to facilitate elephants' movement in human-occupied-landscapes (Kumar et al. 2010). Other studies of elephant movement described similar findings amongst elephants moving across the

human- occupied landscapes between protected areas (Douglas-Hamilton et al. 2005, Galanti et al. 2006).

In areas where there is a high degree of forest fragmentation, it is important to preserve these remnants of forest fragments and ensure their connectivity. In addition, improving the habitat quality in these forest fragments through restoration might increase natural forage for elephants and hopefully reduce crop raiding incidences.

The national Central Forest Spine (CFS) master plan is extremely important and it should look into more specific areas of potential elephant corridors to facilitate their movements. The proposed primary and secondary linkages in CFS might not be adequate in providing sufficient connectivity for elephants across these huge landscapes. As such, on the ground surveys should be conducted to identify core areas for corridors. Subsequently, the forest fragments should be maintained rather than converted to major agricultural or other developments to facilitate elephant's movement along these corridors and in an effort to reduce HEC. Furthermore, the proposed goal of embedding the three priority sites (Belum–Temengor, Taman Negara and Endau Rompin) in Managed Elephant Ranges (MERs) mentioned in Section 2.2 of the National Elephant Conservation Action Plan (NECAP) should be realized promptly.

Mitigation efforts such as erecting electric fences without blocking elephant's movements while protecting crops should be in place for areas with high HEC incidences. When designed, placed and maintained well, electric fences have been proven to reduce HEC for some parts of India, Sri Lanka, Africa as well as Peninsular Malaysia (Saaban and Othman 2003, Kioko et al. 2008, Perera 2009). Most importantly, these fences have to be well maintained regularly; as shown in the results, HEC occurrence was irregular and highly unpredictable. At the same time, the level of tolerance amongst villagers or plantation owners should and can be increased through electric fence mitigation efforts in an effort to reduce impacts and loss caused by HEC.

The information on the relationship between human density and threshold, forest fragments and plantation availability is useful to be incorporated in management guidelines and actions with the objective to restore elephant populations and increase their shrinking

distribution. However, if elephants are trapped in high human density areas with blocked movements to adjoining forests or fragments or if all other mitigation efforts fail, translocation might be a necessary last resort to ensure the survival of elephants and maintenance of HEC under levels tolerable by people. However, it is important to note that translocation will not be a useful long-term solution to remove habitual crop-raiders as shown by Fernando et al. (2012). As HEC is a spatial phenomenon occurring beyond the scale of my grids (25 km²), mitigation and management of HEC strategies should be targeted on a broader scale rather than a settlement area. For example, construction of electric fences for crop guarding should be done for all farmers surrounding a HEC area.

A number of studies have reported that African and Asian elephants spend a substantial amount of time outside protected areas (Joshua and Johnsingh 1993, Desai and Baskaran 1996, Douglas-Hamilton et al. 2005, Fernando et al. 2008). Contrastingly, elephants in Peninsular Malaysia don't seem to thrive outside forests and protected areas. A clear example was seen in Sungai Betis and Nenggiri Forest Reserves in Gua Musang (located north of Peninsular Malaysia) where elephants were not detected by many indigenous people I interviewed. Both forest reserves are well known for rampant logging, one of the causes of massive flood destruction in areas of Gua Musang in late 2014 (Mohamed Idris 2015). Possibly, the loud noises produced by logging machines might be repelling elephants from the area. This was consistent with findings by Rabanal et al. (2010) where they found that even low-impact seismic operations would cause considerable temporary habitat loss for species with large ranges like elephants. This might explain why elephants in Peninsular Malaysia are mostly restricted to protected area where anthropogenic disturbances are kept minimal or almost none. Therefore, conservation of protected areas especially the three MERs (Royal Belum State Park, Taman Negara and Endau Rompin) is a critical in ensuring elephants' persistence and survival across the whole landscape.

