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The Direct and Indirect Impacts of Logging on Mammals in Sabah, Borneo

Amy Fitzmaurice

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DECLARATION OF OWN WORK

I declare that this thesis, “The Direct and Indirect Impacts of Logging on Mammals in Sabah, Borneo,” is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature

Name of student	Amy Fitzmaurice
Name of supervisor(s)	Robert Ewers Marcus Rowcliffe Ana Nuno

amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

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List of acronyms

AF	Amy Fitzmaurice
CBD	Convention of Biological Diversity
CITES	Convention of International Trade of Endangered Species
JT	Josh Twining
KFR	Kalabakan Forest Reserve
MP	Maria Peni
MSK	Min Sheng Khoo
MS	Madani Samad
OW	Oliver Wearn
RF	Riparian forest
RG	Ryan Grey
SB	Sabri Bationg
SAFE	Stability of Altered Forest Ecosystems Project
SEARRP	South East Asia Rainforest Research Programme
SSC	Single sample count
UCT	Unmatched count technique
VJR	Virgin jungle reserve
WWF	World Wildlife Fund

amy.v.fitzmaurice@hotmail.co.uk

Abstract

The threats to biodiversity in South East Asia include selective logging for timber and clear felling for oil palm, and wildlife hunting for subsistence and for trade markets. The conservation value of these degraded logged forests before conversion to oil palm in Sabah, Borneo, for threatened biodiversity has been poorly studied and wildlife hunting is a difficult topic to research due to its sensitivities, therefore there is a lack of data.

This project evaluated the impacts of logging on mammals.
(i) indirect impacts - interview based questionnaires used to gather baseline data from local people about wildlife knowledge, perceptions about wildlife and local activities affecting biodiversity, and wildlife hunting by local people.
(ii) direct impacts - differences in community composition, species richness and species occupancy along a logging gradient to develop 'zones of disturbance', using randomised camera trap data of species and wildlife hunting activity, logging bulldozer data and logging extraction data.

Local people's knowledge about local wildlife was low, with 36% of respondents (n = 112) correctly identifying local species. Only 7 respondents admitted to hunting recently and 20 respondents had hunted. Logging was the main activity that was stated to be affecting biodiversity, followed by farming and wildlife hunting. The zones of disturbance logging activities and wildlife hunting were shown to impact species presence, with some species only occurring in green zones (currently unlogged forest), such as stink badger *(Mydaus javanensis)* and some species only occurring in red zones (high logging activity), including species of conservation concern, such as Sunda clouded leopard *(Neofelis diardi)* and Sunda pangolin *(Manis javanica).* The occupancy analysis and zones of disturbance show that the majority of species may be tolerant of logging and wildlife hunting disturbances, such as Sambar deer *(Rusa unicolor).* Species tolerance to disturbance during logging needs further investigation to provide valuable information for logging concession management plans and species action plans to reduce disturbance and highlight if these degraded forests have conservation value.

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amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

1. Introduction


The female wild boar killed by explosives.

Barbaric bombing of wild boar in Wildlife Sanctuary

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Biodiversity is threatened globally by a variety of factors, of which the majority are anthropogenic demands on the Earth's natural resources (Gavin et al. 2010). Many of these threats stem from human behaviour, such as logging for timber, clear felling for oil palm plantations and wildlife hunting for subsistence. For some species, the threat is caused by the global demand for certain products, for example, pangolin scales (Wyatt, 2013). Mascia et al. (2003) stated that "Biodiversity conservation is a human endeavor: initiated by humans, designed by humans and intended to change human behaviour." and Balmford and Cowling (2006) noted, "Conservation is primarily not about biology but about people and the choices they make." There is a need to better understand the impacts and drivers of human behaviour on biodiversity and other people. Resultantly, this project investigated both the direct and the indirect impacts of logging on mammals and their tolerance of disturbance in Sabah.

One major cause of biodiversity loss is wildlife subsistence hunting for food, but other wildlife is sold due to the incentives that the wildlife trade offers, such as rhino horn. There is evidence of species extinction from hunting, and historical evidence of species decline to present day (Wyatt, 2013). For example, Shepherd (2012) found common palm civets *(Paradoxurus hermaphroditus)* being sold at markets to supply the demand for civet coffee, which may be causing a decline in this species. The drivers of non-sustainable hunting have been widely documented, such as subsistence hunting and wildlife trade for pets or medicines (Wyatt, 2013). Road expansions cause forest fragmentation and easier access to wildlife. Increased technology is leading to higher demand for wildlife moving from subsistence hunting into commercial (Poulsen et al. 2009). Another two major causes of habitat and biodiversity loss are selective logging for timber and clear felling for oil palm plantations. Habitat and biodiversity loss comes from destruction and disturbance of tropical forests by bulldozers to increase logging access to reach high value trees (Bernard et al. 2009).

In 2005, the global legal wildlife trade of species was worth US $21 billion (Engler and Parry-Jones, 2007) and in 2009, US $324 billion (TRAFFIC, 2009). The global illegal trade of species is estimated between US $5 billion to $20 billion a year. It is argued that the legal wildlife trade is facilitating the illegal trade (Wyler and Sheikh, 2008). IFAW (2013) ranked illegal wildlife trade as the fourth largest global illegal activity after narcotics, counterfeiting and human trafficking, ahead of oil, art, gold, human organs, small arms and diamonds (Fison, 2011).

In 2005, a third of global forests (1.3 billion hectares) were designated for timber production to be selectively logged. Global deforestation in the tropics comes from the demand for palm oil. Coverage ranges from 1% to 20% of land throughout Sabah, which is the highest in Malaysian Borneo (Fitzherbert, 2008), with the demand expected to double by 2020 (STI, 2014). Globally, there is currently little evidence of species extinction from selective logging and clear felling for oil palm, though abundant data shows local extinctions and noticeable species declines (Gardner, 2010). For example, Felton et al. (2003) reported adult orangutan *(Pongo pygmaeus)* numbers in Kalimantan, Indonesian Borneo, were lower in selectively logged peat forests than intact neighbouring sites. Logging not only affects large mammals, but also small mammals, where Emmons (2000) showed that treeshrew species are severely affected by logging.

Previous research investigating wildlife hunting within oil palm and logging landscapes is sparse. Previous literature does show that logging correlates with wildlife hunting, due to increased access to forests from roads, allowing vehicle access and intensification of wildlife hunting because vehicle use allows for more animals to be removed and mobility reduces detection by enforcement (Poulsen et al. 2009; Wyatt, 2013) For example, Poulsen et al. (2009) showed that the development of logging led to a 69% increase in populations of five logging towns in Congo, leading to a 64% increase in bushmeat hunting. Poulsen et al. (2011) found that both logging and hunting have strongly disturbing effects on African species, with pig and ape populations being reduced.

There is little previous published literature investigating both logging and wildlife hunting simultaneously and there has been no previous published literature investigating logging activities in relation to community composition, species richness, and species occupancy while logging is happening. This project investigated the direct and indirect impacts of logging on mammal species in Sabah, Malaysian Borneo, at the Stability of Altered Forest Ecosystems Project. SAFE is the world's largest ecological experiment examining the impact of tropical deforestation and forest fragmentation on biodiversity and ecosystem processes (Ewers et al. 2011; Turner et al. 2012; Struebig et al. 2013). As part of the SAFE project, approximately 8,000 ha of forest is currently logged prior to outright conversion to oil palm plantation. This presented the unique opportunity of investigating the direct impacts of logging while logging of tropical rainforest is occurring to understand the differences in mammal occupancy along a logging gradient and their tolerance to disturbance.

This project investigated the indirect impacts of logging, specifically wildlife hunting by local people to obtain baseline data for the area, through interview based questionnaires. This baseline data is vital for future enforcement teams to better manage their time and to focus their efforts on areas known for wildlife hunting and for policy and management plans at state levels (St John et al. 2013). Direct impacts of logging were investigated by carrying out camera trapping and collecting bulldozer GPS and logging extraction data. Studies have focused on comparing before and after logging, but the question addressed here is the impact logging activities have during logging and how tolerant species are to the levels of disturbance from logging and wildlife hunting. To reduce the impacts of logging and wildlife hunting in the future, in depth knowledge of species tolerance to disturbance and the differences in community composition, species richness and species occupancy along a logging gradient, as well as the type and quantity of wildlife hunting occurring in which areas (and whether it correlates with logging) can assist in developing buffer zones (from mapping the zones of disturbance) in future logging concession management plans and assist wildlife enforcement teams. This valuable information can be used by South East Asia Rainforest

amy.v.fitzmaurice@hotmail.co.uk

Research Programme (SEARRP) and local NGOs when developing species management plans in relation to land development and species action plans in relation to national and international conservation targets.

1.1 Project aims

The focus of this research is to investigate socio-demographic background and knowledge and perceptions of local people in Sabah about wildlife hunting, and to investigate community composition, species richness, and species occupancy along a gradient of disturbance in relation to logging impacts of bulldozer movements, logging extraction and wildlife hunting to develop zones of disturbance.

Aim 1. What are the potential indirect impacts of logging, specifically through wildlife hunting, on mammal species in Sabah?

To answer this question, the following hypotheses were tested:

1. Respondents' knowledge of animals will be significantly affected by the socio-demographics of respondents.
2. Respondent knowledge will be higher for species that are known to be hunted in South East Asia and Borneo.
3. The 'zones of disturbance' will show that wildlife hunting is occurring in areas that are heavily logged.

Aim 2: What are the direct impacts of logging on mammal species during logging in Sabah?

To answer this question, the following hypotheses were tested:

1. The majority of species will be intolerant of disturbance, based on previous literature.
2. The 'zones of disturbance' will show that logging activities are affecting mammal occupancy along a disturbance gradient.

2. Background

© Amy Fitzmaurice (forest fragment within an oil palm landscape) (2014)

The direct impacts of logging and the indirect impacts of logging, specifically wildlife hunting are threatening biodiversity globally and particularly in South East Asia and Borneo (Garbutt and Prudente, 2008; MacDonald and Willis, 2013; Wyatt, 2013). This project will provide new insight into mammal tolerances to the impacts of logging at the SAFE project on a short-term basis, by providing unique mapping of the 'zones of disturbance'. These zones will highlight the degree of tolerance mammals have to the proximity and intensities of the logging and wildlife hunting activities. Mapping these zones has not been conducted in previous literature.

2.1 Wildlife hunting in Borneo

2.1.1 History of wildlife hunting

Mammal species known to be hunted for trade in Borneo are Sumatran rhinoceros *(Dicerorhinus sumatrensis)* due to the recent rhino horn boom, Sunda pangolin *(Manis javanica),* Bornean orangutan *(Pongo pygmaeus),* sun bear *(Helarctos malayanus)* (Meijaard and Sheil, 2008), and Sunda clouded leopard *(Neofelis diardi).* Mammal species known to be hunted for meat (subsistence) are ungulates (Garbutt and Prudente, 2008). Species reported to be hunted, that have been recorded at the SAFE project are listed in Appendix II, 1. Rigg (2006) states that livelihood options for forest people now are economic market-based rather than forest-subsistence-based. Hunting has been increasing in Borneo in recent years, particularly in Kalimantan and Sabah, where WWF and the Malaysian Government's Sabah Wildlife Department are starting a wildlife enforcement team during 2014 to monitor wildlife hunting (Fitzmaurice, 2014). Malaysia is a signatory to the CITES agreement and should be working towards the new Aichi targets of the CBD (CBD, 2014) to reduce threats to endangered and protected species.

2.1.2 Reasons for hunting

Both subsistence and trade hunting are reported to occur in Borneo (WWF, 2014). For example, rhino and pangolin trades are at levels that are drawing conservation attention (Wyatt, 2013), where recently Sabah Wildlife

amy.v.fitzmaurice@hotmail.co.uk

Department teamed up with Lush to reduce pangolin trade (Mongabay, 2014). In Malaysian Borneo, pangolins can be sold for a minimum of US $25, where this is an incentive since many people earn under US $222 per month (Bationg, 2014). Wildlife hunting for subsistence is often done in forest areas, due to the remoteness and lack of access to buy food (Wyatt, 2013).

2.1.3 Ecological consequences of hunting

The majority of species of interest in this project are illegal to hunt, although some can be hunted with permits, such as pig, muntjac and mousedeer (Kawanishi et al. 2008; Timmins et al. 2008a; Timmins et al. 2008b). Illegal wildlife hunting is a growing global concern and wildlife crime is a current target for United for Wildlife (UFW, 2014).

The loss of species within an ecosystem has ecological consequences on forest dynamics (Poulsen et al. 2009). Meijaard and Sheil (2008) state that hunting is likely to change species in several aspects, from densities and distribution to demographics and thus can affect community dynamics. Meijaard et al. (2011) found through interview based surveys in Kalimantan, Indonesian Borneo, that between 750-1800 Bornean orangutans were killed between 2008 to 2009, suggesting hunting could be a serious threat to this species in Kalimantan. Struebig et al. (2007) found in Kalimantan, Indonesian Borneo, flying foxes are hunted, estimating from interviews with hunters and traders that 4,500 individuals were extracted in 30 days from a single location, which could cause severe population declines. Furthermore, Harrison et al. (2013) found excessive hunting led to defaunation and changed tree recruitment dynamics in Borneo, in turn affecting other fauna.

An associated problem with wildlife hunting is by-catch killing of non-target species. For example, Luskin et al. (2014) found that gibbons were sometimes by-catch from hunting parties that used dogs, where the animal was neither eaten nor sold. Other by-catch species have included; deer, sun bear, pangolin and porcupine, and even arboreal species like gibbons, binturongs, macaques, flying foxes and slow loris (Harrison et al. 2011).

2.1.4 Research needs

There has been little research into hunting activities within disturbed forested areas surrounded by oil palm. Three recent studies have investigated hunting in plantation-forest landscapes, Bennett et al. (2000), Pangau-Adam et al. (2012) and Luskin et al. (2014). Luskin interviewed hunters, agricultural workers and wild meat dealers in Jambi in Sumatra and found that hunting was mainly for trade with wild boar being sold regularly. There is no published evidence that has investigated hunting in oil palm plantation-forest landscapes in Malaysian Borneo. Effective law enforcement requires information on why, where, how and by whom illegal activities are undertaken and the ability to act on this knowledge strategically, often with limited human and financial resources (Stokes, 2010). Baseline data on wildlife hunting in Sabah surrounding the SAFE project is therefore important. This data can be used by other organisations working in Borneo to assist in understanding wildlife hunting in Borneo and pressures upon individual species or groups.

2.2 Methods of investigating sensitive behaviours

Studying wildlife hunting is challenging due to many species being protected by national or international legislation and researchers need to consider the incentives participants face and any consequences to participants for discussing illegal activities of wildlife hunting (Jenkins et al. 2011). There are several sensitive questioning techniques available to reduce the consequences facing participants and to provide anonymity and confidentiality. This reduces the bias in responses and provides robust data. The single sample count technique was chosen for this project. Please see appendix IV for background, methods and results of the technique.

amy.v.fitzmaurice@hotmail.co.uk

2.3 Logging in Borneo

2.3.1 History of logging and oil palm

Globally, one of the largest causes of tropical forest degradation is timber logging and one of the largest causes of deforestation is clear felling for oil palm plantations *(Elaeis guineensis)* in South East Asia (Bernard et al. 2009).

Globally 28% of tropical forests are being logged for timber (Casson and Obidzinski, 2002), with an additional 403 million hectares of tropical forest designated for logging (Blaser et al. 2011). Eighty percent of the world's new agricultural land comes from the conversion of degraded logged tropical forest (Gibbs et al. 2010), with oil palm production increasing by 9% yearly (European Commission, 2006). Borneo has one of the highest rates of logging in South-East Asia, being $100m^3ha^{-1}$, (Collins et al. 1991) where selective logging has degraded 80% of Bornean lowlands (Curran and Trigg, 2006). Sabah, occupies less than 10% of Borneo, where total forest cover is estimated at 37,600 km^2 (51%) of Sabah in 2010. Deforestation rates are less than in the 1980s, where the average deforestation rate was 0.75% per year between 1990 to 2010, although the condition of Sabah's remaining lowland forests are of conservation concern (Reynolds et al. 2011).

Global land coverage of oil palm was 3.6 million ha in 1961 and increased to 13.9 million ha in 2007. In Malaysia between 1990 to 2005, oil palm increased from 1.8 million ha to 4.2 million ha, where 1 million hectares of forest was deforested (FAO, 2006; Wilcove and Koh, 2010; MPOB, 2014). Koh and Wilcove (2008) estimated that between 1990-2006, 55% of oil palm expansion occurred on natural forests. In Sabah in the 1990s oil palm covered 358,000 ha which grew to 1.5 million ha in 2010 (Gunarso et al. 2013).

The logging concessions within the project's study area target expensive timber species first, such as species from the *Shorea* genus. This degraded forest is then left until it is clear felled for oil palm planting, which can be from months to years. When logging concession's clear fell, they leave some tree species unlogged, for example, species from the *Macaranga* and *Ficus*

amy.v.fitzmaurice@hotmail.co.uk

genera for cultural reasons (Ryan Grey, 2014). All plots have been logged twice before since the 1970s (Ewers et al. 2011), where Gaveau et al. (2014) estimate that 266,257km^2 of Bornean forest has been logged since 1973.

Act No. 5 of 1990, Government of Malaysia and Indonesia states that concession managers are obligated to prevent detrimental impacts to protected species (CBD, 1990; Gaveau et al. 2013) and they are also obligated to allocate logging exclusion zones around waterways to reduce silting (Meijaard and Sheil, 2008). However, forests are still vulnerable to illegal logging (Singh et al. 2014). The Sabah Forestry Department estimated that less than 40,000 ha of forest in Sabah have been illegally logged in recent years (Reynolds et al. 2011).

2.3.2 Reasons for logging and oil palm

Indonesia, Malaysia and the Philippines together exported more than 80% of all tropical timber in latter decades of the twentieth century, with forestry providing income worth US $39 billion for developing countries in 2006 (Berry et al. 2010). Another motivation is oil palm, which is the world's most consumed vegetable oil (Carter et al. 2007), where Malaysia produced 17.4 million tonnes in 2008, equating to 87% of global output (FAS, 2008). The profits per hectare for a typical Malaysian oil palm plantation averages at between US $528 to US $790 annually (Nantha and Tisdell, 2009).

2.3.3 Ecological consequences of logging

Studies have highlighted that selectively logged forests can recover over time, but oil palm conversion represents a greater threat to biodiversity (Wilcove and Koh, 2010; Edwards et al. 2013; Edwards et al. 2014). The literature states a variety of positive and negative impacts of logging on different species across Borneo, with the majority negatively affecting species.

Clark and Covey (2012) highlight that tree species richness reduced in late successional stages after logging, which in turn affects fauna. For example, Gardner et al. (2007) showed species composition did change across a gradient of land uses from protected areas to high human activity areas, where species richness did not change. Wells et al. (2006) found that movements of small mammals in Borneo differed significantly between species, where all species were affected by logging. They also found that some species travelled further in unlogged compared to logged forest, where the main movement strategies of small mammals were not influenced by logging but a response to heterogeneous habitats. For civets, Heydon and Bulloh (1996) found that density in Sabah significantly declined in logged forests (6.4 individuals per sq km) compared to primary forest (31.5 individuals per sq km). For some species, this is not the case, Heydon (1994) found that the number of sambar deer *(Rusa unicolor)* positively correlated with areas with severely degraded forests. Meijaard and Sheil (2008) highlighted that Bornean primates appeared to adapt to selective logging, changing their behavioural patterns and diet. Small mammals, such as squirrels, became more carnivorous in logged areas (Emmons, 1995). Meijaard and Sheil (2008) conclude that the most logging-tolerant species are herbivore and omnivore mammals.

Meijaard and Sheil (2008) compiled a table of Bornean species from the literature that are reported to be sensitive to logging impacts because of phylogenetic traits (Appendix II, 1). They also stated that several endemic Bornean species may be in-tolerant to logging impacts due to inhabiting lowlands. From this literature review, Appendix II, 1, states additional species that are reported to be sensitive to logging impacts in Borneo.

The conservation value of logged forest is uncertain, however, Berry et al. (2010) analysed 2,500 species of 11 taxon groups, covering up to 19 years of post-logging regeneration, and quantified the impacts of logging on biodiversity within lowland dipterocarp forests of Sabah, Borneo. They found that logged forest retained considerable conservation value, where floral species richness was higher in logged forest than in primary forest, whilst faunal species richness was typically lower in logged forest. They also highlight that in most studies 90% of species recorded in primary forest were also present in logged forest, including species of conservation concern.

amy.v.fitzmaurice@hotmail.co.uk

To have logging, roads must be established, causing additional impacts to mammals, where Gaveau et al. (2014) showed that on Borneo, 271,891 km of primary logging roads were created between 1973 and 2010. In Sumatra, tiger occurrences have been shown to negatively correlate with distance to public roads (Linkie et al. 2006), this could be the case for the felids of Borneo, where Wearn et al. (2013) detected four out of the five felid species that occur in Borneo at the SAFE project, highlighting which species could potentially be impacted by logging roads. Schuette et al. (2013) stated that conflict-prone species with decreased tolerance along with changes in human land uses could threaten carnivore community structure and dynamics. Research states the logging correlates with wildlife hunting (Wyatt, 2013). For example, Meijaard (1999, 2001) showed a correlation between the timber trade and illegal trade of Malaysian sun bear gall bladders in Borneo. Further research is needed to understand is complex relationship further.

2.3.4 Research needs

Preceding research by The Orangutan Tropical Peatland Project, The Heart of Borneo Rainforest Foundation and the SAFE Project has focused on primate and felid occurrence and more recently bushmeat surveys (Cheyne and Macdonald, 2011; Cusack, 2011; Cheyne et al. 2013; Wearn et al. 2013). Further research is needed on all mammal species to investigate the impacts of logging disturbance on a community scale and to understand mammal tolerance to disturbance during logging.

2.4 Methods of investigating logging impacts

To investigate logging impacts on mammal species, a detection/non-detection sampling technique of non-invasive randomised camera trapping was chosen due to capture rates being higher than transect walks and because it is a well used method for studying rare and elusive species (Thompson, 2004; Ancrenaz et al. 2012). Furthermore, for species that cannot be individually identified, camera trapping data can be used to infer about differences in occupancy spatially and between species (Sollmann et al. 2013).

2.5 Project background

Multidisciplinary approaches are rare in conservation, where research focusing on wildlife through natural and social science's are different disciplines of studying conservation science. However, all the disciplines are linked, with one aspect affecting another. This project therefore conducted both natural science research on wildlife (investigating the direct impacts of logging) as well as social science research with local people (investigating the indirect impacts of logging, specifically wildlife hunting).

2.6 Study area

This study was conducted in Kalabakan Forest Reserve (KFR) in the state of Sabah, Malaysian Borneo and forms part of the SAFE Project (Ewers et al. 2011) (Figure 2.1). Multiple, intense logging activities have been conducted since 1978 and are still ongoing today with areas of twice logged forests, where 7200 hectare is earmarked and being converted into oil palm plantations. This landscape is now heterogeneous containing logged land and oil palm plantations, where varying intensities and timings of log extractions occur. In 2010, a land cover map indicated that 54% of the KFR is still forest cover (Miettinen et al. 2011). There has been no previous research investigating the presence of wildlife hunting at the SAFE project.

Some of the most threatened species are tropical mammals and many are poorly studied due to the complexities of doing so (Linkie et al. 2007), where 21-48% of mammals are predicted to be extinct by 2100 (Brook et al. 2003). Excluding bats, 38% of Borneo's mammals are endemic to Borneo, with many being threatened. There have been a few large mammal extinctions on Borneo, such as the tapir, where there is little evidence to understand its extinction (Earl of Cranbrook, 2010). To prevent further extinctions, investigating threats to species and developing mitigation recommendations are important. The species of interest to this project (Appendix II, 2) have been seen at the SAFE project and there is limited research into direct and indirect impacts of logging in Sabah on these species.

amy.v.fitzmaurice@hotmail.co.uk

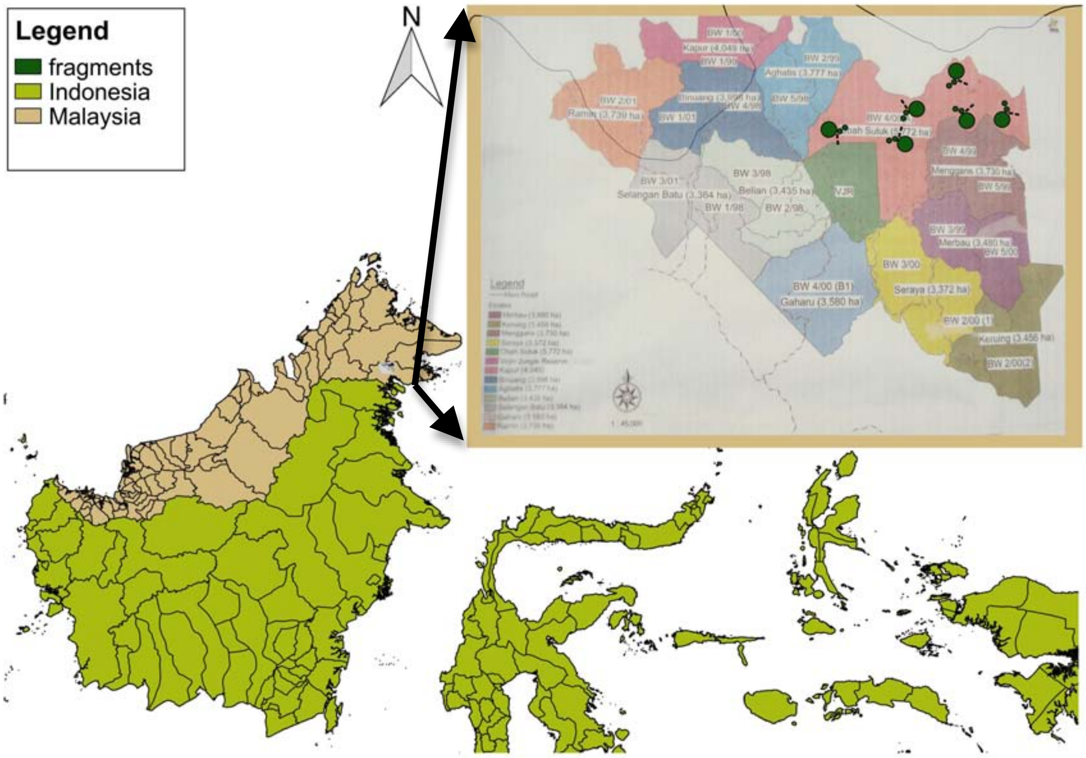

Figure 2.1 The study area within Sabah within Malaysian Borneo.

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3. Methodologies

© Ryan Grey (Researcher and research assistant setting a camera) (2014)

amy.v.fitzmaurice@hotmail.co.uk

This project applied a multidisciplinary approach combining techniques from natural and social sciences including collecting and analysing data on direct and indirect impacts of logging on mammals using social surveys, camera trapping, logging bulldozer GPS data and logging extraction data.

3.1 Indirect impacts of logging – social surveys

Social surveys were conducted at six separate companies (3 logging, 2 oil palm and SAFE project) during May to July 2014, by conducting opportunistic face-to-face interviews with volunteers, limiting the age to 16 years and over due to the sensitive nature of talking about wildlife hunting (Appendix III for final questionnaires). Four SAFE staff members were trained to conduct the surveys as interpreters (RG, MO, MS and MSK) during May 2014. The aim was to gather baseline data on socio-demographic information, local knowledge about local wildlife, perceptions of local activities and wildlife and information on wildlife hunting. The questionnaire was split into 4 sections:

1. Individual socio-demographic information, such as age, sex and occupation (10 questions).
2. Knowledge of local wildlife, whether respondents know the animal and if it's allowed to be hunted legally (22 animal questions), here the animals were chosen from the literature review based on a gradient of low to high levels of being hunted in South East Asia and Borneo.
3. Perceptions on changes in local animals and what activities might be affecting wildlife and people (9 questions).
4. Hunting activities, where questions were targeted to ask people about wildlife hunters and questions for hunters themselves (29 questions).

Socio-demographic information was important to help understand any underlying causes for hunting wildlife, such as low income, which often correlates with subsistence hunting (Loibooki et al. 2002). Knowledge and perceptions are important to understand the accuracy of the information that respondents are giving and to access any changes to the forest environment. The wildlife hunting section collected information about wildlife hunting and hunters themselves, to give an indications as to whether wildlife hunting is occurring within the study area.

3.1.1 Pilot study

The questionnaires were developed using the assistance of several resources (Francis et al. 2004; Nasi et al. 2008; Petroczi et al. 2011; Newing et al. 2011; Nuno et al. 2013; Nuno and St John, under review). The questionnaire was translated from English into Malay and checked by three separate SAFE staff and researchers (JT, RG and MP) for language and grammar. Before conducting the main data collection phase, a pilot study was done to access survey understanding and feasibility. An earlier version of the questionnaire was administered and the English and Malay versions were updated, as question structure changed due to language translation. The pilot was conducted in May 2014 on SAFE staff on an individual voluntary basis with the assistance of MP and RG as interpreters (sample size = 7). Based on the pilot survey, minor changes were made to the questionnaire, particularly related to wording of questions; for this reason, the pilot data was not included in the main data analysis.

3.1.2 Survey interviews

The SAFE project staff and myself contacted the palm oil and logging companies and visited each company with request letters (Appendix III) to gain permission. Our sampling was stratified to oil palm and logging workers due to available access to collect data from respondents. At the logging camps, we conducted the interviews after 6pm, after work finished and in a confidential environment. We used both the Malay and English versions of the questionnaire, because many of the workers preferred to speak English rather than Malay. Additionally, some interviews were conducted in Chinese and translated from the Malay version during the interview itself. For the oil palm companies, we conducted the interviews after 3pm, after work finished and surveys again conducted in a confidential environment. The single sample count was used as the sensitive questioning technique, for background, methods and results of this unsuccessful technique, please see appendix IV.

3.2 Direct impacts of logging – camera trapping

We deployed the remotely-operated digital cameras (Reconyx HC500) based on previously designed randomised GPS camera trapping points following OW sampling design. For each plot, there is one 100ha area, two 10ha areas and four 1ha areas. The grids contain 48 camera trap points, with 2 grids in the 100ha areas and 1 grid per 10ha area and the grids for the 1ha areas fall over two 1ha areas (Figure 3.1a) (Ewers et al. 2011; Wearn et al. 2013). Randomised camera trapping was chosen because it has been shown to improve the detectability of a greater number of species, as it assumes nothing about previous knowledge of species of interest. Non-random deployment interacts with non-random space-use by animals, causing biases in inferences about relative abundance from detection frequencies (Wearn et al. 2013). For example, Wearn et al. (2013) showed that random camera trapping detected elusive felid species in Borneo and that non-random camera trapping may have underestimated the relative abundance of bay cats *(Pardofelis badia).*

Three plots were chosen to be able to investigate mammal species in forests with different intensities of logging activities. We sampled E, D and B plots of reducing intensities of logging disturbance between May to July 2014, with E highly logged, D medium logging and B had no logging, but all plots have been logged twice previously since 1970s.

OW GPS points (gpx.file) were opened using BaseCamp to map the points and were transferred to the GPS (GPSmap 60CSx). There were 39 cameras available, where 13 GPS points were randomly generated in Excel for each plot. Within 5m of each GPS point the cameras were randomly set on a tree or post at 30cm above the ground to maximize the range of species captured. Some cameras were set higher, but pointed downwards, due to the circumstances found at each point. No bait or lures were used and disturbance was kept to a minimum to reduce the impact on species' behaviour. Cameras were programmed to take 10 consecutive photographs for each trigger event. We noted if the cameras' detection zone contained a

amy.v.fitzmaurice@hotmail.co.uk

logging road, trail or footpath, as some animals are associated with these and hunters may use these access points to obtain access to wildlife.

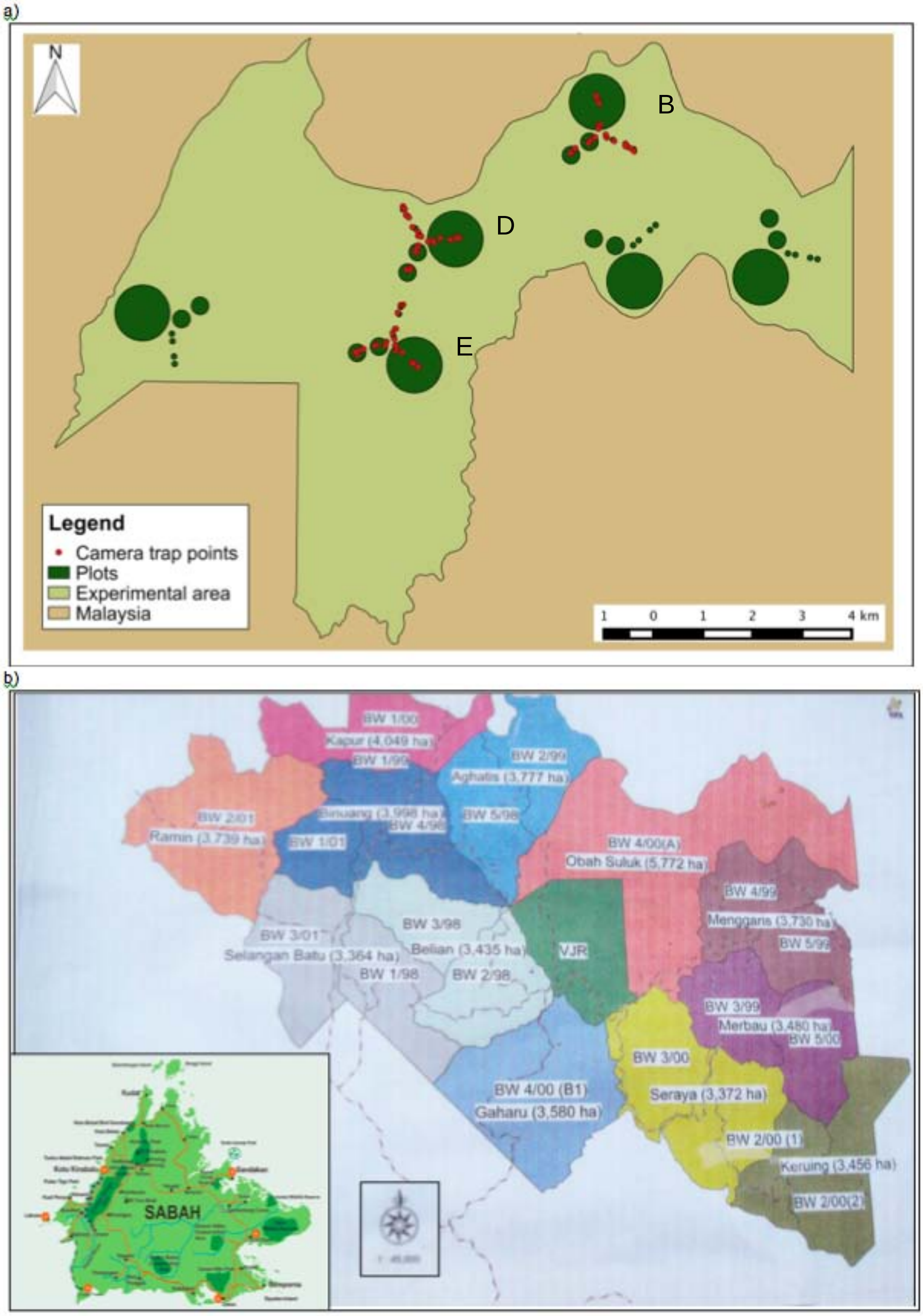

Figure 3.1. a) The randomised camera trapping points for the two deployments in plots E, D and B within the SAFE experimental design area. b) Study area in Sabah, where the SAFE experimental area is within Obah Suluk estate.

For the second deployment, the cameras were set at new randomised points to spread the effort of cameras between the grids evenly for each plot. At the end of both deployments, between 3 and 5 cameras would have been present in each grid for each plot. During camera collection, the cameras were checked for damage, mis-firing and low batteries. The dates, GPS coordinates, camera numbers, SD card numbers, battery percentages and deployment times were recorded on a sampling sheet for each camera and repeated when cameras were checked and redeployed (Raw data sheets – Appendix III). The species from the camera trap photographs were identified using Payne and Francis (2007) and photos were organised in the software Picasa, which has the ability to tag the species in the photographs.

3.3 Direct impacts of logging – logging bulldozers and logging extraction

Data was received from GPS data loggers that record the bulldozers' locations, where the SAFE project has permission from the logging company to ask workers to record this information. The data set is from January 2013 to December 2013, excluding March, where no data was collected. This data was used to investigate the intensities of logging activities in relation to the camera trap points within plots E, D and B. The data was transformed to be compatible with QGIS mapping software to produce a map illustrating logging activity surrounding all plots where high logging activity was of interest. This type of logging intensity was used to design the zones of disturbance, to highlight areas which may be causing greater levels of disturbance to mammals and which could be the focus of future management plans to reduce logging impacts and develop buffer zones. Data of the quantity of trees extracted within the study area during June 2012 to June 2014 was collected from one logging company to understand another type of intensity of logging in relation to the plots and possible impacts of logging on mammal species.

amy.v.fitzmaurice@hotmail.co.uk

3.4 Zones of disturbance

The bulldozer, logging extraction and hunting data (OW camera traps), were mapped in QGIS with the camera trap points from this study to investigate the intensities of disturbance to map the zones of disturbance. The different measures included:

1. Measuring the distance from each camera point to the nearest logging bulldozer track in kilometers. A bulldozer track is defined in this case, as a continue bulldozer movement through the plots, if the bulldozer track leaves and re-enters the plot, it still counts as one track.
2. Counting the number of logging bulldozer tracks within a 0.25km radius, 0.50km radius and a 1km radius from each camera point.
3. The number of logs extracted from each block within 0.25km radius, 0.50km radius and 1km radius from each camera point.
4. The presence of camera trap evidence of wildlife hunting within the hectares.

This data was then used to investigate the intensities of disturbance, by creating Red, Orange, Yellow and Green zones of disturbance. Green zones have logging bulldozer tracks more than 1km away and no other disturbance variables. Yellow zones have 1 disturbance variable, where the logging bulldozer activity or logging extraction does not occur within the 0.25km radius. Orange zones have 2 disturbance variables, where either one or both of the logging bulldozer activity or logging extraction do not occur within the 0.25km radius. Red zones have 2 to 3 disturbance variables, where either one or both of the logging bulldozer activity or logging extraction do occur with the 0.25km radius or logging extraction numbers were greater than 10,000 trees in either the 0.50km and 1km radius. The three disturbance variables are logging bulldozer activity, logging extraction and wildlife hunting.

amy.v.fitzmaurice@hotmail.co.uk

3.5 Ethics statement

This research had been approved by the ethics committee of Imperial College London. Non-invasive camera trapping was the chosen method of monitoring to reduce impacts on mammal species. Full permission was gained from land owners, concession holders and Yayasan Sabah and Benta Wawasan Sdn Bhd to conduct the camera trapping surveys. For the social surveys, permission from the oil palm and logging companies was obtained to conduct the questionnaire. Informed consent was gained from the participants for both the pilot study and the main survey. The aim of the study, that data would be kept confidential and the respondents had the choose to stop the interview at any time was stated at the start of the interview. To reduce the risk of harm to the respondents, the companies, participating stakeholders and Imperial College, no identifying information was collected from respondents and we do not identify the companies in this report. For the ethics report – please see Appendix III.

3.6 Data analysis

3.6.1 Social surveys

Data were visually assessed for normality using histograms and QQ plots. General linear model of a multi-way ANOVA regression with Gaussion error was used to analyse the dependent variable, knowledge (no. of correctly identified animals per respondent) and the independent variables sex, age, age respondent finished education, occupation company, income and length of time respondent had been in the forest, to investigate the variables impact on knowledge. A stepwise process was used to find the best model, by removing variables that had no significant relationship with knowledge.

3.6.2 Camera trapping and logging data

For the camera trapping data uni-variate and bi-variate analyses were conducted to visualize the data. To investigate whether there were any differences in species occupancy and detectability between the 3 plots. Detection frequency (d) (the number of captures per 100 camera trap nights)

amy.v.fitzmaurice@hotmail.co.uk

and naïve occupancy (the proportion of sampled locations at which the species was detected) were calculated before conducting occupancy models for each species. The R package unmarked was used to run occu function for a occupancy statistical model per species. All data were used with the zones of disturbance data to conclude which species are tolerant or intolerant to disturbance from direct and indirect impacts of logging.

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4. Results

4.1 Aim 1 – Indirect impacts of logging

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For social survey main data 112 of 118 approached participated, hence 112 surveys were considered for data analysis. Appendix V has additional evidence about wildlife hunting within the study area.

4.1.1 Relationships between respondent knowledge and socio-demographics

Socio-demographic information (Table 4.1) and knowledge of 22 local animals were obtained from all respondents in order to access their levels of knowledge and whether socio-demographic variables influence knowledge. Given that people working in/associated with logging and oil palm companies were targeted, the sample is mainly composed of men.

Table 4.1 Summarises socio-demographic information used in data analysis. Mean and Standard deviation were used to describe normally distributed data.

Variables	**Level**	**Measure**
Gender	Male Female	99 people 13 people
Age	Age range Mean SD	17 to 57 32 9.8
No. of children	Range Mean SD	0 to 7 1.6 1.7
Age respondents finished school	Age range Mean SD	0 to 35 15.1 4.7
Occupation company	Logging Oil palm SAFE project	44 people 56 people 12 people
Income (MYR)	Income Range <500 500-700 700-900 900-1200 1200-1500 >1500	<500 to >1500 2 people 14 21 24 26 25
Length of time respondents have been working and living in the forest (years)	Time range Mean SD	1 month to 35 years 7.8 8.39

Knowledge of local wildlife varied depending on the species (Figure 4.1), where either the common Malay names or common English names were accepted as correct identifications. Thirty-six percent of respondents correctly identified animals and 33% of respondents knew that wildlife hunting was illegal for those animals that they correctly identified. Elephants *(Elephas maximus borneensis)* were well-known, but 7 species, such as flat-headed cat *(Prionailurus planiceps)* and common palm civet *(Paradoxurus hermaphroditus)* were not correctly identified by any respondents. Animals were often misidentified (Appendix IV, 1), examples being rhino as pig and cats as civets. Fifty percent or more of respondents correctly identified the following species, in order of highest percentage: elephant *(Elephas maximus borneensis)*, orangutan *(Pongo pygmaeus)*, bearded pig *(Sus barbatus),* red muntjac *(Muntiacus muntjac)*, rhino *(Dicerorhinus sumatrensis)*, sambar *(Rusa unicolor),* pangolin *(Manis javanica)* and clouded leopard *(Neofelis diardi).*

To understand whether respondents knew more about animals that are known to be hunted in South East Asia and Borneo (Figure 4.1), the data was explored visually to show that the greater the levels of hunting of an animal, the more respondents correctly identified the animal.

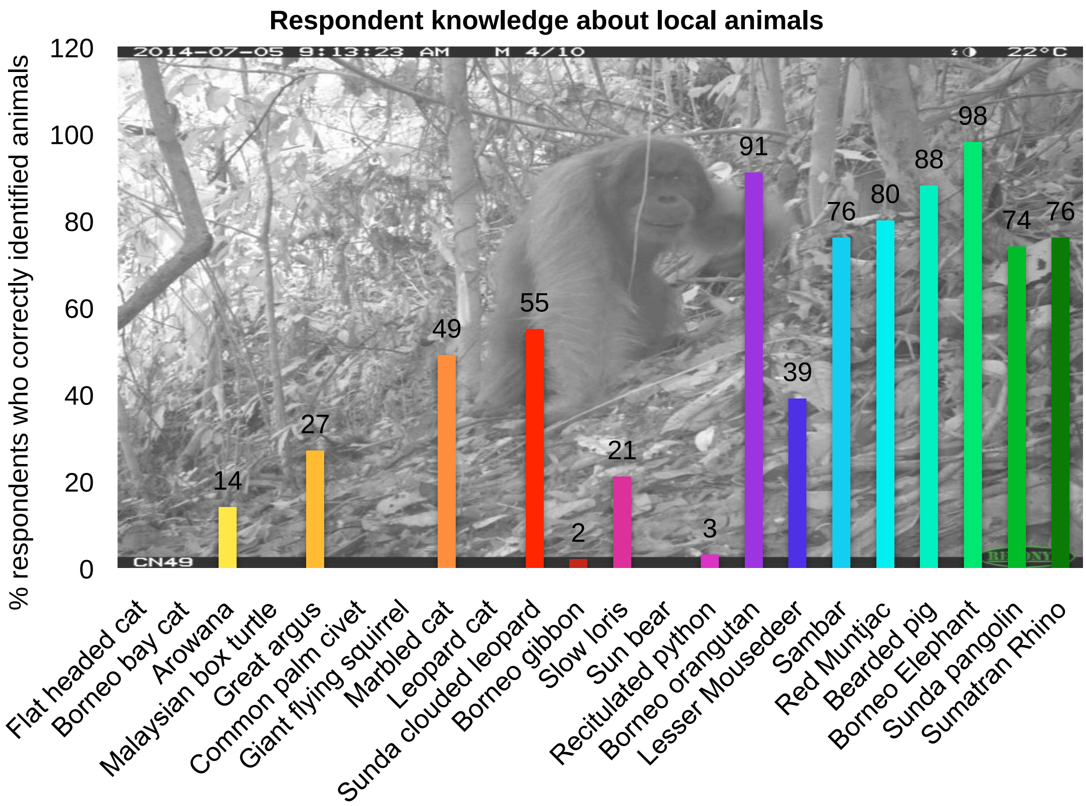

Figure 4.1 Respondent knowledge of local wildlife in the order that animals are known to be hunted from literature, from low to high levels of hunting.

amy.v.fitzmaurice@hotmail.co.uk

The knowledge level about local wildlife was affected by respondents' age they finished education, their age, the length of time they had been in the forest and the occupation company they worked for. In general, the people who left school after secondary level correctly identified more animals (df = 1, F value = 20.0, P < 1.946•••), where younger respondents got more animals correct (df = 1, F value = 6.35, P < 0.013•). The more time spent in the forest, the more animals they correctly identified (df = 1, F value = 5.91, P < 0.016•) and when considering occupation company (logging, oil palm or SAFE project), respondents from the SAFE project correctly identified more animals than respondents from logging and oil palm companies (df = 2, F value = 4.00, P < 0.021•). Other variables considered in the analysis but removed from the final model because they did not have an influence on knowledge were sex and income.

4.1.2 Relationships between respondent perceptions and animals

The number of respondents that answered questions about local wildlife and activities varied depending on the questions, where the data from the questionnaire was used to investigate perceptions of changes in animal populations and activities affecting animals, where data is summarized in Table 4.2. Five species were stated to be increasing, whereas 10 species were stated to be decreasing. Deer, elephants and pigs were thought to be decreasing by the majority of respondents, but 58% responded don't know. The main activity stated to be changing biodiversity was logging, followed by farming, wildlife hunting and building by people.

Table 4.2 Summary of responses to perception questions.

Responses to whether there has been a change in the number of individuals for animals they see, from when they first entered the forest.	Increase (6 people) No change (12) Decrease (31) Don't know (65)
Animals that respondents stated had increased	Pig (2), Deer (2), Monkey (1), Fish (1) Snake (1)
Animals that respondents stated had decreased	Deer (15), Elephant (10), Pig (8), Banteng (3), Snake (2), Forest cats (2), Fish (1), Orangutan (1), Hornbill (1) Pangolin (1).
Responses to are there activities that are changing the forest for forest animals	A higher quantity of respondents (24%) thought that logging was the activity that was most affecting animals, followed by farming activities (18%), wildlife hunting (17%) and building by people (15%).

amy.v.fitzmaurice@hotmail.co.uk

4.1.3 Hunters and respondent knowledge of hunting

All respondents were asked the general questions about wildlife hunting, but only those that self-reported hunting were asked additional hunting questions. Table 4.3 summarises the hunting section findings. This reveals that wildlife hunting is occurring within the study area, but with only 8% stating they knew that other people were hunting, using methods from hunting dogs to guns and bombs. Furthermore, 17% stated their favourite food was pig or deer, for which hunting is illegal without a license. Twenty respondents stated they had hunted before, where eleven shared where they learnt to hunt and only 7 of those 11, stated they had hunted recently. Pigs, deer, fish and birds are being hunted by both genders (age range of 17 – 43), however this data is not representative of hunters within the study area, due to the sample size of 7. Figure 4.2 shows the estates within the study area that respondents said wildlife hunting occurred in and highlights wildlife hunting is occurring within the study area, being highest in VJR Forest Reserve (6%). However, the majority of respondents did not know or were unwilling to say if hunting was occurring in the study area.

Table 4.3 Summary of hunting data.

Questions asked to all respondents (n = 112)	
Responses to whether they know if other people hunt	65% Don't know 27% No 8% Yes
Respondents opinion to which hunting equipment is used within study area	Wire snares, string snares, guns, poison, fishing nets and rods, bombs and dogs.
Locations of where hunting equipment has been seen by respondents	Forest trails, near water, near roads, logged land and oil palm plantations.
Responses to what puts you off hunting	Respondents stated law enforcement as main reason (48%), followed by dangerous animals (26%), not interested in hunting (20%), researchers (8%) and other workers (7%).
Where respondents learnt to hunt	Not a hunter (93 people), Don't know (7), Friends (5), Parents (3), Don't want to answer the question (2), Yourself (1) and Other (1).
Favourite food	Chicken (64), Fish (33), Cow (13), Pig (11), Deer (8), Buffalo (3), Seafood (2), Goat (1) and Don't know (1).
Responses to did you used to be a hunter	Yes (20 people) No (92)
Questions asked to hunters only (n = 7)	
Reasons for hunting	Food, culture, sport, fun and chasing animals off land.
Which animals hunters hunted	Pigs, fish, deer and birds

Hunters use of animals hunted	Food (55%), trade, sale and pets.
Hunting frequency	Monthly to yearly, where 2 people did not want to answer.
Hours spent hunting	From 3 to 5 hours, where 2 people did not want to answer.
Transport used when hunting	Walking and motorbike and 2 people did not want to answer.
Last hunting trip	2006, 2008, Jan 2014, Mar 2014, Apr 2014, May 2014 and Jun 2014.
Catch from last hunting trip	Fish, deer, pigs and birds
Outcome of last catch	Food, sale and pets.

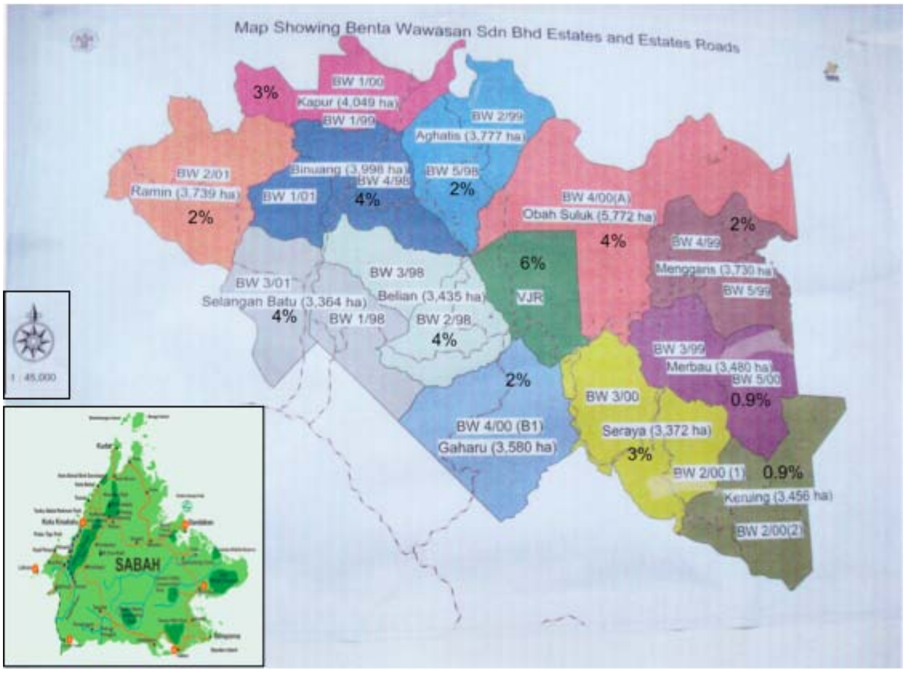

Figure 4.2 Map of the estates within the study area, which occur within Sabah state, showing the percentage of people who thought wildlife hunting took place in those estates, with VJR forest reserve being highest at 6%.

Single sample count was used as the sensitive questioning technique to investigate the quantity of people that hunt wildlife. This technique was unsuccessful, where the results are presented in appendix IV and the possible reasons for being unsuccessful are discussed in Chapter 5.

amy.v.fitzmaurice@hotmail.co.uk

4.2 Aim 2 – Direct impacts of logging

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4.2.1 Species data

The randomised camera trapping at plots E, D and B detected 29 mammal species (Appendix IV, 2) between May to July 2014, between two separate camera deployments across 73 points (Figure 3.1 – Chapter 3). Four cameras malfunctioned and no photographs were taken, thus no species were detected at those points. These data were not included in the analysis, due to causing false absences of all species for those points. The camera trap effort equaled 1792 nights. This project compared data from plots along a gradient of logging of disturbance caused by salvage logging in their vicinities. Plot E had been highly disturbed from logging in surrounding areas over the preceding 12 months. Plot D had been moderately disturbed by logging and plot B had not been disturbed by any salvage logging. The salvage logging is occurring outside the plots and logging bulldozer activity occurs within and outside the plots (0.001km – 1.91km from camera points).

Community composition of species between the currently logged and currently unlogged plots varied, where currently logged plots are E and D where logging activities are in close proximity and B is a currently unlogged plot with no logging activities in close proximity. Seventeen species that occurred in unlogged forest also occurred in the logged forest. In total 20 species were detected in unlogged forest, where 3 species were only detected in unlogged forest, such as the stink badger *(Mydaus javanensis).* In total 26 species were detected in logged forest, where 5 species were only detected in logged forest, such as the binturong *(Arctictis binturong)* and marbled cat *(Pardofelis marmorata).* All small mammals were present in all 3 plots. Medium sized mammal presence varied, and for large mammals, all species were present in all 3 plots apart from 2 species, Sunda clouded leopard *(Neofelis diardi)* and yellow muntjac *(Muntiacus atherodes)*, which were absent from D and B, and E and D, respectively.

Visual assessment showed that species richness changed along the gradient of logging (E = 23, D = 22 and B = 20 species), with the currently unlogged forest having lower species richness compared to currently logged plots.

amy.v.fitzmaurice@hotmail.co.uk

To investigate whether there were any differences in the occupancy of species between the three plots (E, D and B), species occupancy analysis was used. Figure 4.3 and appendix IV, 3, describe the detection frequency (d) and the naïve occupancy for each species to illustrate species presence and absence data. Bearded pig *(Sus barbatus)* and red muntjac *(Muntiacus muntjak)* were commonly detected species and several species had low detection and occupancy, such as the Sunda pangolin *(Manis javanica)* and Sunda clouded leopard *(Neofelis diardi).*

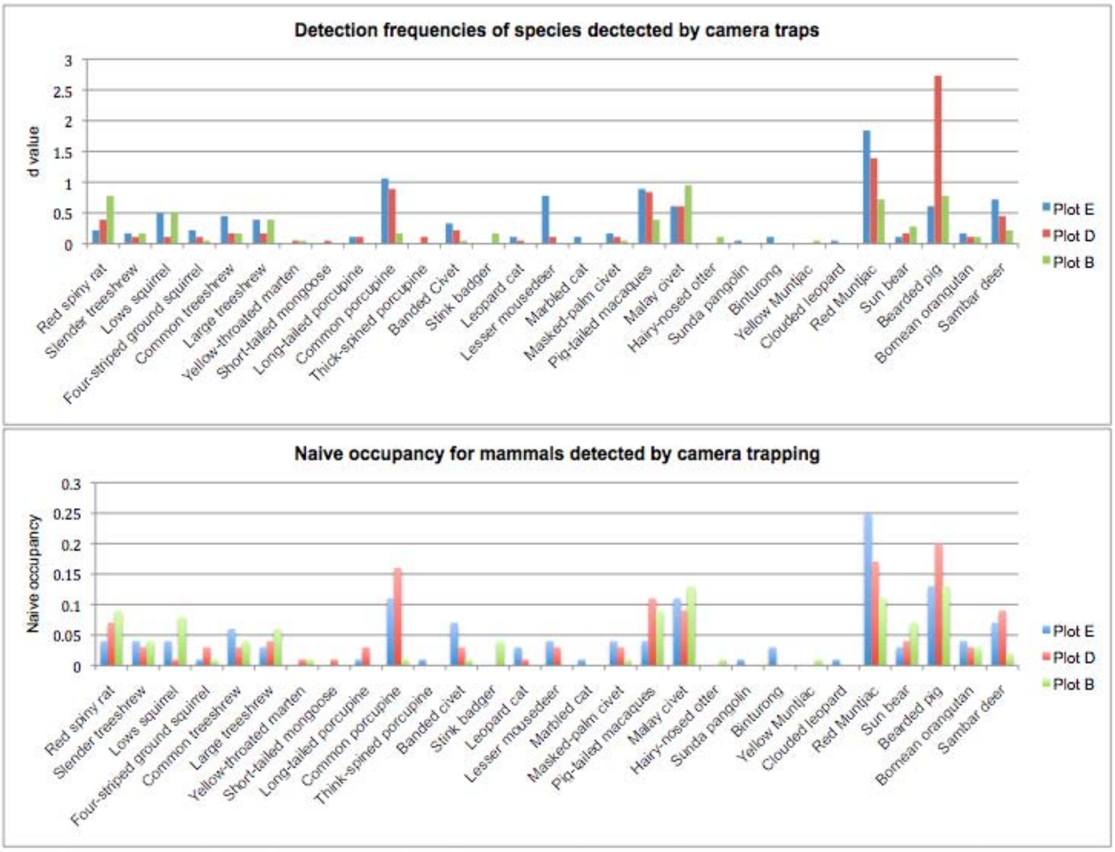

Figure 4.3 a) Detection frequency and b) naïve occupancy showing the variation between species in currently unlogged and logged forests.

From the detection frequency and naïve occupancy visual exploration, it suggests that some species are either tolerant or intolerant to disturbance (Appendix IV, 2), where small, medium and large mammal tolerance of disturbance varies.

amy.v.fitzmaurice@hotmail.co.uk

To further investigate species tolerance, as detection frequency and naïve occupancy may not truly reflect detectability or occupancy depending on whether the variations in detectability confound the occupation pattern (Mackenzie et al. 2006). Therefore ‘occu’ occupancy models were run for each species in relation to levels of disturbance (high, medium and none). For small mammals, in general their occupancy and detectability was greater in currently logged forest with high disturbance. Medium sized mammals occupancy and detectability in relation to logging disturbance varied depending on the species and for 5 species there was not enough data to make conclusions. For large mammals, in general their occupancy and detectability was greater in currently logged forest with high disturbance and for two species there was not enough data to make a conclusion. Appendix IV, 4, summarises the species occupancy models.

To investigate species tolerance to logging and the addition of wildlife hunting as a disturbance variable, the species data was analysed in parallel to the zones of disturbance data and species presence within those zones.

4.2.3 Zones of disturbance

The bulldozer data shows logging bulldozer activity surrounding each of the plots, where activities continue to occur throughout 2014. The research plots for this project, E, D and B had varied levels of bulldozer activity (Figure 4.4). Plot E has high bulldozer activity, D has medium bulldozer activity, and B no activity, as low activity occurs within a 1km radius of camera trap points only. Logs were extracted legally (Appendix IV, 5) and express the level of disturbance surrounding the study site plots. This gives an indication about where logging is occurring and how much is taking place, therefore basic levels of disturbance can be inferred.

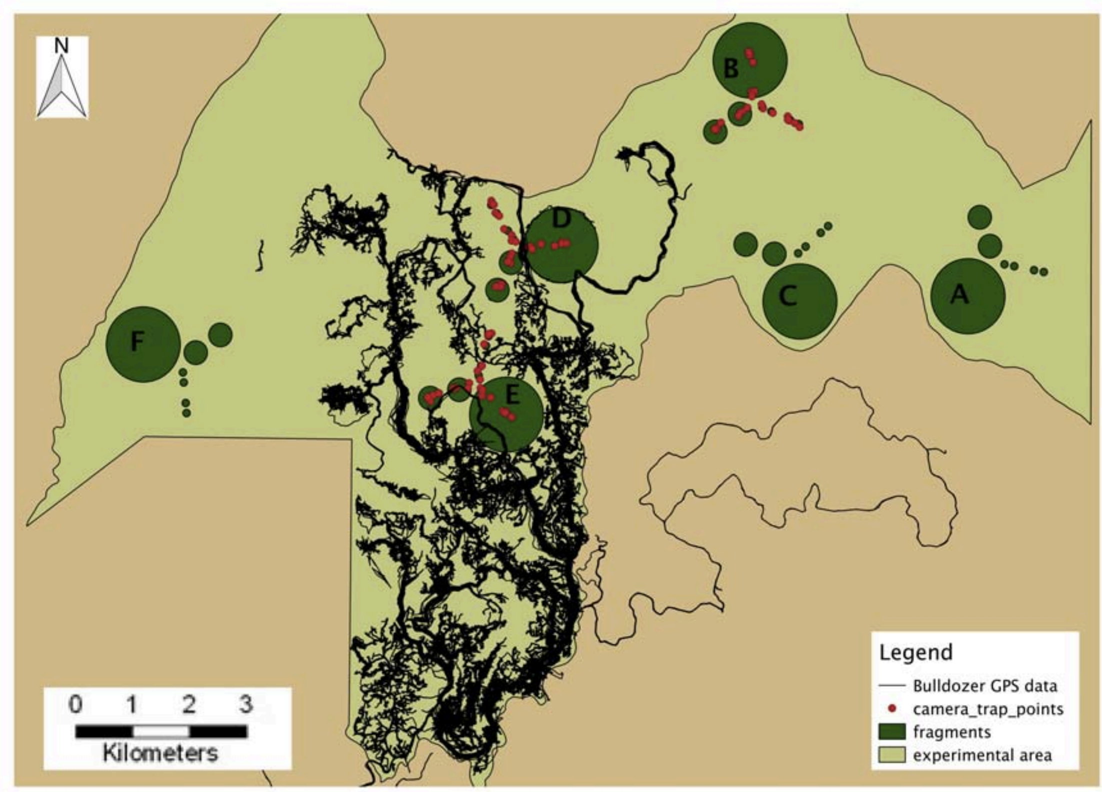

Figure 4.4 Bulldozer activity (January 2013 to December 2013) surrounding the study plots E, D and B. E had the most activity and thus higher levels of disturbance to mammals occupying E. D had some bulldozer activity and thus lower levels of disturbance to mammals occupying D. B had no bulldozer activity.

The zones of disturbance were mapped to investigate the intensities of disturbance variables (Figure 4.5) (logging bulldozer tracks, logging extraction and wildlife hunting) and whether species are tolerant or intolerant to these disturbances within these zones. Appendix IV, 6, summarises data used to develop the zones of disturbance and states the disturbance level for each camera trap location. The zones of disturbance are separated into Green, Yellow, Orange and Red of increasing levels of disturbance.

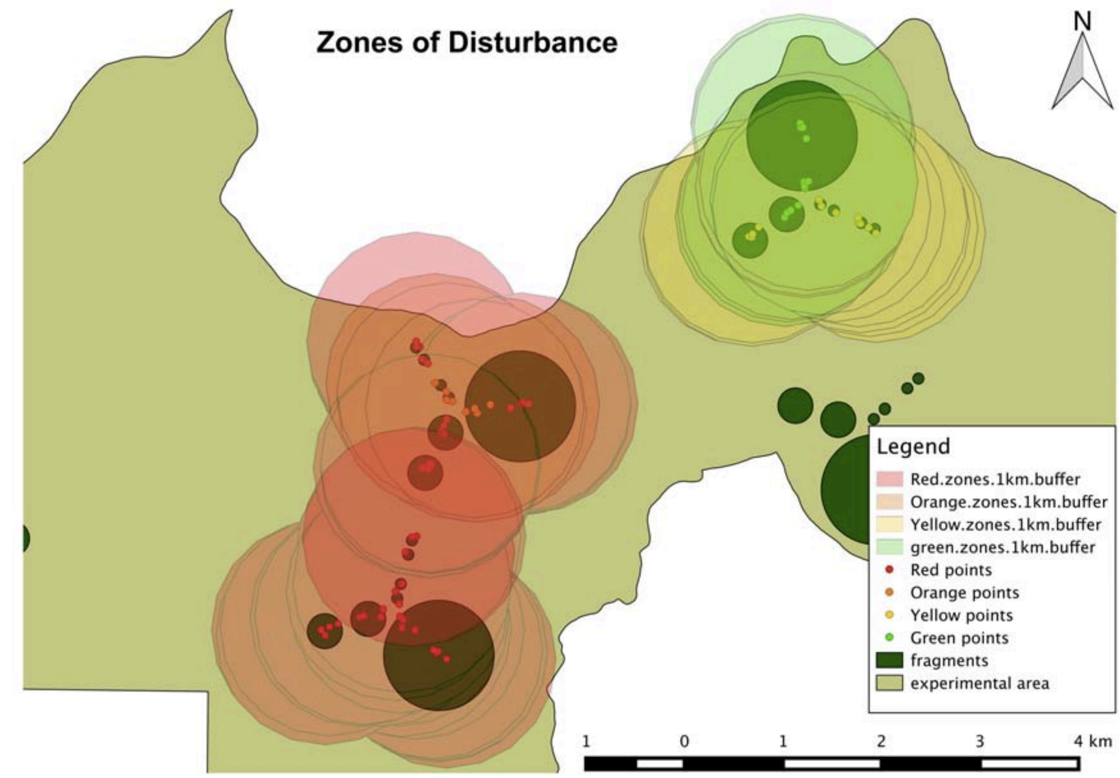

Figure 4.5 Showing 1km buffers around each camera trap point to present the zones of disturbance in relation to the disturbance variables: bulldozer data, logging extraction data and OW camera trap wildlife hunting data.

A 1km buffer zone surrounding each camera trap point was chosen, as the zones of disturbance highlight that disturbances are greater within the 1km radius, which could affect wide ranging species and therefore 1km may be a suitable buffer to reduce these disturbances to mammals.

Visual assessment of species presence within these zones showed that small, medium and large mammals presence varied where results were similar to the occupancy modelling analysis. Some species occurred in all 4 zones of disturbance, further highlighting that most species appear to be tolerant of these disturbances. There were 15 species detected in Green zones, 14 species in Yellow zones, 17 species in Orange zones and 24 species in Red zones. Additionally, some species were only found in certain zones, highlighting that some species may be intolerant of these disturbances. For example, stink badger *(Mydaus javanensis)* only occurred in Green zones, however, many species tolerance can not be determined from the data

amy.v.fitzmaurice@hotmail.co.uk

presented due to the lack of data. The zones also highlighted that the wildlife hunting detected on camera traps (OW) was occurring in both currently medium logged areas (D) and unlogged areas (B).

From these zones of disturbance, analysing the occupancy analysis and visually analysing the species data, appendix IV, 2, summarises the species detected by camera trapping and their IUCN status, population status, species size (small, medium or large), the plots they occurred in (E, D and B) and their tolerance or intolerance to disturbance variables. Resulting in 20 species being tolerant of disturbance and nine species were data deficient and their tolerance could not be concluded.

From analysing the species data and the zones of disturbance, the data suggests that species may be tolerant of short-term disturbances and further interdisciplinary research of social and natural sciences investigating logging and wildlife hunting is needed to further understand the zones of disturbance and their future use in management plans to reduce disturbance on mammal species.

amy.v.fitzmaurice@hotmail.co.uk

5. Discussion

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This novel project investigated both the direct and indirect impacts of logging on mammals in Sabah. The social surveys and the camera trap data from OW revealed that wildlife hunting is occurring within the study area, suggesting that it could be a disturbance variable impacting local mammal species. Randomised camera trapping showed that species presence and absence varied between currently logged and unlogged forest, with species richness being higher in logged forest. It can be inferred through the occupancy analysis and zones of disturbance that mammal species are impacted by the disturbance variables (logging bulldozer activity, logging extraction and wildlife hunting), where the majority of species detected appear to be tolerant.

The key findings for the social surveys relate to respondent knowledge about local wildlife, perceptions of wildlife and hunting and information from hunters themselves. The respondent knowledge about local wildlife varied, where income and sex were tested variables that did not significantly influence knowledge. The ratio of males (99) and females (13) may have affected the analysis as the samples sizes were unmatched. Previously literature states that income is a factor that influences whether people hunt or not (Loibooki et al. 2002). In this study only 2 respondents earned under 500 MYR per month, suggesting that the socio-demographics of this sample had enough money to buy food rather than hunt. However, some respondents stated their favourite foods were deer and wild pigs, which are illegal to hunt without a license and this shows there may be demand for hunted wildlife.

The knowledge about local animals varied depending upon the species. For animals that 50% or more of respondents correctly identified, bearded pig, muntjac and sambar were species that respondents ate and elephants, orangutans, rhinos, pangolins and clouded leopards are species known for being hunted in South East Asia and Borneo, meaning that knowledge may relate to the levels of hunting per species. Species where often misidentified, and this is particularly important when considering species data for species action plans at national and international levels, as species models predicting population and extinction risk would be based on incorrect data, therefore inadequate management plans would be developed.

For perceived changes in animals, respondents stated deer, pigs and elephants were decreasing. This is interesting because deer and pigs were animals the respondents liked to eat. Additionally, respondents stated that oil palm estates had bounties on pigs because of their damage to crops. Luskin et al. (2014) interviewed local people in Sumatra, who stated that hunting in oil palm plantations may reduce crop damage from wild boar. The possible decrease in elephants may come from two aspects, which were highlighted during the interviews. Firstly, there is one ethnic group that use elephant trunks at weddings and second, that elephants may be poisoned in oil palm due to their destruction of crops. Luskin et al. (2014) also stated that people highlighted that elephants were seen as crop raiding pests in Sumatra, but raiding was rare. Logging was stated to be the main cause for perceived changes in animal populations, suggesting that current logging concession management plans to reduce impacts on the forest are not adequate if local people are noticing animal declines and their perception is that logging is the main cause for these declines.

Both males and females admitted to wildlife hunting within the study area, where the literature review highlighted that only males hunt in Borneo (Garbutt and Prudente, 2008). They hunted pigs, deer, fish and birds for a variety of reasons, such as food and for fun, where the 7 hunters ranged from 17 to 43 years old. These data are not representative of hunters in Sabah, however, this baseline data is useful for developing future studies and questionnaires. Although there appears to be little hunting occurring in the study area from the number of respondents that said they were hunters, respondent knowledge of where wildlife hunting is occurring showed that hunting may be occurring in all estates within the study area, within all habitat types: currently logged forests, currently unlogged forests, unlogged forests and oil palm plantations. Furthermore, it is useful baseline data for further investigations to target areas that have higher reported levels of wildlife hunting, such as VJR. Further research is needed to understand whether the fact that roads go through all estates are allowing greater access to the forest and therefore intensifying wildlife hunting.

In conclusion there was reluctance to talk about the sensitive subject of wildlife hunting, however, there is data confirming that wildlife hunting is occurring within the study area, where this data set is not representative of Sabah, but of this sample group. Improvements can be made to increase both willingness to participate, such as incentives and willingness to divulge information about wildlife hunting, through improved sensitive questioning techniques.

There were several aspects that could have affected the data presented. Many of the respondents had never completed a questionnaire before and frequently did not understand the questions, leading to a large quantity of ‘don’t know’ responses. The pilot study conducted did not highlight these potential problems, as it was conducted at the SAFE project, where staff are used to researchers and have mostly been in education until secondary level and therefore they understood the questions.

Studying sensitive topics in conservation is complex. However it has provided valuable insight in behaviours relating to conservation. Firstly through theory of planned behaviour, where St John et al. (2010) illustrated that attitudes influence behaviour towards conservation. Conservation goals would be more successfully understood by a range of people, if social-psychology theories were used in conservation. Secondly, research has helped our understanding when designing projects that relate to both wildlife and people. Damerell et al. (2013), found that environmental education for children influences both adult knowledge and behaviour.

SSC was used as a sensitive questioning technique for the first time as a conservation tool. The larger than expected number of 0s would indicate that the SSC technique may not be suitable for conservation sensitive topics. However, the results may have been affected by cultural aspects, as many people did not know when their own or their parent’s birthday were, which

amy.v.fitzmaurice@hotmail.co.uk

meant that answers were not representative of the truth, which affected the data set. The SSC was used in the main survey, as the pilot survey did not highlight these above issues. To conclude, the SSC technique can work in conservation sensitive topics, as 53 out of 112 respondents from the main survey understood the technique. The technique should be used for the correct study group, such as well-educated people. Further studies of its capacity to be successful as a conservation questioning tool is needed to understand whether the technique can be developed to be used on less well educated respondents.

Respondents were often reluctant during surveys to respond to wildlife hunting specific questions and 6 out of 118 refused to participate. Lack of time was one reason stated why they did not participate. There was potential for the interpreters to know the respondents or be from the same village, which, from their opinion, removes anonymity. Furthermore some respondents stated they had little knowledge of the area as a reason for not participating. Four out of these six people were male aged between 21 to 41, where this socio-demographic group may be sensitive to discussing wildlife hunting. During 2014, WWF and Sabah Wildlife Department are setting up a wildlife enforcement programme (Fitzmaurice, 2014), which may have affected the survey results as respondents may have thought we were working with the enforcement programme and due to the increased sense of risk for respondents to answer sensitive questions about wildlife hunting, where some respondents mentioned increased enforcement activity in the study area. From this study, 48% of respondents said law enforcement was the main reason why they didn’t hunt. All interviews were conducted with a female white researcher and a Malay speaking interpreter, where all respondents were recorded as communicating directly with the female researcher. However, other social survey results from Indonesian Borneo have been negatively affected by using female interviewers, as male hunters stated they only like to talk about hunting with other males (Van Berkel, 2014). To improve the social survey techniques for gaining information on the sensitive subject of wildlife hunting, a study to understand whether respondent responses are affected by male or female interviewers is important to understand in this culture.

This study showed wildlife hunting is occurring within the study area, however the data is not representative of hunting or hunters in the area for a few key reasons. Firstly, local logging and palm oil workers were surveyed due to friendly terms already in place to gain permission and the focus of this research was impacts of logging, therefore loggers and oil palm workers were of interest and other people in the area were not surveyed, such as inhabitants of villages surrounding the SAFE project or within the study area. Secondly, only 7 respondents admitted to hunting recently. Therefore our estimates of wildlife hunting are underestimates, but still important baseline data for this area. Camera trapping data from OW from 2013 showed that wildlife hunting was occurring within the SAFE study area, but only at six camera locations in plots D and B. However this does not mean wildlife hunting is not present, it may not have been detected. This data is still useful for mapping wildlife hunting disturbances in relation to species presence in the zones of disturbance, but it is important to highlight that it is not representative and further research into wildlife hunting within the SAFE study area is needed.

The key findings from the species data and zones of disturbance relate to community composition, species richness and species occupancy in relation to logging disturbance. Zones of disturbance data led to the conclusions as to whether species are tolerant or intolerant of logging bulldozer activity, logging extraction and wildlife hunting disturbances.

By analysing community composition (Appendix IV, 2), it was highlighted that more species were detected in currently logged forests than the currently unlogged forest, whereas Berry et al. (2010) showed that faunal species was lower in logged forest than primary forests. However, only 1 unlogged forest and 2 logged forests were studied in this project and this may be skewing the results in this case. Community composition changed between the plots E, D and B, suggesting that logging disturbance may cause community composition change. Gardner et al. (2007) also showed that species composition did change across a gradient of land uses. The species richness also varied between the plots (E, D and B), with the unlogged forests having fewer species than logged forests, inferring that logging activities may benefit some species. For example, sambar deer *(Rusa unicolor)* were shown to be tolerant of disturbance variables, while Heydon (1994) similarly found that sambar deer *(Rusa unicolor)* numbers positively correlated with degraded forests. The community composition and species richness between currently logged and unlogged plots is biased due to 2 logged sites and only 1 unlogged sites. However, the results still highlight that species that occur in unlogged forest also occur in logged forest, even species of conservation concern. Berry et al. (2010) found that for 11 taxon groups, 90% of species recorded in primary forest were also present in logged forest. The differences between species presence in unlogged and logged are valid, but further research is needed to understand these differences at different time scales and levels of disturbance. This is important for understanding each species and for developing future conservation action plans and managing wildlife in an increasingly anthropogenic environment.

Several threatened species were detected in highly disturbance areas, such as Sunda clouded leopard *(Neofelis diardi),* marbled cat *(Pardofelis marmorata)*, Sunda pangolin *(Manis javanica)* and binturong *(Arctictis binturong)*, where previous literature states these species are sensitive to logging and wildlife hunting activities (Appendix VI, 1). Highlighting that further research is need. Some species were not detected in all plots, this does not mean it is not there, therefore we don't know whether species are more or less abundant in other plots and thus whether they are tolerant of disturbance or not.

The analysis of detection frequency (d) and naïve occupancy showed the species tolerance and intolerance varied between small, medium and large species. The occupancy modelling analysis was used to further analyse species occupancy and true detectability in relation to logging disturbance (high, medium or none), which showed similar results and the zones of

amy.v.fitzmaurice@hotmail.co.uk

disturbance highlighted species tolerance of disturbance. Small sized mammals appear to be tolerant of disturbance. This result is interesting because Emmons (2000) showed that treeshrew species are severely affected by logging. Perhaps treeshrew species can tolerate short-term impact of logging as indicated by the results, suggesting that short-term logging concessions may not negatively impact these species. Medium sized mammal tolerance to disturbance varied depending on the species. There was not enough evidence from the occupancy models to suggest intolerance, as stink badger *(Mydaus javanensis)* and the hairy-nosed otter *(Lutra sumatrana)* were only detected at low frequencies in plot B. This could be highlighting that these species are intolerant of disturbance and prefer currently unlogged habitats. Previous literature on these species is limited and further research is needed, but the research available does suggest that stink badgers are sensitive to logging (Meijaard and Sheil, 2008) and the hairy-nosed otter is sensitive to wildlife hunting (Wright et al. 2008). Pig-tailed macaques *(Macaca nemestrina)* were found to be tolerant of disturbance, where there is no previously literature investigating this species tolerance of disturbance and therefore this result highlights new evidence for a species that is considered Vulnerable (Richardson et al. 2008). All civet species appear to be tolerant. Previous literature states that both the masked palm civet *(Paguma larvata)* and Malay civet *(Viverra tangalunga)* are sensitive to both logging and wildlife hunting (Heydon and Bulloh, 1996; TRAFFIC, 2014), where there is no published literature investigating banded civet *(Hemigalus derbyanus)* tolerance to disturbance, highlighting new evidence for the species. Furthermore, Heydon and Bulloh (1996) found that civet densities were lower in logged forests compared to primary forests. Densities of species were not investigated in this research, but further research into densities could further illuminate species tolerance of disturbance by investigating densities of species along a gradient of disturbances on different time scales. Densities of species would indicate the number of individuals a habitat type could support, indicating whether degraded logged forests have conservation value. Similarly, porcupine species appear to be tolerant to disturbance. However, Shaw (1801, in Meijaard and Sheil, 2008) stated long-tailed porcupine are sensitive to logging and TRAFFIC (2014) reports that common porcupines are hunted and traded. There was not enough data for thick-spined porcupines to suggest tolerance or intolerance. Large mammals appear to be tolerant of disturbance which literature supports in some cases. Meijaard et al (2010) found that orangutans were resilient and showed high numbers occurring in plantation habitats and Ancrenaz et al. (2010) showed orangutan populations can be maintained in slightly logged forests, but declined in heavily logged forests. However, there is conflicting evidence on orangutan tolerance of logging disturbance. Further research is needed into clouded leopard and yellow muntjac, as their tolerance could not be analysed due to the low detection.

For the zones of disturbance, small, medium and large mammals were present in all zones, suggesting their tolerance of disturbance depends on a variety of factors, and not just body size, such as, prey availability within these zones. The 1km buffer was chosen as a suitable distance to understand disturbance impacts of these species because the disturbance variables in this case are accruing at higher intensities at the 1km radius analysis when mapping the zones of disturbance. Further research is needed to understand whether this 1km buffer is a suitable distance to reduce disturbance impacts on mammals during logging and to improve the zones of disturbance technique. The zones also highlighted that the wildlife hunting detected on camera traps (OW) was occurring in both currently medium logged areas (D) and unlogged areas (B). This indicates that the correlation between logging and wildlife is low in this case. However, the data set of 6 hunting locations may not be representative of wildlife hunting in the area and this may be affecting the results.

Meiri et al. (2008) found that Borneo has fewer large mammals than adjacent areas – Sumatra, Java and Malay Peninsula. These mammals are significantly smaller in Borneo, such as sun bears *(Helarctos malayanus)* (Meijaard, 2004). This may mean that they are less vulnerable to environmental changes. This may explain why species are still present, despite the levels of disturbance. Furthermore the occupancy analysis and zones of disturbance results support Meiri et al. (2008) and Meijaard (2004)

amy.v.fitzmaurice@hotmail.co.uk

theory that smaller species can tolerant disturbance, as sun bears appear to be tolerant of disturbance from the occupancy model, despite previous literature stating them being vulnerable to both logging and wildlife hunting disturbances (Wong et al. 2005; TRAFFIC, 2014). Another theory for species to tolerate disturbance comes from Colon (2002), stating that species survival in disturbed habitats may be possible due to undisturbed habitats being in close proximity and serving as a refuge. This theory may explain why the majority of species in the research appear to be tolerant of disturbance, as species may be using the currently unlogged plot B as a refuge.

To conclude, 29 species were detected in currently logged and unlogged forests, where their tolerance of logging bulldozer activity, logging extraction and wildlife hunting varied between small, medium and large mammals. For some species with inconclusive tolerance or intolerance of disturbance, further research is needed, especially for those already of conservation concern and for those that have no current literature. The species that are tolerant of disturbance, this may only be short-term tolerance and further research is needed at different time scales to understand when and if their tolerance of logging and wildlife hunting changes. The zones of disturbance highlight the importance of mapping these zones, which species occur within these zones and that this zoning technique could be considered in future logging concessions and species conservation action plans to reduce logging and wildlife hunting disturbances to mammal species during logging.

There were several aspects that could of affected the data presented. The camera trap sampling was designed to detect as many different mammal species as possible and non-randomised camera trapping has been illustrated to be unrepresentative of species, shown by Wearn et al. (2013) for bay cats in Borneo. Therefore randomised camera trapping was used. However, this method may not be suitable for some species, such as leopard cat *(Prionailurus bengalensis)* and common palm civet *(Paradoxurus hermaphroditus)*, that are captured more often on camera traps when placed along roads rather than off-road (Sollmann et al. 2013). Additionally, this research found that leopard cat detection was low and no common palm civets were detected using the camera traps, although there were direct sightings on roads. However, due to small, medium and large mammals being investigated, randomised camera trapping was chosen because it is the most suitable method for detecting a range of mammal species.

Of the 73 points sampled, 4 cameras malfunctioned and no photographs were taken and therefore no species were detected at those points. Due to the quality of the data set, and spread of cameras across the grids within all hectares sizes for each of the 3 plots, the data is representative of community composition, species richness and species occupancy within the plots. Some species were not detected during the camera trapping surveys due to the camera sampling design (Appendix IV, 2). For example, elephants were seen in all 3 plots during the research time period, but were not detected on the cameras. This may be due to randomised camera placement in forested areas, where in some areas vegetation may have been too dense for elephants.

There are margins of error associated with logging bulldozer data used in developing the zones of disturbance, as workers needed to remember to turn the data loggers on when they started work and turn them off when they finished work to extend battery life. Often the data loggers were left on and the batteries ran out and so data was missing. However, the addition of incentives has reduced the error and data logger information is collected on a regular basis by SAFE staff to monitor the bulldozer data. The data being from 2013 is a limitation in the analysis, as the camera trap data, which the data was correlated with, was collected in 2014. However, since bulldozer activity occurred during the time period of the camera trapping, some inference can be made about the intensities to disturbance in relation to species presence.

The understanding of intensities of disturbance from logging extraction was limited because the sizes of the trees extracted were unknown. The true intensity of logging is unknown, as 100 large trees extracted would cause greater disturbance than 100 small trees extracted. However, this data does give an indication of logging intensity, because some areas have had over 7000 trees extracted whereas others have only had 96.

To gather more information about wildlife hunting within the study area, the following recommendations have been made.

1. To ask hunters about by-catch species they trapped. This is a poorly studied subject and they may be willing to talk about it, because it is accidental killing. For example, one respondent from the main survey said they accidentally killed a pangolin when they were younger in their parent's oil palm plantation.

2. Buffalo was stated as a favourite food and asking respondents which species is important in future studies and as it could be banteng *(Bos javanicus),* a protected species (Timmins et al. 2008c). The information gained from the hunters can be used to develop studies to gain further information, especially on young female hunters.

Several recommendations can be made to improve future research similar to this project. Firstly, research stations should pay for permanent research assistants to go on field courses to improve their knowledge and identification of species, as animals were often misidentified (Appendix IV, 1). Second, a recommendation of using global camera trap records to compile information about global wildlife hunting could be used as an additional source of information to indicate where future social science studies investigating wildlife hunting should occur. This research has shown that some mammals are either tolerant or intolerant to the disturbances, therefore a future research area would be to investigate the short and long-term impacts of logging on the movements of species, by radio tracking at the SAFE project, alongside working with Sabah Wildlife Department and local hunters to refine the wildlife hunting datasets for the area. If logging disturbance causes some species to spread, this could have consequences other than the conservation of threatened species, such as spreading bovine TB, which mousedeer are carriers of (Uttenthal et al. 2006; Semaur et al. 2008). Further short-term studies like this one are needed to understand the impacts of logging on mammals while logging activities are occurring, particularly to understand impacts and tolerances to disturbance of threatened species and the correlation between logging and wildlife hunting. This data is important for developing buffer zones and regulating wildlife hunting activities, such as the riverine buffers which are already in legislation (Meijaard and Sheil, 2008) and to develop species action plans for Sabah.

In conclusion, this project showed that wildlife hunting is occurring within the study area and that small, medium and large mammals appear to be tolerant of logging and wildlife hunting disturbances on a short-term scale, highlighting that these degraded disturbed forests may have conservation value for mammal species and further research is needed to understand these tolerances and the importance of these habitats for species conservation.

amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

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amy.v.fitzmaurice@hotmail.co.uk

Appendices

Appendix I - Thesis short film

Title:	'The Direct and Indirect Impacts of Logging on Mammals in Sabah, Borneo'.
Description:	This short film documents the research involved during the project.
Documentary length:	5 minutes.
Filmed by:	Amy Fitzmaurice.
Edited by:	Matthew Price.

Please find the online link to the thesis short film below, where the password is 'thesis'.
https://vimeo.com/104959262

amy.v.fitzmaurice@hotmail.co.uk

Appendix II – Background tables

Appendix II, 1 - Species that are reported to be vulnerable to logging and wildlife hunting, where information was taken from (Meijaard and Sheil, 2008)* and from the literature review. Many species are poorly studied and thus their sensitivity to logging is unknown.

Species	**Sensitive to logging**	**Reported to be hunted**
Moonrat *(Echninosorex gymnurus)*	Raffles (1821)*	
Grey tree rat *(Lenothrix canus)*	Miller (1903)*	
Wooly tree rat *(Pithecheirops otion)*	Emmons (1993)*	
Four-striped ground squirrel *(Lariscus hosei)*	Dahaban et al. (1996)*	
Three-striped ground squirrel *(Lariscus insignis)*	Yasuda et al. (2003)*	
Horsefield's flying squirrel *(Iomys horsefieldi)*	Waterhouse (1838)*	
Shrew-faced squirrel *(Rhinosciurus laticaudatus)*	Laidlaw (2000)* Yasuda et al. (2003)*	
Pen-tailed treeshrew *(Ptilocercus lowii)*	Gray (1848)*	
Treeshrews	Emmons (2000)	
Flying foxes		Strubig et al. (2007) Harrison et al. (2011)
Hairy-nosed otter		Wright et al. (2008)
Stink badger *(Mydaus javanensis)*	Lechenault, in Desmarest (1818)*	
Long-tailed porcupine *(Trychis fasciculate)*	Shaw (1801)*	
Common palm civet *(Paradoxurus hermaphroditus)*		Shepherd (2012)
Civet species	Heydon and Bulloh (1996) Syakirah et al. (2000)*	
Banded linsang *(Prionodon linsang)*	Hardwicke (1821)*	
Sun bear *(Helarctos malayanus)*	Meijaard (1999) (2001) Wong et al. (2005)	Meijaard (1999) (2001) Meijaard and Sheil (2008)
Sunda pangolin *(Manis javanica)*		Meijaard and Sheil (2008)
Bearded pig *(Sus barbatus)*	Davies et al. (2001)* Wong et al. (2005)	
Greater mousedeer *(Tragulus napu)*	Heydon and Bulloh (1997) Davies et al. (2001)*	
Lesser Mousedeer *(Tragulus kancil)*	Heydon and Bulloh (1997) Davies et al. (2001)*	
Yellow Muntjac *(Muntiacus atherodes)*	Davies et al. (2001)*	
Clouded leopard *(Neofelis diardi)*	Griffith (1821)*	Garbutt and Prudente (2008) TRAFFIC (2014)
Borneo bay cat *(Catopuma badia)*	Gray (1847)*	
Leopard cat *(Prionailurus bengalensis)*		Shepherd (2012) TRAFFIC (2014)
Marbled cat *(Pardofelis marmorata)*	Martin (1837)*	TRAFFIC (2014)
Sumatran rhinoceros *(Dicerorhinus sumatrensis)*	Fischer (1814)*	Meijaard and Sheil (2008)

Western tarsier *(Tarsius bancanus)*	Horsefield (1821)*	
Hose's Langur (Presbytis hosei)		Nijman (2005)
Borneo orangutan *(Pongo pygmaeus)*	Felton et al. (2003)	Meijaard and Sheil (2008) Meijaard et al. (2011)

Appendix II, 2 - Species seen at the SAFE project that were of interest to this project (SAFE, 2014).

SAFE project species	**How often species seen**	**Habitat seen in**
Moonrat *(Echinosorex gymnura)*	Commonly seen	Primary forest Logged forest Palm oil plantation
Giant squirrel *(Ratufa affinis)*	Rarely seen	Primary forest
Giant red flying squirrel *(Petaurista petaurista)*	Rarely seen	Primary forest
Prevost's squirrel *(Callosciurus prevostii)*	Rarely seen	Primary forest
Colugo *(Galeopterus variegates)*	Sometimes seen	Logged forest
Yellow-throated marten *(Martes flavigula)*	Commonly seen	Primary forest Logged forest
Stink badger *(Mydaus javanensis)*	Sometimes seen	Logged forest
Short-tailed mongoose *(Herpestes brachyurus)*	Rarely seen	Palm oil plantation
Common porcupine *(Hystrix brachyura)*	Sometimes seen	Primary forest Logged forest
Long-tailed porcupine *(Trichys fasciculate)*	Rarely seen	Logged forest
Banded civet *(Hemigalus derbyanus)*	Sometimes seen	Logged forest
Common palm civet *(Paradoxurus hermaphroditus)*	Commonly seen	Logged forest
Malay civet *(Hemigalus derbyanus)*	Often seen	Primary forest Logged forest Palm oil plantation
Masked palm civet *(Paguma larvata)*	Commonly seen	Logged forest
Binturong *(Arctictis binturong)*	Sometimes seen	Primary forest Logged forest
Bearded pig *(Sus barbatus)*	Often seen	Logged forest
Greater mousedeer *(Tragulus napu)*	Commonly seen	Logged forest
Lesser mousedeer *(Tragulus kanchil)*	Sometimes seen	Primary forest Logged forest
Red Muntjac *(Muntiacus muntjak)*	Commonly seen	Primary forest Logged forest
Sambar deer *(Rusa unicolor)*	Often seen	Logged forest
Borneo pygmy elephant *(Elephas maximus borneeensis)*	Commonly seen	Logged forest
Sunda pangolin *(Manis javanica)*	Sometimes seen	Logged forest
Sun bear *(Helarctos malayanus)*	Sometimes seen	Primary forest Logged forest
Flat-headed cat *(Prionailurus planiceps)*	Sometimes seen	Primary forest
Leopard cat *(Prionailurus bengalensis)*	Often seen	Primary forest Logged forest Palm oil plantation
Marbled cat *(Helarctos malayanus)*	Sometimes seen	Primary forest Logged forest
Sunda clouded leopard *(Neofelis diardi)*	Rarely seen	Logged forest

Grey leaf monkey *(Presbytis hosei)*	Sometimes seen	Primary forest Logged forest
Maroon Langur *(Presbytis rubicunda)*	Commonly seen	Primary forest
Long-tailed macaque *(Macaca fascicularis)*	Often seen	Logged forest
Bornean slow loris *(Nycticebus menagensis)*	Rarely seen	Logged forest
Bornean gibbon *(Hylobates albibarbis)*	Commonly seen	Primary forest Logged forest
Bornean orangutan *(Pongo pygmaeus)*	Often seen	Primary forest Logged forest

Appendix III – Method documents

English questionnaire

Interviewer name: ______________________________

Date: ________________

Participant number: ___________

Your name is not on this document and the information you give is confidential/secret

READ

Hello, my name is Amy Fitzmaurice and I am a student at Imperial College in London and this is __________________ from the Stability of Altered Forest Ecosystems (SAFE) project we work together. It will take about 30 to 45 minutes.

Would you like to do the questionnaire, the information you give is confidential/secret. You may stop at any time.

If **NO**, write gender and approximate age of respondent and FINISH and say THANK YOU.

Sex: [Circle one] Male Female

Age: [Tick one]
16-20 _____
21-41 _____
42-62 _____
63+ _____

If **YES**, WRITE DOWN interview start time Start time: __________

Section One: Individual socio-demographic information

1. Sex: [Circle one] Male Female

2. Age: __________

3. Are you married?
a) Yes
b) No

4. How many children do you have?

____

5. What age did you leave school?

____

6. What is your occupation?

____

7. Where are you from? [Circle one]
a) Sabah
b) Other ______________________________

8. Ethnicity [Circle one]
a) Malay
b) Indonesian
c) Bajau
d) Orang Asli
e) Chinese
f) Filipino
g) Other __________________
h) None
i) Don’t want to answer this question

9. Monthly Income [Circle one]
a) < 500 MYR (<£100)
b) 500 to 700 MYR (£100 to £140)
c) 700 to 900 MYR (£140 to £180)
d) 900 to 1200 MYR (£180 to £240)
e) 1200 to 1500 MYR (£240 to £300)
f) > 1500 MYR (>£300)

10. Do you have a different method to find money?

____

____

____

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Section Two: Knowledge

11. I want to show you some animals, please tell me the local Malay name of the animal and whether it is allowed to hunt the animal or not [Circle one for each animal]

Animal name	Local name				
a) Asian elephant		Allowed	Not allowed	Don't know this animal	Don't know
b) Sumatran Rhino		Allowed	Not allowed	Don't know this animal	Don't know
c) Barking deer (Muntjac)		Allowed	Not allowed	Don't know this animal	Don't know
d) Mousedeer		Allowed	Not allowed	Don't know this animal	Don't know
e) Sambar deer		Allowed	Not allowed	Don't know this animal	Don't know
f) Flat-headed cat		Allowed	Not allowed	Don't know this animal	Don't know
g) Marbled cat		Allowed	Not allowed	Don't know this animal	Don't know
h) Borneo bay cat		Allowed	Not allowed	Don't know this animal	Don't know
j) Leopard cat		Allowed	Not allowed	Don't know this animal	Don't know
j) Sunda clouded leopard		Allowed	Not allowed	Don't know this animal	Don't know
k) Bearded pig		Allowed	Not allowed	Don't know this animal	Don't know
l) Slow Loris		Allowed	Not allowed	Don't know this animal	Don't know
m) Giant flying squirrel		Allowed	Not allowed	Don't know this animal	Don't know
n) Bornean Gibbon		Allowed	Not allowed	Don't know this animal	Don't know
o) Bornean Orangutan		Allowed	Not allowed	Don't know this animal	Don't know
p) Sunda pangolin		Allowed	Not allowed	Don't know this animal	Don't know
q) Common palm civet		Allowed	Not allowed	Don't know this animal	Don't know
r) Sun bear		Allowed	Not allowed	Don't know this animal	Don't know
s) Reticulated pythons		Allowed	Not allowed	Don't know this animal	Don't know
t) Malayan box turtle		Allowed	Not allowed	Don't know this animal	Don't know

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u) Great Argus Pheasant		Allowed	Not allowed	Don't know this animal	Don't know
v) Asian arowana		Allowed	Not allowed	Don't know this animal	Don't know

Section Three: Perceptions

12. Do you have animals that have special meaning to your culture or religion? [Circle one]
a) Yes
b) No
c) Don't know

13. If Yes, what animals and why?

____

14. Do you have plants that have special meaning to your culture or religion[Circle one]
a) Yes
b) No
c) Don't know

15. If Yes, what plants and why?

____

16. How long have you been working or living the forest?

____

17. Have you seen a change in the number of animals you see from when you first entered the forest?
a) Increase
b) No change
c) Decrease
d) Don't know

18. If Increase or Decrease, please can you tell us which animals.

Increase ____

Decrease ____

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19. Are there are any activities that are changing the forest animal populations or mixture of animals? [Tick all that apply]
a) Forest changes (like rainfall or temperature) ____
b) Buildings by people ____
c) Logging ____
d) Farming ____
e) Wildlife hunting ____
f) Don't know ____
g) Other ______________________________
h) None ____

20. Are there are any activities that are changing the forest for local people? [Tick all that apply]
a) Forest changes (like rainfall or temperature) ____
b) Buildings by people ____
c) Logging ____
d) Farming ____
e) Wildlife hunting ____
f) Don't know ____
g) Other ______________________________
h) None ____

Section Four: Hunting activities

21. Do you know if other people hunt animals? [Circle one]
a) Yes
b) No
c) Don't know

22. What hunting equipment do you see other people using? [Tick all that apply]
a) Wire snares
b) Metal snares
c) Guns
d) Poisons
e) Fishing nets
f) Other __________________________________
g) None
h) Don't know

23. Where do you normally see hunting equipment? [Tick all that apply]
a) Forest trails
b) Near water
c) Near roads
d) Logged land
e) Palm oil plantations
f) Other ________________________________
g) Don't know

24. I am going to read you four questions and at the end of the questions, you just need to tell me how many of the questions you say yes to.
You can answer the questions honestly as your answers are confidential/secret.

Number of questions answered yes __________

1.	Is your birthday between January and June?
2.	Do you hunt animals?
3.	Is the last number of our mobile number an even number, 2, 4, 6, 8?
4.	Is your father's birthday between January and June?

25. Opinion of SSC technique.
a) At what level did you feel your answers will be kept confidential/secret?

High Medium Low Don't know

b) At what level did you feel comfortable responding to the questions?

High Medium Low Don't know

26. Where does hunting take place in this area?
Please place stickers onto the map to show where you have seen or heard wildlife hunting is happening.

27. Where did you learn to hunt? [Circle one]
a) Parent
b) Friend
c) Self taught
d) Other _____________________________
e) Don't know
f) Do not want to answer

If they answer e) or f), please only ask the following questions, 29, 32, 45, 46 and 47. If they answer a, b, c or d, please continue with the rest of the questionnaire.

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28. Which of the following reasons explains why you hunt animals? [Tick all that apply]
a) Food ____
b) Income ____
c) Cultural norms ____
d) Sport ____
e) Fun ____
f) Other ______________________

29. What puts you off hunting animals? [Tick all that apply]
a) Dangerous animals _____
b) Researchers _____
c) Other workers _____
d) Law enforcement _____
e) Other _____________________________________

30. What animals do you hunt? [Tick all that apply]
a) Pigs ____
b) Deers ____
c) Monkeys and apes ____
d) Birds ____
e) Cats ____
f) Rodents ____
g) Fish ____
h) Pangolins ____
i) Amphibians (frogs) ____
j) Reptiles (snakes and lizards) ____
k) Other ____
l) None ____
m) Do not want to answer ____

31. What is the most useful hunting animal to you and why?

____
Do not want to answer ____

32. What animal is your favourite to eat?

____
Do not want to answer ____

33. What do you do with your hunted animals [Tick all that apply]
a) Eat
b) Sell
c) Trade for other items
d) Gift
e) Other __________________________________
f) Don't know
g) Do not want to answer

34. If you sell your animal, where do you sell it?

____

Do not want to answer

35. Do you hunt all year round? [Circle one] If Yes, go to Question 37. If No, go to Questions 36.
a) Yes
b) No
c) Do not want to answer

36. If No, what seasons do you hunt?

____

Do not want to answer

37. How often do you go hunting? [Circle one]
a) Daily
b) Weekly
c) Monthly
d) Yearly
e) Do not want to answer

38. What month do you catch the most animals?

____

Do not want to answer

39. How many hours do you spend hunting on one trip?
______________ hrs

40. What type of transport do you use to go hunting? [Tick all that apply]
a) Walk
b) Car
c) Motor bike
d) Bicycle
e) Bus
f) Other ________________
g) Don't know
h) Do not want to answer

41. When did you last go hunting?

____

Do not want to answer

amy.v.fitzmaurice@hotmail.co.uk

42. What did you catch?

____

____

Do not want to answer

43. What did you do with your animal?

____

Do not want to answer

44. Opinion of direct questioning technique.

a) At what level did you feel your answers were anonymous?
High Medium Low Don't know

b) At what level did you feel comfortable responding to the questions?
High Medium Low Don't know

45. Did you use to be a hunter?
a) Yes
b) No
c) Don't know to answer

46. If yes, why did you stop hunting?

____

47. What do you think is the most beautiful animal from the forest?

____

End of questionnaire

[WRITE DOWN End time] **End time** ____________________

READ

Thank you for completing this survey.
"PLEASE DON'T DISCUSS THESE QUESTIONS WITH OTHER PEOPLE THAT ARE YET TO COMPLETE THIS SURVEY"

Questions for the Enumerator

1) Did the respondent talk to the female researchers during the interview?

    a) Yes
    b) Sometimes
    c) No

2) Was this respondent willing to answer the questions?
    a) Yes
    b) Sometimes
    c) No

3) Did you think this respondent understand the range of questions?

    a) Yes
    b) Sometimes
    c) No

4) Do you think this respondent was replying honestly to the questions?

    a) Yes
    b) Sometimes
    c) No

Comments

amy.v.fitzmaurice@hotmail.co.uk

MSc Conservation Science 2013/14
Ethics Assessment form

Name:	Amy Fitzmaurice
Project title:	The direct and indirect impacts of logging on mammals in Sabah, Borneo.
Supervisor(s):	Robert Ewers, Marcus Rowcliffe and Ana Nuno.

Project summary (<500 words):
Borneo is regarded as a biodiversity hotspot where illegal bushmeat hunting and deforestation for timber and plantations are drivers of biodiversity and habitat loss (Sodhi et al. 2004). For example, deforestation can be 300,000 hectares annually in Indonesia and the demand for palm oil, a major driver of plantation expansion, is expected to double by 2020 (STI, 2014). Moreover, illegal wildlife hunting is a growing concern and wildlife crime is a current target for the United for Wildlife organisation. Illegal and unsustainable hunting is indirectly linked to logging operations represent more important threats than direct logging impacts. It is thus vital to understand the direct and indirect impacts of anthropogenic processes, such as logging, on species occurrence and movements to develop mitigation strategies and conserve threatened species. Illegal logging and more recently wildlife crime are major factors of driving political change, thus why baseline data is vital for developing policies (St John et al. 2013).
This project will contribute towards addressing some of the drivers of biodiversity and habitat loss through understanding direct and indirect impacts of logging on mammal species in Sabah at The Stability of Altered Forest Ecosystems Project (SAFE). The SAFE project is one of the world's largest ecological experiments, examining the impact of tropical deforestation and forest fragmentation on biodiversity and ecosystem processes (Strubig et al. 2013; Turner et al. 2012; Ewers et al. 2011). As part of the SAFE project, approximately 8,000 ha of forest is currently logged prior to outright conversion to oil palm plantation, presenting a unique opportunity to investigate the immediate effects of disturbance by logging activities. The aims and methods are as followed;
1. Investigate the impacts of logging on mammal species occurrence before logging and during logging. Non-invasive camera trap data from before logging and during logging to investigate species occupancy using PRESENCE software.
2. Investigate the spatial impacts of logging bulldozer movements on mammal species presence and develop 'zones of disturbance', providing data for management to establish buffer zones around forests during logging to reduce environmental impacts. GPS data from bulldozers and camera trap data will be using to map 'zones of disturbance', using GIS software. The hunting data can be overlapped on top of produced maps to further identify key areas of disturbance.
3. Investigate the 'crowding effect' and 'dispersal effect' in mammals due to direct and indirect impacts of logging. The GPS bulldozer, camera trap and hunting data will be used to investigate mammal behaviour of crowding and dispersal, where crowding is defined as clusters of species and dispersal is defined as movement of an individual or species beyond its normal distribution.
4. Investigate bushmeat hunting by logging workers and palm oil workers in forest habitat, logged habitat and palm oil plantations, using specialized questioning techniques should as single count technique or unmatched count technique. Proposed questions for collection include – who is hunting, which species they hunt, where they hunt, how often they hunt and do they eat or sell bushmeat, while collecting social demographic characteristics.

1. Environmental issues	*Cross here if none of these issues apply, and move on to 2:*
Will you be working in an environmentally sensitive area?	**Yes**/No
Do you require any licenses or permits to enter this area?	Yes/**No**
Will you be collecting samples of any kind?	Yes/**No**
Will you be using destructive sampling methods?	Yes/**No**
Do you anticipate any adverse local environmental effects from your work?	Yes/**No**
Do you anticipate any adverse wider environmental effects from your work?	Yes/**No**
Will you be disturbing threatened species?	Yes/**No**

Please use this space to elaborate on your answers and how you intend to address any issues:
The SAFE project is an environmentally sensitive area due to the nature of the experiment, where areas of land are being logged and illegal hunting is occurring. Health and Safety standards will be adhered to and

amy.v.fitzmaurice@hotmail.co.uk

research will always be conducted with a SAFE research assistant, thus no lone working will occur. The non-invasive camera trapping techniques reduce the disturbance to local wildlife including threatened species.	
2. Animal/plant handling issues	*Cross here if none of these issues apply, and move on to 3:* ***X***
Will you be capturing or handling animals or plants?	Yes/No
Do you require any licences or permits for capture/handling?	Yes/No
Do you anticipate any adverse effects on the individuals handled?	Yes/No
Have you received the appropriate training or experience?	Yes/No
Have you agreed a handling protocol with your supervisor?	Yes/No
Will you be taking samples back to the UK or to an in-country lab?	Yes/No
Do you require import or export permits for any samples?	Yes/No
Please use this space to elaborate on your answers and how you intend to address any issues:	
3. Human subjects issues	*Cross here if none of these issues apply, and move on to 4:*
Will you be collecting information from or about people?	**Yes**/No
Will you be collecting information from children (under 18)?	Yes/**No**
Will you be gaining free, prior and informed consent from all subjects?	**Yes**/No
Will you be discussing sensitive topics or illegal behaviour?	**Yes**/No
Could the research cause physical, psychological or personal harm to its subjects?	Yes/**No**
Could the research violate or challenge cultural norms or practices?	Yes/**No**
Will you be ensuring anonymity and confidentiality for subjects?	**Yes/**No
Will you be witholding information or misleading subjects or other people?	**Yes**/No
Will you be observing subjects covertly?	Yes/**No**
Will you be offering payments to subjects?	Yes/**No**
Will you be collecting biological samples from people?	Yes/**No**
Will you be feeding back your results to your subjects and/or other stakeholders?	**Yes**/No
Do you have a plan for secure storage or disposal of data on subjects?	**Yes**/No
Please use this space to elaborate on your answers and how you intend to address any issues: We will be conducting social surveys with local palm oil and logging workers regarding activities of bushmeat hunting. All survey participants will have consented to participation and can stop participating at any point during the surveys and project. Due to the sensitive nature of the topic of illegal bushmeat hunting, sensitive survey techniques will be used to maximize participant uptake, where a statement explaining the purpose of the survey and who we, the surveyors are is important so participants are not mislead and anonymity and confidentially of data will be clearly stated to each participant in each survey. The surveys results will be publicly available to all stakeholders, but no personal data will be specified. During the data collection all data will be safely stored at the SAFE project research station and after the project, personal data will be removed from surveys to provide future confidentiality.	
4. Collaboration issues	*Cross here if none of these issues apply, and move on to 5:*
Are you using other people's data or intellectual property?	**Yes**/No
Will you be using field assistants?	**Yes**/No
Will you pay your field assistants?	**Yes**/No
Have your collaborators been involved in the development of your proposal?	**Yes**/No
Could the research cause physical, psychological or personal harm to your collaborators or field assistants, or challenge their cultural norms?	**Yes**/No
Will you be collaborating with in-country researchers?	**Yes**/No
Will you be training people or building capacity in-country?	**Yes**/No
Are there any potential conflicts of interest between you and any other actor?	**Yes**/No
Do you intend to analyse and publish your work jointly with your collaborators?	**Yes**/No

amy.v.fitzmaurice@hotmail.co.uk

Do you intend to make your data available to collaborators or others?	**Yes**/No
Do you have a written agreement on collaboration with the appropriate people?	**Yes**/No
Please use this space to elaborate on your answers and how you intend to address any issues: Oliver Wearn (PhD student) is a collaborator of this project and has provided previous camera trap data, where his work will be fully acknowledged at any written or publication point. The project consists of one SAFE research assistant and two Malay undergraduate research assistants, where SAFE cover the funds for the SAFE research assistant and funding has been applied for to cover the Malay research assistant costs. All collaborating organisations, individuals and co-supervisors has been involved in the design of the project and development of the proposal. The nature of this project of collecting sensitive information during the social surveys, provides additional risk to collaborating organisations and individuals reputations. However, as the project has been designed with these aspects in mind to reduce the risk of incorrect research methods that could cause harm or offense to local cultures and thus project stakeholders. The in-country researchers are the SAFE and Malay research assistants, where this project aims to provide capacity building for them through increased field research skills of camera trapping and social survey techniques and data analysis. There are potential conflicts of interests between myself and other individuals and institutes, due to the type of data collected, what it could be used for (management plans, etc) and the different organisations and individuals involved. However, conflicts have been minimized, by developing the project together from the beginning, as to provide a win-win situation where everyone benefits from this project. The MSc thesis will be written by the lead researcher, where all other stakeholder reports and peer-reviewed publications will be conducted collaboratively, where this information will be available freely on the SAFE and ICCS websites. The written agreements with collaborating organisations, individuals and co-supervisors are in email form.	

5. Institutional issues	*Cross here if none of these issues apply :*
Do you have in-country organisations as partners?	**Yes**/No
Is there the possibility for your work to cause reputational or other damage to Imperial College, MSc partner organisations, or your in-country collaborating organisation?	Yes/**No**
Will you comply with all legal obligations in the UK and your study site?	**Yes**/No
Are you complying with any specific professional ethical codes or guidelines?	**Yes**/No
Have you obtained the appropriate permissions to work in your host country?	**Yes**/No
Please use this space to elaborate on your answers and how you intend to address any issues: The two in-country collaborators are the SAFE project and the Universiti Malaysia Sabah, with Robert Ewers and Henry Bernard as points of contact respectively. All legal obligations will be adhered to, including ethical guidelines for conducted social surveys regarding illegal behaviours. Research visas have been obtained to conduct this project.	
I certify that I will aim to abide by the highest ethical standards in my research, and will immediately consult my supervisor or a course director if I have ethical concerns:	
Signature **AVF**	Date 11.04.14

Appendix IV – SSC and Results tables

Sensitive questioning

There are several sensitive questioning techniques available within all disciplines and within conservation itself to reduce the consequences facing participants and provide anonymity and confidentiality, which reduces the bias in responses and provide robust data.

Unmatched count technique (UCT)

This technique is relatively new and was used must recently by Nuno et al. (2013) in conservation, which has been shown to increase respondents response rate and understanding in relation to bushmeat hunting. However, one limiting factor of UCT is that it needs a large sample size (normally 1000) for statistical analysis to be effective.

Single sample count (SSC)

A novel approach was adopted for this project due to the limitation of UCT of a large sample size, which was not possible in the time frame available. Single sample count (SSC), which does not have this limitation and is similar to UCT in structure. Although SSC has never been used in a conservation context before, which was its limiting factor in this case. SSC is a new technique primarily used to investigate illegal drug use. It too has been shown to increase respondent response rates and understanding (Petroczi et al. 2011). The technique involves asking four questions, 1 of which is the sensitive question, wildlife hunting in this case. The respondent tells the interviewers the number of questions they say Yes to, and not which questions they say Yes to, providing confidentiality and respondents can answer honestly without the interviewers knowing their true response to the sensitive question. Through probability, the percentage of respondents that said Yes to the sensitive question can be calculated. This technique was used during the pilot and main interviews and due to the unexpected large quantity of 0's in the result the results were not analysed, as the data was skewed.

Appendix VI, 1 - Summary for the animal photographs used during the questionnaire interviews and the animals that respondents mistook them for.

Animals used in questionnaire	**Misidentified/incorrectly named as (number of people)**
Rhino	Pig (3)
Muntjac	Mousedeer (10)
Flat-headed cat	Civet (11) Deer (1)
Marbled cat	Leopard (3) Tiger (5) Civet (5) Cheetah (3) Lion (1)
Bay cat	Cheetah (2) Tiger (5) Civet (2) Monkey (1) Leopard (2) Lion (2) Puma (1) Squirrel (1)
Leopard cat	Cheetah (6) Tiger (9) Civet (4) Lion (2) Leopard (3)
Sunda clouded leopard	Tiger (5) Cheetah (5) Bear (1) Lion (1)
Slow loris	Tarsier (1) Squirrel (2) Civet (1) Monkey (4)
Giant flying squirrel	Monkey (1)
Gibbon	Orangutan (3) Monkey (90)
Common palm civet	Cat (2) Dog (1) Bear (1)
Sun bear	Dog (3) Panda (1)
Great argus	Peacock (3) Forest chicken (15)

Appendix IV, 2 - The species detected during the camera trapping in the order of body weight (small, medium and large), showing IUCN red list status and population status, tolerance to disturbance and the sites they occurred in. The tolerance or intolerance to disturbance was concluded from analysing the species detection frequency, naïve occupancy, occupancy analysis and from the zones of disturbance developed.

Species	**IUCN RedList Status**	**Population Status**	**Species size**	**Fragment detected**	**Tolerant/Intolerant to disturbance**
Red spiny rat *(Maxomys surifer)*	Least concern	Decreasing	Small	E, D, B	Tolerant
Slender treeshrew *(Tupaia gracilis)*	Least concern	Decreasing	Small	E, D, B	Tolerant
Low's squirrel *(Sundasciurus lowii)*	Least concern	Stable	Small	E, D, B	Tolerant
Four-striped ground squirrel *(Lariscus hosei)*	Near threatened	Decreasing	Small	E, D, B	Tolerant
Common treeshrew *(Tupaia glis)*	Least concern	Decreasing	Small	E, D, B	Tolerant
Large treeshrew *(Tupaia tana)*	Least concern	Decreasing	Small	E, D, B	Tolerant
Yellow-throated marten *(Martes flavigula)*	Least concern	Stable	Medium	D, B	Tolerant
Short-tailed mongoose *(Herpestes brachyurus)*	Least concern	Unknown	Medium	D	*
Long-tailed porcupine *(Trichys fasciculate)*	Least concern	Stable	Medium	E, D	Tolerant
Common porcupine *(Hystrix brachyura)*	Least concern	Decreasing	Medium	E, D, B	Tolerant
Thick-spined porcupine *(Hystrix crassispinis)*	Least concern	Stable	Medium	D	*
Banded Civet *(Hemigalus derbyanus)*	Vulnerable	Decreasing	Medium	E, D, B	Tolerant
Stink badger *(Mydaus javanensis)*	Least concern	Unknown	Medium	B	*
Leopard cat *(Prionailurus bengalensis)*	Least concern	Stable	Medium	E, D	Tolerant
Lesser mousedeer *(Tragulus kanchil)*	Least concern	Unknown	Medium	E, D	Tolerant
Marbled cat *(Pardofelis marmorata)*	Vulnerable	Decreasing	Medium	E	*
Masked palm civet *(Paguma larvata)*	Least concern	Decreasing	Medium	E, D, B	Tolerant
Pig-tailed macaque *(Macaca nemestrina)*	Vulnerable	Decreasing	Medium	E, D, B	Tolerant
Malay civet *(Viverra tangalunga)*	Least concern	Stable	Medium	E, D, B	Tolerant
Hairy-nosed otter *(Lutra sumatrana)*	Endangered	Decreasing	Medium	B	*
Sunda pangolin *(Manis javanica)*	Critically Endangered	Decreasing	Medium	E	*
Binturong *(Arctictis binturong)*	Vulnerable	Decreasing	Medium	E	*
Yellow Muntjac *(Muntiacus atherodes)*	Least concern	Decreasing	Large	B	*
Sunda clouded leopard *(Neofelis diardi)*	Vulnerable	Decreasing	Large	E	*
Red Muntjac *(Muntiacus muntjak)*	Least concern	Decreasing	Large	E, D, B	Tolerant
Sun bear *(Helarctos malayanus)*	Vulnerable	Decreasing	Large	E, D, B	Tolerant
Bearded Pig *(Sus barbatus)*	Vulnerable	Decreasing	Large	E, D, B	Tolerant
Borneo orangutan *(Pongo pygmaeus)*	Endangered	Decreasing	Large	E, D, B	Tolerant
Sambar deer *(Rusa unicolor)*	Vulnerable	Decreasing	Large	E, D, B	Tolerant

* data is inconclusive, as the species detection and occupancy was low and they only occurred at one on the three plots.

amy.v.fitzmaurice@hotmail.co.uk

Appendix IV, 3 - Species detection frequency and naïve occupancy, with species in order of body weight to show small, medium and large mammals.

Common name, *Scientific name*	**Direct sightings**	**Camera trapping**			
		No. photos	**Independent captures**	**Detection frequency*(d)***	**Naïve occupancy**
Small					
Red spiny rat *(Maxomys surifer)*	0	138	25	1.39	0.20
Slender treeshrew *(Tupaia gracilis)*	0	40	8	0.45	0.11
Lows squirrel *(Sundasciurus lowii)*	0	121	20	1.12	0.14
Four-striped ground squirrel *(Lariscus hosei)*	0	49	7	0.39	0.06
Common treeshrew *(Tupaia glis)*	0	100	14	0.78	0.13
Large treeshrew *(Tupaia tana)*	0	110	17	0.95	0.13
Medium					
Yellow-throated marten *(Martes flavigula)*	0	13	2	0.11	0.03
Short-tailed mongoose *(Herpestes brachyurus)*	0	25	1	0.05	0.01
Long-tailed porcupine *(Trichys fasciculate)*	0	17	4	0.22	0.04
Common porcupine *(Hystrix brachyura)*	1	1304	38	2.12	0.29
Thick-spined porcupine *(Hystrix crassispinis)*	0	17	2	0.11	0.01
Banded civet *(Hemigalus derbyanus)*	0	62	11	0.61	0.11
Stink badger *(Mydaus javanensis)*	0	33	3	0.17	0.04
Leopard cat *(Prionailurus bengalensis)*	2	9	3	0.17	0.04
Common palm civet *(Paradoxurus hermaphroditus)*	3	0	0	0	0
Lesser mousedeer *(Tragulus kanchil)*	0	361	16	0.89	0.07
Marbled cat *(Pardofelis marmorata)*	1	12	2	0.11	0.01
Masked palm civet *(Paguma larvata)*	0	31	6	0.33	0.09
Pig-tailed macaque *(Macaca nemestrina)*	1	791	38	2.12	0.25
Long-tailed macaque (Macaca fascicularis)	1	0	0	0	0
Malay civet *(Viverra tangalunga)*	8	304	39	2.17	0.33
Hairy-nosed otter *(Lutra sumatrana)*	0	13	2	0.11	0.01
Sunda pangolin *(Manis javanica)*	0	4	1	0.05	0.01
Binturong *(Arctictis binturong)*	0	20	2	0.11	0.03
Large					
Yellow muntjac *(Muntiacus atherodes)*	0	13	1	0.05	0.01

amy.v.fitzmaurice@hotmail.co.uk

Sunda clouded leopard *(Neofelis diardi)*	0	20	1	0.05	0.01
Red muntjac *(Muntiacus muntjak)*	0	2389	69	3.85	0.54
Sun bear *(Helarctos malayanus)*	0	117	10	0.56	0.14
Bearded pig *(Sus barbatus)*	4	2270	74	4.13	0.46
Borneo orangutan *(Pongo pygmaeus)*	2	65	7	0.39	0.10
Sambar deer *(Rusa unicolor)*	1	1410	25	1.39	0.18
Borneo pygmy elephant *(Elephas maximus borneensis)*	3	0	0	0	0

Direct sightings are incidental records. Independent captures from camera trap image sequences are potentially different individuals. Detection frequency d is the number of captures per 100 camera trap nights. Naïve occupancy is the proportion of sampled locations at which the species was detected.

amy.v.fitzmaurice@hotmail.co.uk

Appendix IV, 4 - summarises the occupancy model outcomes per species.

Species	Model run	AIC	AIC delta
Red spiny rat	N	140.21	0.00
	O	142.28	2.27
	D	143.22	3.01
	Do	145.65	5.44
Slender treeshrew	N	78.92	0.00
	D	82.69	3.76
	O	82.76	3.83
	Do	86.68	7.76
Low's squirrel	Do	103.10	0.00
	N	104.94	1.85
	O	105.34	2.24
	D	107.08	3.99
Four-striped ground squirrel	N	43.25	0.00
	D	46.43	3.19
	O	47.25	4.00
	Do	49.29	6.04
Common treeshrew	N	92.57	0.00
	D	95.32	2.75
	O	95.93	3.37
	Do	98.38	5.82
Large treeshrew	N	93.65	0.00
	D	96.95	3.30
	O	97.29	3.63
	Do	98.23	4.58
Yellow-throated marten	N	28.31	0.00
	D	30.58	2.26
	O	30.58	2.27
	Do	34.58	6.26
Short-tailed mongoose*	N	17.55	0.00
	D	19.30	1.75
	O	19.30	1.75
	DO	23.30	5.75
Long-tailed porcupine	N	38.03	0.00
	O	39.23	1.20
	D	39.25	1.22
	Do	42.70	4.67
Common porcupine	O	175.00	0.00
	Do	175.25	0.26
	D	182.99	7.99
	N	183.25	8.25
Thick-spined porcupine *	N	17.55	0.00
	D	19.30	1.75
	O	19.30	1.75
	do	23.30	5.75
Banded civet	N	95.15	0.00
	O	95.69	0.54
	Do	95.86	0.71
	d	96.64	1.49
Leopard cat	N	38.03	0.00
	D	39.40	1.37

	O	39.44	1.41
	Do	43.40	5.37
Lesser mousedeer	D	71.73	0.00
	O	74.20	2.48
	N	74.51	2.78
	Do	74.84	3.11
Masked palm civet	N	63.68	0.00
	D	66.78	3.10
	O	66.89	3.20
	Do	70.78	7.09
Pig-tailed macaque	N	173.27	0.00
	O	174.08	0.82
	Do	176.41	3.15
	D	176.50	3.24
Malay civet	D	194.32	0.00
	N	195.27	0.95
	Do	195.36	1.04
	O	197.92	3.60
Hairy-nosed otter*	N	20.92	0.00
	O	22.60	1.68
	D	22.60	1.68
	Do	5.68	5.68
Sunda pangolin*	N	17.55	0.00
	D	19.45	1.90
	O	19.45	1.90
	Do	23.45	5.90
Binturong*	D	28.10	0.000
	O	28.10	0.001
	N	28.31	0.212
	Do	32.10	3.999
Yellow muntjac*	N	17.55	0.00
	D	19.28	1.73
	O	19.28	1.73
	Do	23.28	5.73
Red muntjac	O	280.72	0.00
	D	281.65	0.93
	Do	283.43	2.71
	N	284.33	3.61
Sun bear	N	93.13	0.00
	D	95.45	2.33
	O	95.86	2.73
	Do	99.45	6.33
Bearded pig	D	259.51	0.00
	Do	260.48	0.97
	N	274.41	14.90
	O	276.94	17.42
Orangutan	N	71.45	0.00
	D	75.26	3.82
	O	75.36	3.92
	Do	79.26	7.81
Sambar	N	133.12	0.00
	D	133.56	0.44
	O	134.66	1.54
	Do	136.12	3.00

N model ran neither detectability nor occupancy with disturbance. O model ran occupancy with disturbances. D model ran detectability with disturbances. Do ran detectability and occupancy with disturbance.
* species that were only detected in one plot.

Appendix IV, 5 - Raw legal logging extraction data from one logging company in Sabah within the study area between June 2012 to June 2014.

Block no.	No. of trees extracted	Block no.	No. of trees extracted	Block no.	No. of trees extracted
1	0	39	1580	77	905
2	0	40	372	78	2231
3	0	41	3681	79	0
4	0	42	6915	80	0
5	0	43	3162	81	0
6	0	44	472	82	0
7	0	45	4996	83	4807
8	0	46	3723	84	1131
9	0	47	449	85	0
10	0	48	1912	86	854
11	0	49	96	87	7933
12	0	50	2799	88	1501
13	0	51	157	89	895
14	0	52	1056	90	641
15	0	53	308	91	0
16	0	54	1658	92	0
17	0	55	1695	93	2001
18	0	56	2583	94	1699
19	0	57	2713	95	1502
20	0	58	2359	96	985
21	0	59	3948	97	712
22	0	60	3685	98	0
23	0	61	387	99	0
24	0	62	3829	100	0
25	0	63	479	101	692
26	0	64	551	102	2311
27	0	65	2507	103	1079
28	0	66	3203	104	692
29	0	67	1956	105	2423
30	0	68	1510	106	3128
31	0	69	185	107	0
32	0	70	804	108	0
33	0	71	2184	109	0
34	0	72	0	110	0
35	0	73	1046	111	555
36	3995	74	286	112	1018
37	2269	75	2539	113	0
38	2337	76	4366	114	0

Appendix IV, 6 - summaries the data used to develop the zones of disturbance.

Camera points	**Distance from bulldozer activity (km)**	**No. of bulldozer lines (radius 0.25km)**	**No. of bulldozer lines (radius 0.50km)**	**No. of bulldozer lines (radius 1km)**	**Camera within a Block with logging extraction**	**No. of logs extracted (radius 0.25km)**	**No. of logs extracted (radius 0.50km)**	**No. of logs extracted (radius 1km)**	**Plot hectare contains reported hunting**	**ZD (green, yellow, orange, red)**
B100-2-68	1.92	**0**	0	0	No	0	0	0	No	Green
B100-2-63	1.89	0	0	0	No	0	0	0	No	Green
B100-2-62	1.90	0	0	0	No	0	0	0	No	Green
B100-2-69	1.84	0	0	0	No	0	0	0	No	Green
B100-1-57	1.57	0	0	0	No	0	0	0	No	Green
B100-1-56	1.53	0	0	0	No	0	0	0	No	Green
B100-1-58	1.50	0	0	0	No	0	0	0	No	Green
B100-1-59	1.49	0	0	0	No	0	0	0	No	Green
B10-1-35	1.34	0	0	0	No	0	0	0	No	Green
B10-1-29	1.25	0	0	0	No	0	0	0	No	Green
B10-1-31	1.20	0	0	0	No	0	0	0	No	Green
B10-1-34	1.16	0	0	0	No	0	0	0	No	Green
B10-2-47	0.88	0	0	153	No	0	0	0	No	Yellow
B10-2-40	0.79	0	0	161	No	0	0	0	No	Yellow
B10-2-41	0.77	0	0	161	No	0	0	0	No	Yellow
B10-2-43	0.75	0	0	161	No	0	0	0	No	Yellow
B1-1-1	1.54	0	0	0	No	0	0	0	Yes	Yellow
B1-1-10	1.62	0	0	0	No	0	0	0	Yes	Yellow
B1-1-12	1.55	0	0	0	No	0	0	0	Yes	Yellow
B1-2-13	1.77	0	0	0	No	0	0	0	Yes	Yellow
B1-2-24	1.74	0	0	0	No	0	0	0	Yes	Yellow
B1-2-14	1.75	0	0	0	No	0	0	0	Yes	Yellow
B1-2-18	1.80	0	0	0	No	0	0	0	Yes	Yellow
B1-2-23	1.84	0	0	0	No	0	0	0	Yes	Yellow
D100-1-126	0.011	22	105	1043	No	0	2337	10753	No	Orange
D100-1-123	0.073	22	105	1043	No	0	2337	10753	No	Orange
D100-1-121	0.046	22	103	1043	No	0	2337	10753	No	Orange
D100-1-130	0.20	8	67	914	No	0	2337	10753	No	Orange

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D100-2-140	0.41	0	130	760	No	0	2337	12564	Yes	Red *
D100-2-133	0.46	0	109	760	No	0	2337	12564	Yes	Red *
D100-2-134	0.44	0	109	760	No	0	2337	12564	Yes	Red *
D100-2-137	0.42	0	108	760	No	0	2337	8198	Yes	Red *
D10-1-101	0.10	22	113	1232	No	2623	6989	10753	No	Red
D10-1-103	0.13	25	113	1232	No	2623	6989	10753	No	Red
D10-1-107	0.17	38	113	1232	No	2623	6989	10753	No	Red
D10-1-106	0.15	65	113	1232	No	2623	6989	10753	No	Red
D10-2-111	0.21	32	115	1619	Yes	2623	2623	10753	No	Red
D10-2-112	0.19	39	115	1619	Yes	2623	2623	10753	No	Red
D10-2-114	0.21	42	200	1619	Yes	2623	2623	10753	No	Red
D10-2-116	0.21	1	176	1870	Yes	2623	2623	10753	No	Red
D1-1-81	0.068	22	44	1285	No	0	6989	8569	No	Orange
D1-1-78	0.13	22	54	1157	No	0	6989	8569	No	Orange
D1-1-76	0.13	22	27	876	No	0	6989	8569	No	Orange
D1-1-79	0.24	18	33	803	No	0	6989	6989	No	Orange
D1-2-97	0.27	1	99	850	No	286	4652	6989	Yes	Red *
D1-2-91	0.32	0	99	850	No	286	4652	10433	Yes	Red *
D1-2-86	0.32	0	195	722	Yes	286	4652	10433	Yes	Red *
D1-2-84	0.31	0	195	722	Yes	286	4652	10433	Yes	Red *
D1-2-83	0.26	1	195	722	Yes	286	4652	10433	Yes	Red *
E100-1-198	0.14	8	60	2470	No	0	372	10490	No	Red
E100-1-212	0.12	8	60	2470	No	0	372	10490	No	Red
E100-1-203	0.060	8	60	2470	No	0	372	10490	No	Red
E100-1-208	0.17	8	91	2470	No	0	372	10490	No	Red
E100-2-213	0.27	0	48	2470	No	0	3575	17884	No	Red
E100-2-217	0.29	0	48	2470	No	0	3575	17884	No	Red
E100-2-218	0.26	0	48	2470	No	0	3575	17884	No	Red
E100-2-225	0.28	0	256	2470	No	0	10968	17884	No	Red
E10-1-178	0.11	8	218	866	No	0	0	18709	No	Red
E10-1-178(2)	0.11	8	218	866	No	0	0	18709	No	Red
E10-1-183	0.034	8	218	866	No	0	0	18709	No	Red
E10-1-177	0.003	8	231	866	No	0	1695	18709	No	Red
E10-1-180	0.001	8	231	866	No	0	1695	18709	No	Red

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E10-2-196	0.070	37	269	1039	No	1695	1695	18709	No	Red
E10-2-189	0.12	27	269	1039	No	1695	1695	18709	No	Red
E10-2-194	0.15	37	269	1039	No	1695	1695	18709	No	Red
E10-2-191	0.10	37	277	1039	No	1695	6854	18709	No	Red
E1-1-153	0.25	7	604	1050	No	372	4136	19090	No	Red
E1-1-147	0.12	153	604	1050	No	2556	4136	19090	No	Red
E1-1-142	0.065	112	604	1050	No	4136	4136	19090	No	Red
E1-2-162	0.10	324	807	1050	Yes	4136	6473	7462	No	Red
E1-2-166	0.056	248	807	1050	Yes	4136	6473	7748	No	Red
E1-2-155	0.10	248	807	1050	Yes	4136	6473	7748	No	Red

Green zones = more than 1km away from logging bulldozer track and no other disturbance variables.
Yellow zones = 1 disturbance variable, where the logging bulldozer activity or logging extraction does not occur within the 0.25km radius.
Orange zones = 2 disturbance variables, where either one or both of the logging bulldozer activity or logging extraction does not occur with the 0.25km radius.
Red zones = 2 to 3 disturbance variables, where either one or both of the logging bulldozer activity or logging extraction does occur with the 0.25km radius or logging extraction numbers greater than 10,000 trees in either the 0.50km and 1km radius.
The zones of disturbance marked with a * are once that are of the highest priority for reducing disturbance, because all 3 disturbance variables are present.

Appendix V – Additional evidence of wildlife hunting in the study area

The following bullet points highlight additional hunting information obtained during social survey interviews.

- Hunting of orangutans and gibbons occurs to sell as pets to expensive places.
- Pangolin meat is good and expensive, where half from the pilot study thought that hunting this species was allowed.
- They use to see pangolins a lot in the area, but since the logging and the oil palm, and people hunting them (expensive), they don't see them any more, only in the tall, old oil palm plantations.
- People hunt pangolins by smoking them out of hollow trees and attracting them to oil palm trees with ants and then smoke them out.
- Pangolin hunters can get 80 MYR for selling one.
- People hunt porcupines as some contain ball stones, which are expensive and then eat the meat also.

This information highlights the variety of hunting activities occurring within Sabah and the possible threat of wildlife hunting to the following species – pangolins, porcupines, orangutans and gibbons.

Data was obtained from OW, where the observed actions of wildlife hunting were from randomised camera trapping and visual sightings during the period of 2011 to 2014.

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Evidence of wildlife hunting within the study area between the 2011 to 2014 (© Oliver Wearn). a) A hunter with a gun (arrow), where 14 out of 112 respondents stated guns were the equipment being used by hunters within the study area, where the majority of respondents did not know what hunting equipment is being used. b) A hunter carrying what appears to be an ungulate, where it's legs are protruding from his bag (arrow). c) A hunter and a hunting dog. Hunting dogs are often used to drive prey out of the bushes so hunters can shoot them (Wyatt, 2013). 1 respondent out of 112 stated that hunting dogs were being used within the study area.

Appendix VI – Discussion tables

Appendix VI, 1 - Shows for each species detected in the camera trapping research and whether there is literature on whether it is vulnerable to logging and wildlife hunting. Some information was taken from (Meijaard and Sheil, 2008)*. The species with no references, either have no published literature or research states they are not sensitive to logging.

Common name, *Scientific name*	**Sensitive to logging**	**Reported to be hunted**
Small		
Red spiny rat *(Maxomys surifer)*		
Slender treeshrew *(Tupaia gracilis)*	Emmons (2000)	
Low's squirrel *(Sundasciurus lowii)*		
Four-striped ground squirrel *(Lariscus hosei)*	Yasuda et al. (2003)*	
Common treeshrew *(Tupaia glis)*	Emmons (2000)	
Large treeshrew *(Tupaia tana)*	Emmons (2000)	
Medium		
Yellow-throated marten *(Martes flavigula)*		
Short-tailed mongoose *(Herpestes brachyurus)*		
Long-tailed porcupine *(Trichys fasciculate)*	Shaw (1801)*	
Common porcupine *(Hystrix brachyura)*		TRAFFIC (2014)
Thick-spined porcupine *(Hystrix crassispinis)*		
Banded civet *(Hemigalus derbyanus)*		
Stink badger *(Mydaus javanensis)*	Lechenault, in Demmarest (1818)*	
Leopard cat *(Prionailurus bengalensis)*		Shepherd (2012) TRAFFIC (2014)
Lesser Mousedeer *(Tragulus kanchil)*	Heydon and Bulloh (1997) