



A camera trap study on the spatio-temporal behaviour of Asian elephant (*Elephas maximus*) to mitigate human-elephant conflicts in the Dong Phayayen-Khao Yai Forest Complex, Thailand

*En viltkamerastudie på det spatiala och temporal beteendet av asiatiska elefant (*Elephas maximus*) för att lindra konflikter med människor i Dong Phayayen-Khao Yai Skogskomplex, Thailand*

Adam J. Norton-Turner

Master's thesis • 60 credits

Swedish University of Agricultural Sciences, SLU

Department of Wildlife, Fish, and Environmental Studies

Examensarbete/Master's thesis, 2020:20

Umeå 2020



A camera trap study on the spatio-temporal behaviour of Asian elephant (*Elephas maximus*) to mitigate human-elephant conflicts in the Dong Phayayen-Khao Yai – Forest Complex, Thailand

*En viltkamerastudie på det spatiala och temporala beteendet av asiatiska elefant (*Elephas maximus*) för att lindra konflikter med människor i Dong Phayayen-Khao Yai Skogskomplex, Thailand*

Adam J. Norton-Turner

Supervisor:	Navinder J. Singh, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies
Examiner:	Petter Axelsson, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies
Credits:	60 credits
Level:	Second Cycle, A2E
Course title:	Master's thesis in Biology, A2E – Wildlife, Fish, and Environmental Studies
Course code:	EX0970
Course coordinating dept:	Department of Wildlife, Fish, and Environmental Studies
Place of publication:	Umeå
Year of publication:	2020
Cover picture:	Adam J. Norton Turner, Khao Yai National Park, Thailand
Title of series:	Examensarbete/Master's thesis
Part number:	2020:20
Keywords:	Camera trapping, climate change, conflict mitigation, conservation, <i>Elephas maximus</i> , human-elephant conflict, lunar cycles, relative abundance index, seasons, spatio-temporal behaviour.

Swedish University of Agricultural Sciences

Faculty of Forest Sciences

Department of Wildlife, Fish, and Environmental Studies

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file.

If you are more than one author you all need to agree on a decision. Read about SLU's publishing agreement here: <https://www.slu.se/en/subweb/library/publish-and-analyse/register-and-publish/agreement-for-publishing/>.

YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.

.

Abstract

Human-elephant conflicts (HEC) in Asian elephant (*Elephas maximus*) range countries have been increasing during the past half-century and are a major conservation issue for governments. Research suggests studying the spatio-temporal behavioural patterns of *E. maximus* could indicate behavioural preferences and help mitigate such conflicts. These behavioural preferences could be influenced by factors such as seasonal and lunar cycles, and habitat type. This study aims to determine at what degree these influencing factors are driving *E. maximus* behaviour and HEC. Considering previous studies on seasonal and lunar cycles and habitat utilisation affecting *E. maximus*' behaviour and HEC it asks; How do these factors influence *E. maximus* behaviour and HEC events? Considering these factors, are there any correlations between HEC events and behaviour observed within an adjacent protected forest complex?

HEC event data was obtained from the Wang Mee district; a community adjacent to a protected area, the Dong Phrayayen – Khao Yai – forest complex in Thailand. This community has undergone increasing HEC in recent years. The data was analysed to identify the effects of the aforementioned factors on HEC frequency. Furthermore, camera trap data within the forest complex are also utilised to analyse the effects of these factors on behaviour, such as changes in the observations of *E. maximus*' mean distance to forest borders and habitat utilisation measured with relative abundance index (RAI). Analysis of data indicates a significant correlation between lunar and seasonal cycles and HEC events. HEC events were greater during hot and monsoon compared with the cold season. The RAI of *E. maximus* observations at forest borders were also significantly higher during hot season when compared to RAI at greater distances. First and last quarter moon phases indicated a significant increase in HEC in general. Seasonal and lunar cycles also determined the selection of mixed deciduous forest habitats, indicating a general increase in utilisation during the cold season. Utilisation during the cold season also varied greatly depending on the lunar cycle – increasing during the first quarter and lowest during full moon phases, indicating high variability. The results indicate that studying habitat selection preferences and seasonal and lunar cycles are important factors for park and HEC managers when mitigating conflicts. By understanding *E. maximus*' behaviour and habitat needs managers can better plan for effective management and HEC mitigation.

Keywords: camera trapping, conflict mitigation, conservation, *Elephas maximus*, human-elephant conflict, human-wildlife conflict, lunar cycles, relative abundance index, seasons, spatio-temporal behaviour.

Table of contents

1. List of tables	7
2. List of figures	8
3. Abbreviations	10
4. Introduction	11
4.1. Study Area	13
5. Methods	17
5.1. Camera Trap Study.....	17
5.2. Relative Abundance Index.....	18
5.3. HEC Study	18
5.4. Data Analysis and Statistics	19
6. Results	21
6.1. Human-elephant conflict influenced by seasonal and lunar cycles	21
6.2. Habitat use influenced by seasonal cycles.....	22
6.3. Habitat use influenced by lunar cycles	23
6.4. Mixed deciduous habitat use influenced by the interaction of seasonal and lunar cycles	24
6.5. The Influence of seasonal and lunar cycles on the utilisation of park borders	25
7. Discussion	27
7.1. Tendency for border utilisation and HEC incident density according to seasonal and lunar cycle	27
7.2. Habitat selection by seasonal cycle.....	28
7.3. Habitat selection by lunar cycle	29
8. Conclusion	30
9. References	31

1. List of tables

Table 1; Habitat types of Dong Phayayen-Khao Yai forest complex with corresponding area size (km ²) and percentage cover.....	15
Table 2; A summary of the data obtained during the ten-year camera trap survey divided into each subsequent protected area (PA). Camera trap nights (CTN) are the accumulative nights cameras were placed in each PA. Individual elephant records is the sum of individual elephant counted in each PA. Camera trap locations are the total number of unique camera trap locations in each PA. Total events equal the sum of observations (i.e. triggers of a camera trap) for each PA.	18
Table 3; List of packages used in R statistical software to extract environmental metadata used within the data frame for statistical analysis.....	19
Table 4; The statistical tests utilised for explanatory and response variable. * indicates an interaction between variables in the model.....	20
Table 5; Mixed deciduous forest percentages for this study and Pradhan et al., 2007.	28

2. List of figures

- Figure 1; The five separate protected areas (PAs) making up the Dong Phrayayen-Khao Yai Forest Complex in Thailand. Khao Yai National Park is separated from the other four PAs, Thap Lan, Pang Sida, Dong Yai, and Ta Phraya by the 304-highway dividing the park into two distinguished areas with two separate populations of elephants. Each PA has a different protection designation as indicated in the map legend.14
- Figure 2; Habitat types of DPKY – forest complex: “AG” = Agriculture, “AP” = Airport, “BB” = Bamboo, “DD” = Dry Dipterocarp, “DE” = Dry Evergreen, “EU” = Eucalyptus Plantation, “GR” = Grass, “MD” = Mixed Deciduous, “OC” = Old Clearing, “SG” = Secondary Growth, “TP” = Teak Plantation, “UR” = Urban, “WA” = Water Body. “•” indicate camera trap stations over the ten-year study. .16
- Figure 3; Graph showing the predicted values of HEC incident density (with standard error bars and scaled) modelled as a function of season at the Wang Mee district study site. Results indicate a significant increase in HEC incident density for hot and monsoon season when compared with cold.21
- Figure 4; Graph showing the predicted values of HEC incident density (with standard error bars and scaled) modelled as a function of lunar phase at the Wang Mee district study site. Results indicate a significant increase in HEC incident density for first and last quarter as well as full moon when compared with new moon lunar phase22
- Figure 5; Graph showing the predicted values of relative species index (with standard error bars and scaled) of *E. maximus* modelled as a function of the interaction between habitat type and season in the DPKY – forest complex. Results indicate that mixed deciduous forest (MD) has a significantly higher RAI during the cold season than any other season and habitat type scenario within the data set, signifying the temporal utilisation of this habitat type by *E. maximus*...23
- Figure 6; Graph showing the predicted values of relative species index (with standard error bars and scaled) of *E. maximus* modelled as a function of the interaction between habitat type and lunar phase in the DPKY – forest complex. Results indicate that mixed deciduous forest (MD) has a significantly higher RAI during the first quarter and new moon lunar phases. Results signify the variation in utilisation of this habitat by *E. maximus*.24
- Figure 7; Graph depicting the relative abundance index (with standard error bars and scaled), of *E. maximus* modelled as a function of the interaction between habitat type mixed deciduous forest (MD), lunar phases and season in the DPKY

– forest complex. Results indicate a significant increase in MD utilisation during the cold season with first quarter and new moon lunar phases.....25

Figure 8; Graph depicting the RAI (scaled) of *E. maximus* observations modelled as a function of the interaction between distance and season in the DPKY – forest complex. Results indicate that there is a significant decrease in the distance of observations and an increase in RAI at park borders during hot season when compared with monsoon season.26

3. Abbreviations

AG	Agriculture
BB	Bamboo
CTN	Cameras Trap Nights
DE	Dry Evergreen
DPKY	Dong Phayayen-Khao Yai – Forest Complex
DYWS	Dong Yai Wildlife Sanctuary
GLM	Generalised Linear Model
GR	Grassland
HEC	Human-elephant Conflict
KYNP	Khao Yai National Park
MD	Mixed Deciduous Forest
NP	National Park
PA	Protected Area
PSNP	Pang Sida National Park
RAI	Relative Abundance Index
SG	Secondary Growth
TLNP	Thap Lan National Park
TPNP	Ta Praya National Park

4. Introduction

Conflict mitigation within conservation is a growing topic with Human-elephant conflicts (HEC) at the forefront, especially where these human-wildlife conflicts undermine conservation efforts (Acharya, et al., 2016). HEC have been increasing steadily over the past half-century across all Asian elephant, *Elephas maximus*, range countries; from India (Sukumar, 1989) to South-east Asia. It is one of the most significant conservation issues facing governments and policymakers (Sukumar, 2006). The annual cost associated with crop damages is estimated in the millions of dollars, with people and elephant fatalities consequential (Sukumar, 2006). Thailand is exceptionally impacted by HEC causing many social-ecological issues for protected area managers. The major driving factor in HEC is attributed to substantial fragmentation of natural habitats as elephants leave protected areas in search of food (Santiapillai & Jackson, 1990). During the mid 20th century, Thailand experienced extremely high deforestation peaking in the 1970s as the country converted upland forests into cash crops (Lynam, et al., 2006). Currently, Thailand's available elephant range is estimated at approximately 25000 km² placing the country sixth (of 13) in the rankings of *E. maximus* range countries. The exact total wild population is unknown but estimated between 3000 – 3700 individuals making Thailand's elephants the third largest population (Sukumar, 2006). Thus, this population is extremely important for the conservation of the species placing a lot of global attention on Thailand to preserve them.

Both African elephants (*Loxodonta africana*) and *E. maximus* cause many complex management issues for conservation managers and policymakers due to their ecology. *E. maximus* are mega-herbivores which require vast areas to roam in search of food and water. Research carried out in India (e.g. (Baskaran, et al., 1995); (Williams, et al., 2001); (Sukumar, 2003)) and Sri Lanka (e.g. (Fernando & Lande, 2000)) have estimated the home ranges of *E. maximus* using radio-telemetric studies. These differed significantly from 250-1000 km² for family herds in India and 50-150 km² for the equivalent in Sri Lanka. *E. maximus* forage for 14-19 hrs per day and can consume up to 150kg of vegetation (wet weight) (Vancuylenberg, 1977). They are a highly social species which live in family units (except for bulls which can live in bachelor groups or alone). The basic family units vary from a mother-calf unit (with one or several offspring) to joining other groups creating joint-family units with several adult cows. Where two-four family units frequently associate, they create a 'kin' or bond group, or a clan where several family units or bond groups live in the same area and coordinate their movements. The most extensive formations are sub-populations formed by several clans utilising the same

area to the whole population ((McKay, 1973); (Kurt, 1974); (Sukumar, 1989); (Baskaran, et al., 1995)). Therefore, given this species necessity for access to vast areas for their survival, it is inevitable that HEC transpires.

Despite the differences in spatial utilisation and family group size, another important factor to consider is the habitat types in which *E. maximus* utilise and what drives them to do so. How does this change over time and what factors are causing this change? Furthermore, under which conditional circumstances, considering the afore mentioned, does HEC occur. Does HEC and the utilisation of habitat type under varying climatic/seasonal and lunar cycles correlate? Unfortunately, there is currently little literature available on the spatio-temporal behaviour of *E. maximus* with regards to lunar, seasonal cycles and other environmental factors affecting behaviour which drive HEC. However, there have been some studies indicating higher HEC during certain moon phases suggesting that lunar cycles influence behavioural change (Lamichhane, et al., 2018). Another important aspect for influencing *E. maximus* behaviour is the utilisation of different habitat types according to seasonal change. It has been observed that *E. maximus* select certain habitats according to the season (Pradhan & Wegge, 2007). With that in mind, this study aims to incorporate spatio-temporal behaviour and HEC data to indicate if there are any relationships, i.e. is behaviour and ultimately HEC, influenced by different lunar, seasonal, habitat and climatic factors?

Historic observations by a community HEC manager in the Wang Mee community (and subsequently the HEC research site for this study) bordering Khao Yai National Park, also proposed that HEC events can be predicted by lunar and seasonal cycles (Aphirak Wipawin, *pers. comm.*, 2018). Therefore, I utilise HEC records from this area and hypothesise that;

1. HEC events are significantly correlated to seasonal and lunar cycles.

To further understand the *E. maximus* population in the wider protected area, Dong Phrayayen-Khao Yai – forest complex, I use camera trap data to study the spatio-temporal behaviour and interactions of the population with seasonal and lunar cycles and habitat type. Therefore, this study's hypotheses are as follow;

2. Variations in habitat use by *E. maximus*, as expressed by relative abundance index, are influenced by the interactions between habitat type and seasonal cycles.
3. Variations in habitat use by *E. maximus*, as expressed by relative abundance index, are influenced by the interactions between habitat type and lunar cycles.

4. The tendency of *E. maximus* to utilise park borders as indicated by a decrease in the mean distance of observations towards the boundaries, are influenced by seasonal and lunar cycles.

Finally, this study concludes by comparing the results of the HEC data with the Dong Phrayayen-Khao Yai – forest complex camera trap data to identify any correlations in spatio-temporal behaviour.

4.1. Study Area

Thailand is home to over 100 national parks and many other protected areas (Curtis & Doak, 2012). Khao Yai (KYNP) was the first park to be gazetted a national park, since then a further 204 protected areas (national parks, wildlife sanctuaries and non-hunting areas) have since been designated in Thailand (Lynam, et al., 2006). Eventually, the four protected areas adjacent to KYNP were amalgamated and inscribed a UNESCO World Heritage Site in 2005 (Curtis & Doak, 2012) creating the Dong Phrayayen-Khao Yai Forest Complex (DPKY). The DPKY forest complex comprises five non-contiguous parks, internally fragmented into seven sections by roads and major tracks (Goosem, 1997). DPKY is home to more than 800 species of fauna, including 112 mammal species, 392 bird species and 200 reptile and amphibian species (Curtis & Doak, 2012). Furthermore, it is internationally important for the conservation of 19 threatened, four endangered (including *E. maximus* of which there are an estimated 300 – 350 in the complex and contiguous area) and one critically endangered species (Curtis & Doak, 2012). These protected areas (PA) have experienced a myriad of threats in recent years including Rosewood (*Dalbergia cochinchinensis*) poaching, encroachment, pressures from developing infrastructure (especially roads), tourism and HEC; all of which undermine conservation efforts (Tim Redford, Freeland 2018, *pers. comm*). Therefore, mitigating these impacts are vital to preserving the PA's unique flora and fauna where sound management decisions rely on investigating these issues further.

The DPKY – forest complex is the study site of this project, consisting mostly of tropical and dry evergreen forests with sporadic areas of mixed deciduous and bamboo forest, plantations and secondary forests. DPKY lacks a buffer zone and is subject to encroachment and edge effects altering the ecosystem at the borders. DPKY comprises five protected areas with two subpopulations of *E. maximus* that have not been observed mixing (Tim Redford, Freeland 2018, *pers. comm*). One population lives in KYNP, in a 2165.55 km² tropical evergreen forest surrounded by mixed deciduous forest and some patchy grasslands. This area is separated from the other four protected areas by the 304-highway traversing the complex north to south. The non-contiguous parks situated to the east of the complex comprise of Thap Lan (TLNP), Pang Sida (PSNP) and Ta Phraya (TPNP) National Parks and Dong Yai Wildlife Sanctuary (DYWS), a 3989.45 km² forest mosaic of

predominately tropical and dry evergreen. This area covers nearly twice that of KYNP and would provide a large enough area for several elephant family groups to have a considerable home range, upwards of 1000 km². Adjacent to the north-east of KYNP and partially encroaching its borders lies the community of Wang Mee, a district of villages scattered along the border, with a population size of 6894 (as of 2019) utilising the adjacent area mainly for arable farming of corn, cassava, banana and rice. This area has experienced increasing HEC since 2015 (Figure 1).

DPKY forest complex is a mosaic of different habitat types as depicted in figure 2. The most abundant habitat is dry evergreen forest (DE) (72.1% cover) with scattered mixed deciduous (MD) (7.3% cover) and bamboo forest (BB) (4.2% cover) making the majority of its natural habitats. The forest complex is also subject to human encroachment, including plantations, agricultural (AG) (11.2% cover) and old clearings (OC) (0.6% cover) as indicated in Table 1.

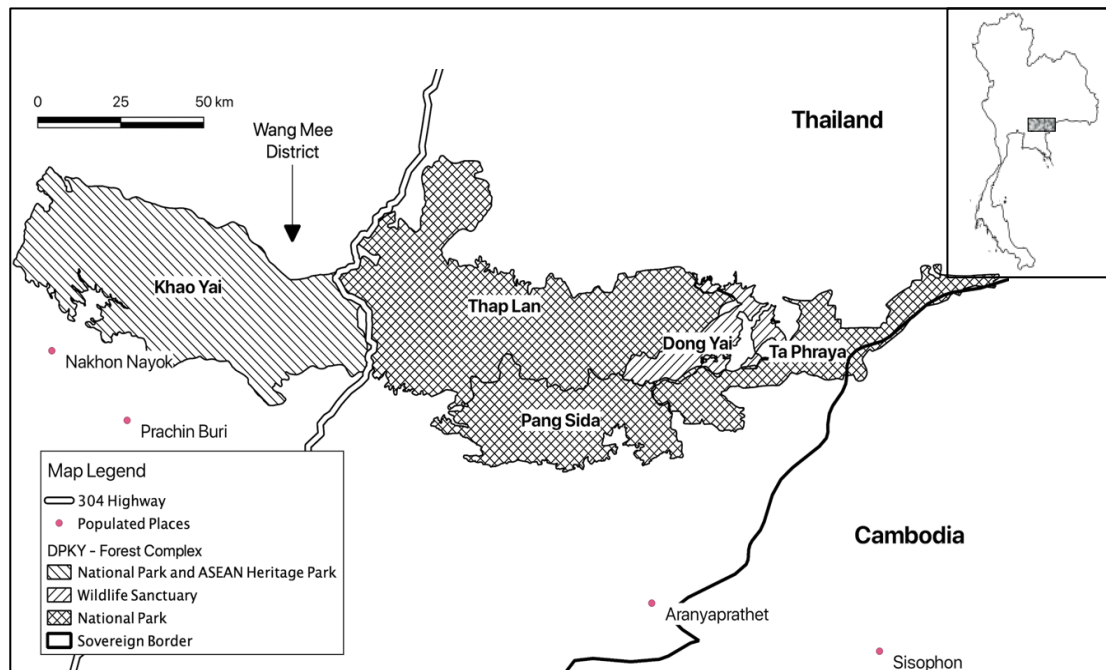


Figure 1; The five separate protected areas (PAs) making up the Dong Phrayayen-Khao Yai Forest Complex in Thailand. Khao Yai National Park is separated from the other four PAs, Thap Lan, Pang Sida, Dong Yai, and Ta Phraya by the 304-highway dividing the park into two distinguished areas with two separate populations of elephants. Each PA has a different protection designation as indicated in the map legend.

Table 1; Habitat types of Dong Phrayayen-Khao Yai forest complex with corresponding area size (km²) and percentage cover.

Habitat	Area km²	% Cover
Dry Evergreen	4467.6	72.1
Agricultural	693.3	11.2
Mixed Deciduous	451.14	7.3
Bamboo	257.4	4.2
Secondary Growth	168.20	2.7
Grassland	66.3	1.1
Old Clearing	34.79	0.6
Water body	29.29	0.5
Teak Plantation	19.43	0.3
Eucalyptus	2.9	0.05
Dry Dipterocarp	1.5	0.02

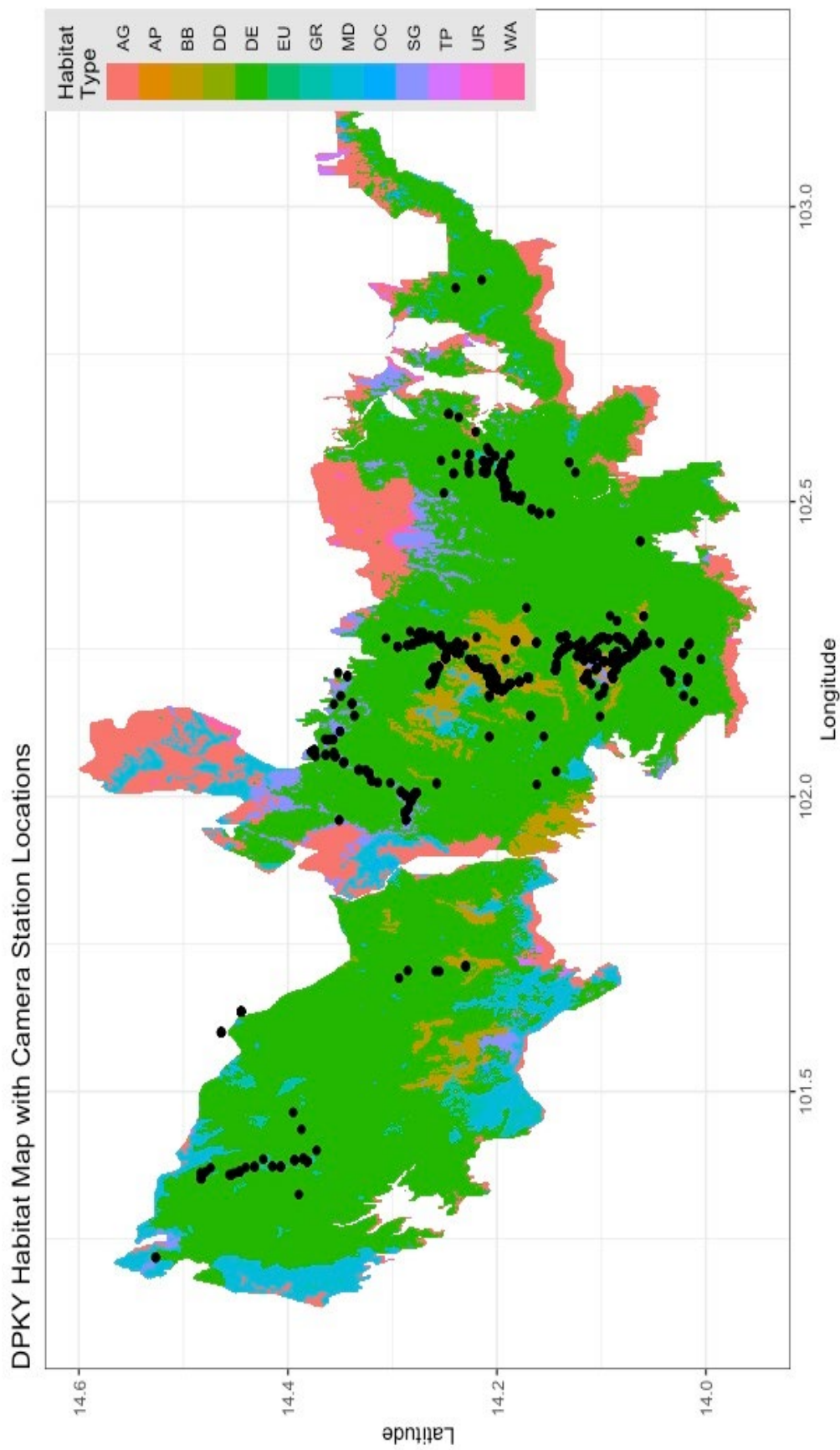


Figure 2: Habitat types of DPKY–forest complex: “AG” = Agriculture, “AP” = Airport, “BB” = Bamboo, “DD” = Dry Dipterocarp, “DE” = Dry Evergreen, “EU” = Eucalyptus Plantation, “GR” = Grass, “MD” = Mixed Deciduous, “OC” = Old Clearing, “SG” = Secondary Growth, “TP” = Teak Plantation, “UR” = Urban, “WA” = Water Body. “•” indicate camera trap stations over the ten-year study.

5. Methods

5.1. Camera Trap Study

A camera trap study throughout the DPKY forest complex was implemented between March 2008 and February 2017. The study's design was highly opportunistic and variable in its spatial and temporal extent due to resource constraints and objectives. The survey was initially designed for an Indo-Chinese tiger (*Panthera tigris corbetti*) presence study and subsequently focused on locations suitable for tigers such as ridgelines, river-valleys, access roads and trails (Karanth, 1995); (Karanth & Nichols, 1998). The surveys commenced in the parks with the highest probability of tiger presence. TLNP and PSNP were the first to be sampled and subsequently expanded to KYNP, DYWS and TPNP as resources became available. The survey's effort consisted of exploratory surveys aimed at determining tiger presence in an area. Surveys were typically running for three months and consisted of semi-permanent to roving surveys. Elephant observation data obtained for this study are subsequently bycatch data, as this was not initially the target species. Despite this, the data contains 2938 entries of elephant observation events, consisting of 6923 individual elephant records over 36890 camera trap nights (CTN) in total. There are approximately 935 unique camera trap locations across the 5 PAs (Table 2). Figure 2 depicts the different habitat types found within the forest complex as well as the camera trap locations indicated by black points on the map.

Table 2; A summary of the data obtained during the ten-year camera trap survey divided into each subsequent protected area (PA). Camera trap nights (CTN) are the accumulative nights cameras were placed in each PA. Individual elephant records is the sum of individual elephant counted in each PA. Camera trap locations are the total number of unique camera trap locations in each PA. Total events equal the sum of observations (i.e. triggers of a camera trap) for each PA.

PA	CTN	Individual elephant records	Camera trap locations	Total events
KYNP	2013	260	51	124
TLNP	16675	3127	458	1479
PSNP	14939	2911	354	1023
TPNP	153	5	4	5
DYWS	3110	620	68	307
<i>Total</i>	<i>36890</i>	<i>6923</i>	<i>935</i>	<i>2938</i>

5.2. Relative Abundance Index

To measure the capture frequency of *E. maximus* observations during the camera trap study, a *relative abundance index* (RAI) can be utilised as the number of sightings per camera trap days (Carbone, et al., 2001); (O'Brien, et al., 2003). RAI readings, therefore, determine the frequency of *E. maximus* for each camera trap station by summing all detections per trapping period and multiplying by 100, then dividing by the total CTN (Jenks, et al., 2011) (Equation 1).

Equation 1; Formula used to calculate the Relative Abundance Index

$$\text{RAI} = \frac{\text{Sum (detections per trapping period)} \times 100}{\text{CTN}}$$

5.3. HEC Study

HEC data was collected in the Wang Mee district by the HEC manager working within the community. An HEC event was defined by the raiding of elephants in the agricultural areas at Wang Mee district, bordering Khao Yai National Park. The level of damage the crops sustained was not considered, it only required that the elephant was seen in the fields or there were tracks leading into them. Upon such

events the manager would be called by the local conflict mitigation teams or locals. Otherwise daily patrols were carried out along the border to look for new tracks. There are several individual elephants who repeatedly commit raids, mostly consisting of bulls and an occasional matriarchal group. The raids have become increasingly more regular since 2015. Data collection was undertaken from May 2015 to October 2018, consisting of 1930 separate events.

The units of HEC in this analysis were measured as number of incidents per calendar month. Therefore, HEC incident density is the sum of events within a month multiplied by 100 and divided by the number of days within that particular month (Smith & Kasiki, 2000). These units were chosen because they allow comparisons to be made with the same month across all years (Equation 2).

Equation 2; Formula used to calculate HEC incident density

$$\text{HEC} = \frac{\text{Sum of HEC incidents (per month)} \times 100}{\text{Days in given month}}$$

5.4. Data Analysis and Statistics

R statistical software (R Core Team, 2013) was utilised for data manipulation and statistical analysis. Specialised R packages enabled the addition of environmental data such as lunar and seasonal cycles and spatial data; topographical and habitat type (Table 3).

Table 3; List of packages used in R statistical software to extract environmental metadata used within the data frame for statistical analysis.

<i>Package name</i>	<i>Comments</i>
camtrapR	Camera trap summaries
suncalc	Lunar Cycles, Day/Night, Sunrise and set.
spatial, rgeos, rgdal	Spatial mapping and Habitat Type

A data frame was constructed of the camera trap data obtained with the addition of the supplementary data mentioned in table 3, aided by specialist packages. Consequently, analyses were run under differing criteria using different statistical methods. The HEC incident density is tested using a generalised linear model (GLM) where HEC is modelled as a function of the interactions between seasonal and lunar cycles. The variation in habitat use according to the interaction with either seasonal or lunar cycles utilised relative abundance index (RAI) as the response variable and tested using a GLM. A GLM was also utilised to analyse the response variable distance as a function of the interaction with lunar and seasonal cycles.

Table 4; The statistical tests utilised for explanatory and response variable. * indicates an interaction between variables in the model.

HEC event data		
<i>Explanatory Variables</i>	<i>Response Variable</i>	<i>Statistical Test</i>
Season	HEC incident density	GLM
Moon	HEC incident density	GLM
DPKY – forest complex camera trap data		
<i>Explanatory Variables</i>	<i>Response Variable</i>	<i>Statistical Test</i>
Habitat * Season	RAI	GLM
Habitat * Moon	RAI	GLM
Habitat (MD) * Moon * Season	RAI	GLM
Distance * Season	RAI	GLM

6. Results

6.1. Human-elephant conflict influenced by seasonal and lunar cycles

HEC incident density is modelled as a function of season to identify any correlations. Figure 3 depicts that season is highly significant for predicting HEC events. HEC is more significantly common during hot season (GLM, model coefficient = 1.27, SE = 0.05, t-value = 27.6, p-value = <0.001) and monsoon season (GLM, model coefficient = 0.37, SE = 0.05 t-value = 7.9, p-value = <0.001) when compared to cold season.

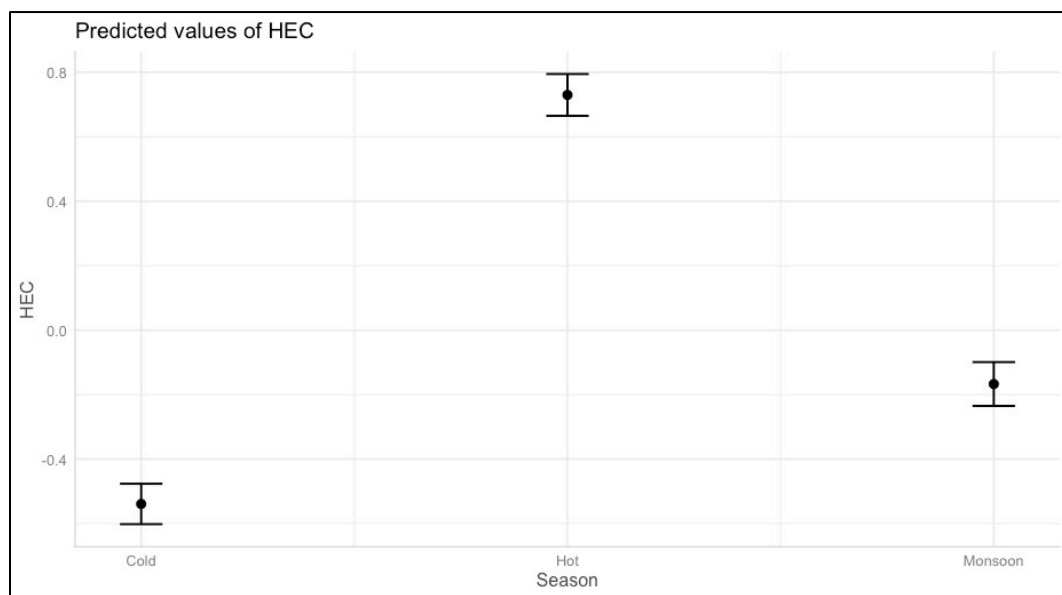


Figure 3; Graph showing the predicted values of HEC incident density (with standard error bars and scaled) modelled as a function of season at the Wang Mee district study site. Results indicate a significant increase in HEC incident density for hot and monsoon season when compared with cold.

Furthermore, HEC incident density and lunar cycles were analysed to identify any correlations. HEC is modelled as a function of lunar cycle and identified significant results. All moon phases display significantly higher HEC event intensity when

compared with new moon phase. First quarter (GLM, model coefficient = 0.8, SE = 0.06, t-value = 12.8, p-value = <0.001), full (GLM, model coefficient = 0.4, SE = 0.06, t-value = 6.9, p-value = <0.001) and last quarter (GLM, model coefficient = 0.73, SE = 0.07, t-value = 10, p-value = <0.001) moon phases indicate high significance (Figure 4).

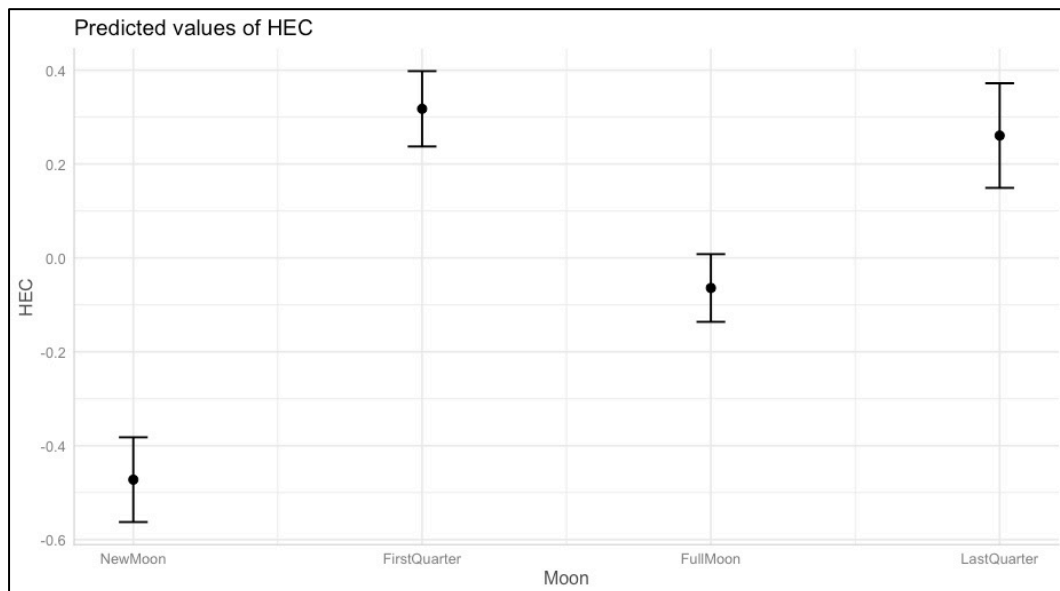


Figure 4; Graph showing the predicted values of HEC incident density (with standard error bars and scaled) modelled as a function of lunar phase at the Wang Mee district study site. Results indicate a significant increase in HEC incident density for first and last quarter as well as full moon when compared with new moon lunar phase

6.2. Habitat use influenced by seasonal cycles

To study the effects of seasonal cycles on *E. maximus* habitat use within the forest complex a GLM was utilised. Figure 5 displays the interaction between habitat use and season. When RAI is modelled as a function of the interaction between habitat and season, there is a significant effect of the interaction between mixed deciduous habitat and cold season (GLM, model coefficient = 2.8, SE = 0.14, t-value = 19.3, p-value = <0.001).

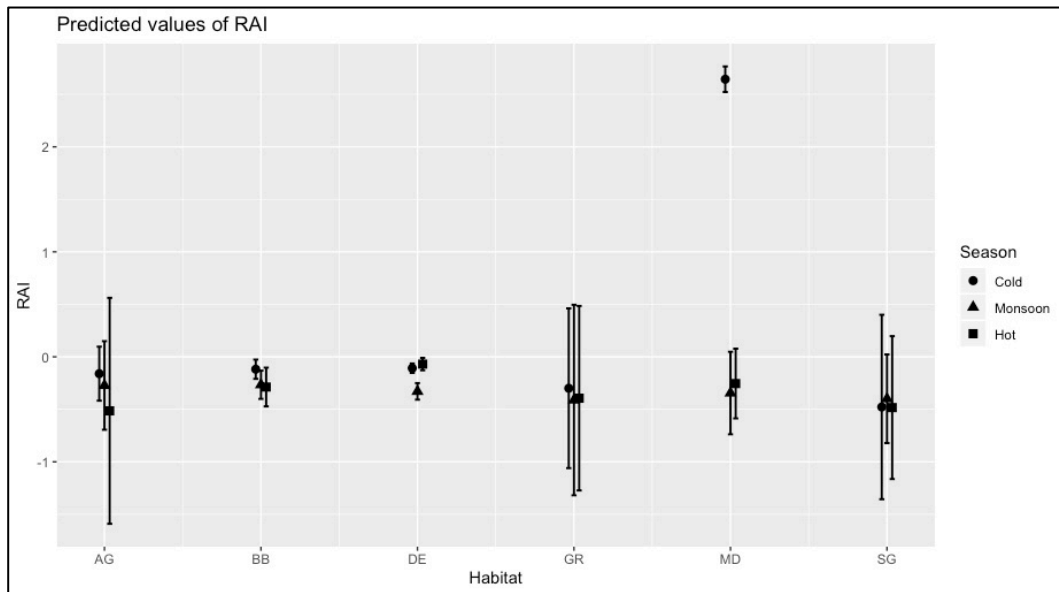


Figure 5; Graph showing the predicted values of relative species index (with standard error bars and scaled) of *E. maximus* modelled as a function of the interaction between habitat type and season in the DPKY–forest complex. Results indicate that mixed deciduous forest (MD) has a significantly higher RAI during the cold season than any other season and habitat type scenario within the data set, signifying the temporal utilisation of this habitat type by *E. maximus*.

6.3. Habitat use influenced by lunar cycles

Modelling habitat use during different lunar cycles within the forest complex indicates significant results. When RAI is modelled as a function of the interaction between habitat and moon phase there is a significant increase in overall MD usage (GLM, model coefficient = 2.8, SE = 0.26, t-value = 10.74, p-value = <0.001). First quarter (GLM, model coefficient = 3.25, SE = 0.37, t-value = 8.9, p-value = <0.001) and new moon (GLM, model coefficient = 2.6, SE = 0.32, t-value = 6.6, p-value = <0.001) phases indicating a significantly higher level of use for MD when compared with full moon lunar phase (Figure 6).

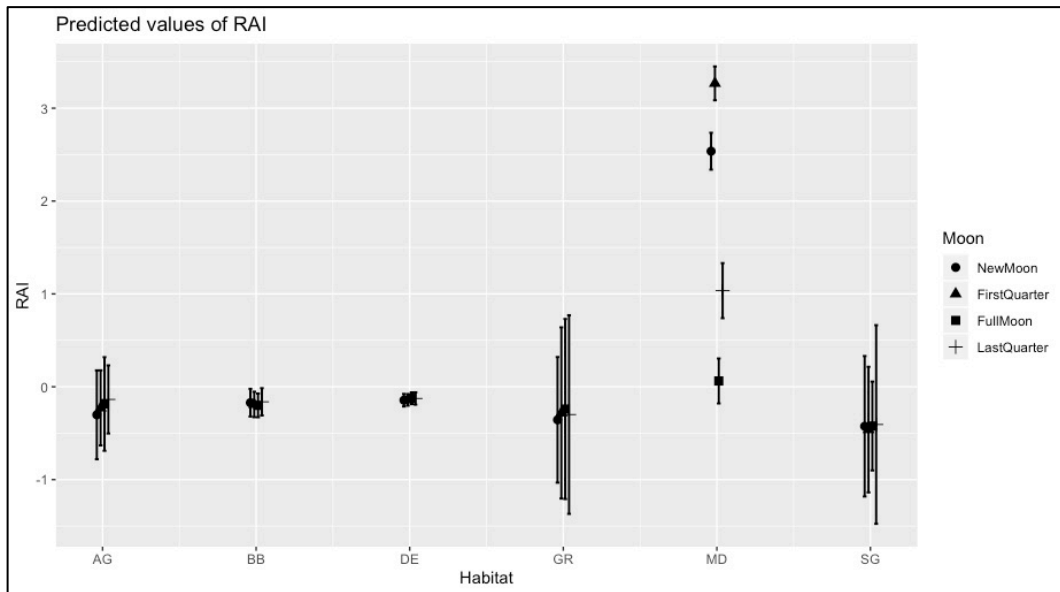


Figure 6; Graph showing the predicted values of relative species index (with standard error bars and scaled) of *E. maximus* modelled as a function of the interaction between habitat type and lunar phase in the DPKY – forest complex. Results indicate that mixed deciduous forest (MD) has a significantly higher RAI during the first quarter and new moon lunar phases. Results signify the variation in utilisation of this habitat by *E. maximus*.

6.4. Mixed deciduous habitat use influenced by the interaction of seasonal and lunar cycles

To identify any significant changes in MD habitat use, the interaction between seasonal and lunar cycles were modelled. RAI was modelled as a function of the interactions between MD habitat type, with season and lunar cycles indicating significant results (Figure 7).

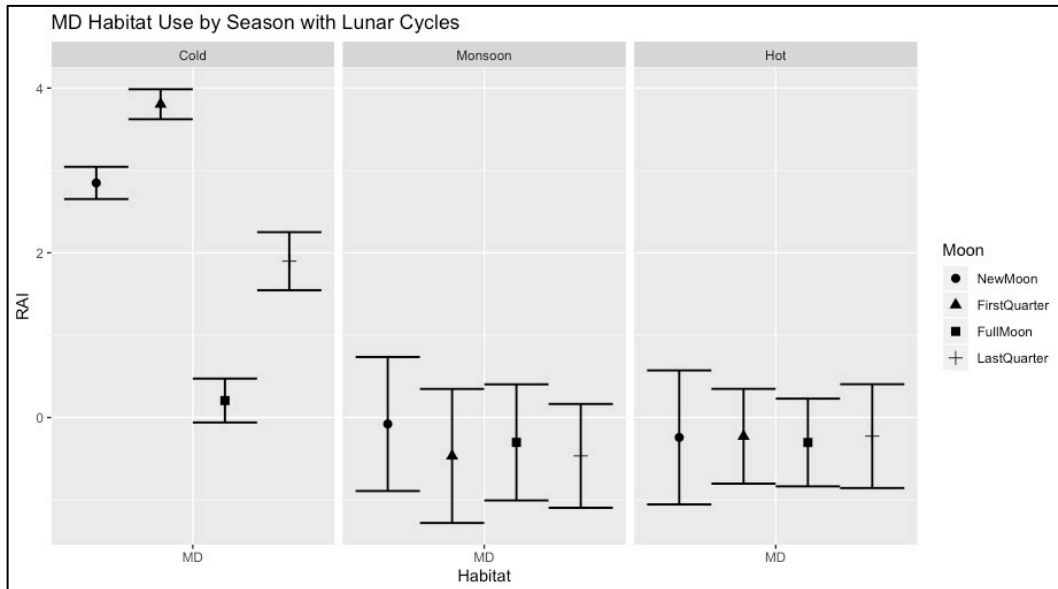


Figure 7; Graph depicting the relative abundance index (with standard error bars and scaled), of *E. maximus* modelled as a function of the interaction between habitat type mixed deciduous forest (MD), lunar phases and season in the DPKY–forest complex. Results indicate a significant increase in MD utilisation during the cold season with first quarter and new moon lunar phases.

Results indicate the significance between the interactions of MD habitat type during the cold season with a significant increase in RAI compared to other seasons (GLM, model coefficient = 2.9, SE = 0.72, t-value = 4.05, p-value = <0.001).

6.5. The Influence of seasonal and lunar cycles on the utilisation of park borders

To understand the tendency of *E. maximus* to utilise park borders, RAI is modelled as a function of the interaction between distance and season. Results indicate hot season show a significant increase in RAI at borders as the mean distance of *E. maximus* observations decreases (GLM, model coefficient = $-2.7e-5$, SE = $1.4e-5$, t-value = -1.86, p-value = 0.06) (Figure 8). However, results indicated no significant influence of border utilisation by *E. maximus* according to lunar phases.

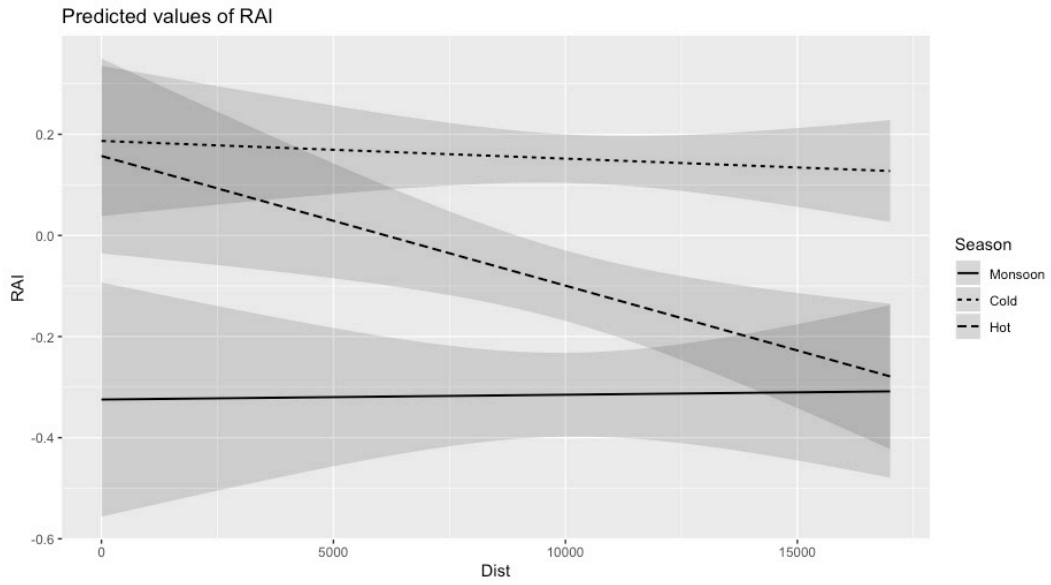


Figure 8; Graph depicting the RAI (scaled) of *E. maximus* observations modelled as a function of the interaction between distance and season in the DPKY – forest complex. Results indicate that there is a significant decrease in the distance of observations and an increase in RAI at park borders during hot season when compared with monsoon season.

7. Discussion

7.1. Tendency for border utilisation and HEC incident density according to seasonal and lunar cycle

HEC incident density results suggest a significant increase during both the hot and monsoon seasons when compared with the cold season (p -value = <0.001) (Figure 3). Results also indicate lunar cycles as having a significant effect on HEC incident density with first quarter and last quarter displaying the highest densities (p -value = <0.001) (Figure 4). A study by Lamichhane et al., (2018) support these results with a study of *E. maximus* conflicts at Chitwan Nation Park, Nepal, with the frequency of conflicts most significant during the full moon and secondly first-quarter moon phases. Therefore, the hypotheses of this study are not rejected indicating that seasonal and lunar cycles have a significant impact on HEC incidents.

The tendency of *E. maximus* to utilise park borders during different seasonal and lunar cycles was also hypothesised in this study. Results from camera trap data indicate that RAI was higher at lower distances to the park border during hot season when compared with monsoon season (p -value <0.06) (Figure 8). Therefore, the hypothesis for seasonal border utilisation is not rejected indicating some significance. Regarding changes in border utilisation during different lunar phases, results indicate that there is no statistical significance thus we reject this hypothesis.

Furthermore, when comparing the seasonal cycle results for both HEC incident density and the distance to park borders from camera trap data results, a relationship can be identified. It is during hot season that both the utilisation of park borders (Figure 8) and HEC incident density (Figure 3) are highest. These results indicate that there is a tendency for *E. maximus* to move towards the borders and subsequently into agricultural areas during these periods causing HEC. The opposite is also true, during monsoon season HEC incidents and utilisation of borders lower. These results ultimately disclose that HEC events are predictable by use of camera trap data, thus helping protected area managers plan for and counter HEC in contiguous areas.

7.2. Habitat selection by seasonal cycle

A similar study to this was undertaken by Pradhan & Wegge (2007) studying *E. maximus* utilisation of mixed deciduous forests according to seasonal cycles. Despite the differences in classification and slight variations in dominant tree species between the study sites of Pradhan's and this study, *E. maximus* were observed to highly select these habitats during the cold season even though they represent a small percentage of the total area in each study (Table 5).

Table 5; Mixed deciduous forest percentages for this study and Pradhan et al., 2007.

Author	Mixed Deciduous Forest %	Protected Area
Norton Turner, 2020	7.3	DPKY – Forest Complex, Thailand
Pradhan et al., 2007	18	Bardia National Park, Nepal

The cause for the overrepresented selection of mixed deciduous forests is due to their diets. *E. maximus* eat a variety of plants with over 100 different species comprising an array of plant family groups including; *Fabaceae* (legumes), *Poaceae* (grasses), *Cyperaceae* (sedges), *Palmae* (palms), *Euphorbiaceae* (spurges), *Rhamnaceae* (buckthorn) and *Malvales* (mallows, sterculias and basswoods) (McKay, 1973); (Sukumar, 1989). These groups can differ in quantities consumed depending on whether they live in tropical dry or moist forests. *E. maximus* living in moist forests (such as rainforests) diets are comprised entirely with browse and fruits. DPKY forest complex, however, is a tropical dry forest, and therefore the population's diet comprises of ca. 70% browse in the dry season and grasses in the wet season when they become plentiful (Sukumar, 1989). Tree bark is also an important food source as it provides roughage and contains essential minerals such as calcium. Joshi & Singh (2008), studied the feeding behaviour of *E. maximus* in the Rajaji NP and witnessed the population extensively feeding on *Acacia catechu*, *Lagerstroemia parviflora*, *Ehretia laevis*, *Dalbergia sissoo*, *Tectona grandis* and *Aegle marmelos* deciduous plant species, synonymous to mixed deciduous forests. They also studied periods when *E. maximus* fed on these species, including which parts of the trees were favoured. *A. catechu*, *D. sissoo* and *T. grandis* were utilised by *E. maximus* during the cold season and predominantly stripped of bark during feeding, indicating the importance of mixed deciduous forests during this season reinforcing the hypothesis of this study. Therefore, the variations in habitat use by *E. maximus* are influenced by the interactions between habitat type and seasonal cycles. As the results indicate, when RAI is modelled as a function of the interaction between habitat and season, there is a significant increase in MD use during the cold season (p-value = <0.001) (Figure 5 and 7 indicate habitat use by *E. maximus* according to season).

7.3. Habitat selection by lunar cycle

The selection of mixed deciduous forests by *E. maximus* according to lunar cycle revealed some significant results. Utilisation of this habitat was most significant during first quarter and new moon phases (p-values = 0.001) indicating the effects of lunar cycles on *E. maximus* behaviour (Figure 6). MD habitat utilisation also varied significantly during cold season and moon phases within that same season (p-value = 0.001) (Figure 7). There is no literature available where the study of habitat selection according to moon phase has undergone for *E. maximus* for comparison. However, it has been reported that the temporal component of mammal activity, incorporating moon illumination, provides important insights into the management of large mammal species in protected areas (Bhatt, et al., 2018). If park managers understood the temporal activity of its inhabitants coupled with the habitats they require, better management decisions would result. *E. maximus* are required to travel large distances to search for food and water, however, within the confines of a protected area resources can become scarcer as *E. maximus* populations grow coupled with the increasing threats upon the ecosystem such as anthropogenic and climatic sources. Park managers must fully understand the carrying capacity of the park and strive to enhance this by enriching important habitats such as mixed deciduous forests. We may not fully understand why *E. maximus* utilise this habitat according to lunar cycle conditions, but it is evident that this habitat is important. Covering only 7.3% of the DPKY forest complex, mixed deciduous forests have a lot of space for expanding. HEC is a major cause for concern for *E. maximus* range countries and it may not be a coincidence that HEC incident density is less during cold season, as highlighted by this study. By increasing the extent of important habitats within the park, HEC could be mitigated. For example, grassland habitats are selected for during the wet season (Sukumar, 1989) and could help mitigate conflicts during that season.

8. Conclusion

The current study's results suggest that seasonal and lunar cycles are significantly correlated with HEC incidents. It has also successfully highlighted the tendency of *E. maximus* to utilise the protected area's borders during the same seasonal and lunar conditions as heightened HEC incidents were observed. Therefore, by means of camera trap data utilisation from inside a protected area it is possible to monitor the movements of large mammal species achieving a greater understanding of their behaviour. By understanding these species spatio-temporal behaviour it could help aid managers in planning for mitigating human-wildlife conflicts in contiguous areas. Habitat type also plays a significant part in maintaining regular water availability. *E. maximus* seek grassland habitat during hot and dry periods. Therefore, the augmentation of this habitat within the park would help alleviate drought stress on many species and could help retain the *E. maximus* population within the park during the hot season, a time when HEC incident density is highest. Another extremely important habitat highlighted by the current study was mixed deciduous forest. The use of mixed deciduous forest by *E. maximus* was extremely significant to specific seasonal and lunar cycles, indicating the requirement of this habitat according to certain temporal conditions. These seasonal needs have been studied prior to this study and are inextricably associated to diet. However, the variations in utilisation of mixed deciduous forest habitat according to lunar cycle are unclear and require further research to establish a better understanding. The current study highlights the importance of incorporating lunar cycles into movement and activity patterns of *E. maximus* especially when HEC are an increasing phenomenon, to fully understand their spatio-temporal behaviour and mitigate conflict.

9. References

- Acharya, K., Paudel, P., Neupane, P. & Köhl, M., 2016. Human-Wildlife Conflicts in Nepal: Patterns of Human Fatalities and Injuries Caused by Large Mammals. *PLOS ONE*, 11(9).
- Baskaran, N., Balasubramaniam, M., Swaminathan, S. & Desai, A., 1995. Home range of elephants in the Nilgiri Biosphere Reserve, South India. *In A week with elephants: proceedings of the international seminar on the conservation of Asian elephant*, June. Volym 296–313.
- Bhatt, U., Habib, B., Sarma, H. & Lyngdoh, S., 2018. Catch me if you can: Species interactions and moon illumination effect on mammals of tropical semi-evergreen forest of Manas National Park, Assam, India. *bioRxiv*.
- Carbone, C. o.a., 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation*, 4(1), pp. 75-79.
- Curtis, T. & Doak, N., 2012. *UNESCO World Heritage 36 COM. Item 7 of the Provisional Agenda. Report on The Mission to Dong Phrayayen – Khao Yai Forest Complex*. Bangkok, IUCN.
- Fernando, P. & Lande, R., 2000. Molecular genetic and behavioral analysis of social organization in the Asian elephant (*Elephas maximus*). *Behavioral Ecology and Sociobiology*, 48(1), pp. 84-91.
- Goosem, M., 1997. Internal fragmentation: the effect of roads, highways, and powerline clearings on movements and mortality of rainforest vertebrates. i: *Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities*. Chicago: University of Chicago Press.
- Jenks, K. o.a., 2011. Using Relative Abundance Indices from Camera-Trapping to Test Wildlife Conservation Hypotheses – An Example from Khao Yai National Park, Thailand. *Tropical Conservation Science*, 4(2), pp. 113-131.
- Joshi, R. & Singh, R., 2008. Feeding behaviour of wild Asian Elephants (*Elephas maximus*) in the Rajaji National Park. *The Journal of American Science*, 4(2).
- Karanth, K., 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture—recapture models. *Biological Conservation*, 71(3), pp. 333-338.
- Karanth, K. & Nichols, J., 1998. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, 79(8), pp. 2852-2862.

- Kurt, F., 1974. Remarks on the social structure and ecology of the Ceylon elephant in the Yala National Park. *In The behaviour of ungulates and its relation to management 2*, p. 618–634.
- Lamichhane, B. o.a., 2018. Spatio-temporal patterns of attacks on human and economic losses from wildlife in Chitwan National Park, Nepal. *PLOS ONE*, 13(4).
- Lynam, Round & Brockelman, 2006. Status of Birds and Large Mammals in Thailand's Dong Phrayayen - Khao Yai Forest Complex. *Wildlife Conservation Society and Biodiversity Research and Training (BRT) Programme, Bangkok*, p. 244pp.
- McKay, G., 1973. Behavior and ecology of the Asiatic elephant in south-eastern Ceylon. *Smithsonian Contributions to Zoology*, Issue 125, pp. 1-113.
- O'Brien, T. G., Kinnaird, M. F. & Wibisono, H. T., 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, Volym 6, pp. 131-139.
- Pradhan, N. M. B. & Wegge, P., 2007. Dry season habitat selection by a recolonizing population of Asian elephants *Elephas maximus* in lowland Nepal. *Acta Theriol*, Volym 52, p. 205–214.
- R Core Team, 2013. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna: u.n.
- Santiapillai, C. & Jackson, P., 1990. The Asian Elephant: An Action Plan for Its Conservation. *IUCN-SSC Action plans for the conservation of biological diversity*.
- Smith, R. & Kasiki, S., 2000. *A spatial analysis of human-elephant conflict in the Tsavo ecosystem, Kenya. A Report to the African Elephant Specialist Group, Human-Elephant Conflict Task Force, of IUCN*, Gland, Switzerland: IUCN.
- Sukumar, R., 1989. *The Asian Elephant: Ecology and Management*. u.o.:Cambridge University Press.
- Sukumar, R., 2003. *The living elephants*. New York: Oxford University Press.
- Sukumar, R., 2006. A brief review of the status, distribution and biology of wild Asian elephants *Elephas maximus*. *International Zoo Yearbook*, Issue 40, pp. 1-8.
- Vancuylenberg, B., 1977. Feeding behaviour of the asiatic elephant in South-East Sri Lanka in relation to conservation. *Biological Conservation*, 12(1), pp. 33-54.
- Williams, o.a., 2001. Elephant-Human Conflicts in Rajaji National Park, North-western India. *Wildlife Society Bulletin (1973-2006)*, 29(4), pp. 1097-1104.

Appendix 1



*A pair of *E. maximus* prior to a raid.*



A young bull waiting near KYNP's border.



A healthy and well-nourished individual.



Another healthy individual observed at border.

Latest issue number in our series Examensarbete/Master's thesis

- 2020:7 Downstream migration and survival of Atlantic salmon (*Salmosalar L.*) kelts and fallbacks when passing a hydropower plant
Author: Frans Byström
- 2020:8 Nocturnal moths use of novel habitats – A case study on a power line in a forest-mire mosaic in boreal Sweden
Author: Oskar Lövbom
- 2020:9 Not everything that glitters is gold: Does linear infrastructure create an ecological trap for Golden Eagles?
Author: Michelle Etienne
- 2020:10 Comparative movement behaviour and habitat selection of semidomestic herbivore: Central-place grazing versus free-range grazing in Reindeer (*Rangifer t. tarandus*)
Author: Muhammad Fawad Sharif
- 2020:11 How does species density affect activity patterns of three sympatric ungulate species in a Scandinavian boreal forest?
Author: Linda Zetterkvist
- 2020:12 The importance of Ecoparks for saproxylic beetles – A study on general ecological hypotheses in differently managed landscapes
Author: Albin Larsson Ekström
- 2020:13 Restoration strategies in boreal forests – Prescribed burning and gap cutting effects on plant diversity and community composition
Author: Clara Espinosa Del Alba
- 2020:14 Moose movement speed and home range during the rutting season
Author: Irene Hjort
- 2020:15 The direct and indirect relation between ungulates on small mammals
Author: Michael Wentzel
- 2020:16 The effect of the interplay between fire frequency and grassland structure on tick abundances in the Hluhluwe-iMfolozi Park, South Africa
Author: Thilo Heinecke
- 2020:17 Movement activity and space use – how does the moose react when the tourists come?
Author: Nora Höög
- 2020:18 Anti-predatory responses of white rhinoceros (*Ceratotherium simum*) to simulated risk. Does poaching create a landscape of fear?
Author: Daniel Gamba Caravantes
- 2020:19 Eyes in the nest – Breeding phenology of Golden Eagles characterized using remote cameras
Author: Richard Larsson