5. Conclusion

Understanding the distribution of elephants is essential to monitor changes in elephants' range, which can be used as a proxy of population trends (Fernando et al. 2011). This study is the first to produce a distribution map of elephants and HEC in Peninsular Malaysia focusing in human-dominated landscapes. This study revealed an alarming trend whereby 65% of elephant's range within human-dominated-landscapes was lost in the span of 40 years. Meanwhile, HEC in the form of crop-raiding was viewed as the biggest threat to elephant conservation. Efforts should focus on mitigating HEC using electric fence and increasing people's tolerance towards HEC. On the other hand, the occupancy model has shown that the main determinant of elephant's area of use is human density. Elephants could tolerate areas with low density of human presence but avoid these after a threshold was achieved. Similarly, the availability of forests within 225 km² was also an important determinant of elephant's area of use, important for obtaining resources and part of their movement and foraging strategy. Therefore, it is essential to incorporate land-use planning in maintaining forest connectivity in the identified Managed Elephant Ranges to ensure the survival of elephants within Peninsular Malaysia. Furthermore, the use of questionnaire surveys has proven to be a relatively fast and effective way to obtain information about elephant and HEC presence. This study could be repeated after five or ten years to monitor changes in distribution of elephants and HEC. Additionally, complementary follow-up studies should be conducted in forest areas where people are not available for questionnaire interviews.

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Appendices

Appendix 1. Questionnaire translated to the national language, Bahasa Malaysia.

ID: _____ Penemuduga: _____ Tarikh: _____
(Based on grid system)

Lokasi: _____ GPS: U _____ ° T _____ °

1. Berapa lamakah anda telah tinggal di sini? _____ tahun
(‘Here’ refers to this village (not the house); in areas with no elephants the respondent needs to have lived for a minimum of 30 years; in areas with elephants a few years is enough)

2. Adakah gajah liar di kawasan ini sepanjang tahun lepas? Ya Tidak
(This refers to elephants present in the surroundings of this village; ‘Don’t know’ is not a valid answer — in such case change respondent)

Jika ada [yakni, jawapan bagi soalan #2 ialah ‘Ya’]

2.1. Adakah mereka berada di sini selama-lamanya? Ya Tidak (sejak bila? _____ tahun) Tidak tahu

2.2. Bilakah gajah kerap ke sini?

Jan Feb Mac Apr Mei Jun Jul Ogos Sep Okt Nov Dis

Sepanjang tahun Tidak tetap (setiap tahun) Tidak tahu

**If it is seasonal, find info on the type of the season and whether it correlates to any agricultural activity of the farmers in that area.*

2.3. Apakah jenis gajah liar yang berada di sini? Bersendirian Kumpulan kecil tanpa anak (<5 ind.) Kumpulan dengan anak Tidak tahu
(Multiple options are possible)

Jika tiada gajah [yakni jawapan kepada #2 ialah ‘Tidak’]

2.4. Pernahkah gajah berada di kawasan ini dahulu? Ya Tidak Tidak tahu
(Here ‘No’ means they have never been here)

2.4.1. Sekiranya ada gajah dahulu, bilakah kali terakhir mereka berada di sini? _____ tahun dahulu

(Even if the respondent is not very sure about the last time elephants were present, he / she should give some temporal indication: e.g. in grandparents time. **Please convert this into years**)

3. Sepanjang tahun lepas, pernahkah ada kejadian Konflik Gajah Manusia (KGM)?
 Ya Tidak Tak tahu

(HEC[Konflik Gajah Manusia] refers to elephants causing damage on crops, properties, or people; If the respondent doesn't know, change respondent)

Jika ada KGM

3.1. Setakat manakah KGM merupakan satu masalah di kawasan ini?

Tiada Kecil Sederhana Besar

(Remember that we are not asking how much of a problem it is for the person but for the area)

3.2. Apakah jenis KGM yang terjadi di kawasan ini? (di tahun lepas)

Kerosakan hasil pertanian Pemusnahan Rumah
 Kerosakan hartabenda yang lain Bimbang akan keselamatan
 Kerosakan binatang ternakan Kematian and kecederaan
 Lain-lain _____

(Multiple options are possible; Answers not to be read)

3.3. Sepanjang lima tahun yang lepas pernahkah berlaku sebarang kejadian seperti berikut?

Jika ya, berapa?

Kematian orang: Ya _____ Tidak

Kematian gajah: Ya _____ Tidak

(Please read out; deaths refers to HEC-related incidents)

3.4. Pernahkah kejadian KGM berlaku di sini pada suatu masa dahulu?

Ya Tidak (Jika tidak, sejak bila? _____ tahun)

(Even if the respondent is not very sure about the time, he / she should give some temporal indication: e.g. in grandparent's time. Please convert this into years)

3.5. Di kawasan in, KGM sedang: meningkat stabil menurun tidak tahu

Kenapa? _____

(Open-ended question)

3.6. Bilakah serangan ke atas tanaman sering berlaku di kawasan ini?

Jan Feb Mac Apr Mei Jun Jul Ogos Sep Okt Nov Dis

Sepanjang tahun Tidak tetap (setiap tahun) Tidak tahu

**If it is seasonal, find info on the type of the season and whether it correlates to any agricultural activity of the farmers in that area. _____*

3.7. Apakah jenis gajah yang menyerang tanaman di kawasan ini?

Bersendirian Kumpulan kecil (<5 ind.) tanpa anak Kumpulan dengan anak
 Tidak tahu

(Multiple options are possible)

Appendix 2. Plantation questionnaire developed for interviewing plantation managers.

ID: _____ Interviewer: _____ Date: _____
(Based on grid system)

Location: _____ GPS: N _____ ° E _____ °

1. How long have you worked here? _____ years
2. When was the plantation opened here? _____ years.(_____ acres/hectares).
3. What was the landscape before the plantation was opened?
 Cleared Land for agricultural use Forest Forest Reserve Others _____

Have there been wild elephants in this area within the last year? Yes No
(This refers to elephants present in the surroundings of this village; “Don’t know” is not a valid answer — in such case change respondent)

If elephants are present [i.e. if answer to #4 is Yes]

4.1. Have they always been here ? Yes No (since when? _____ years) Dunno

4.2. When are elephants present here?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> All year round <input type="checkbox"/> irregularly (every year) <input type="checkbox"/> Dunno											

4.3. What kind of wild elephants are present? Loners Small groups (<5 ind.)
without young Groups with young Dunno
(Multiple options are possible)

If elephants are not present [i.e. if answer to #4 is No]

4.4. Were there elephants in this area in the past? Yes No Dunno
(Here ‘No’ means they have never been here)

4.4.1 When was the last time that elephants were present? _____ years ago
(Even if the respondent is not very sure about the last time elephants were present, he / she should give some temporal indication: e.g. in grandparents time. **Please convert this into years**)

5. Has there been any HEC incident in this plantation within the last year?
 Yes No Don’t know

(HEC refers to elephants causing damage on crops, properties, or people; If the respondent doesn't know, change respondent)

6. How much of a problem is HEC in this plantation?

- None Minor Moderate Major

6.1 What form(s) of HEC occur in this plantation? (in the past year)

- Crop damage Staff house breaking Equipment damages
 Safety concerns Death and injuries Others _____

(Multiple options are possible; Answers not to be read)

1.2. How do you mitigate HEC in the plantation?

- Use of patrol group Electric Fence Shoot to kill Shoot to deter.
 Collaborate with government officials Others _____

(Multiple options are possible; Answers not to be read)

6.2.1 Is your choice of mitigation technique effective? Yes No No difference
Why? _____

1.3. What is the estimated annual loss of revenue due to HEC? _____

1.4. What is the percentage of this loss in relation to overall profit? _____ %

6.5 Has there always been HEC here? Yes No (if no, since when? _____ years)
(Even if the respondent is not very sure about the time, he / she should give some temporal indication: e.g. in the previous manager's time. **Please convert this into years**)

1.6. In this plantation, HEC is: increasing stable decreasing dunno
Why? _____

1.7. When does crop raiding occur in this area?

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

-

1.8.

- All year round irregularly (every year) Dunno

1.9. What kind of elephants raid crops in this area? Loners Small groups (<5 ind.) without young Groups with young Don't know
(Multiple options are possible)

7.0 Is there a plan for future expansion of the plantation? Yes No Don't know

7.1 What land type would be involved in the expansion?

- Forest Forest Reserve Others _____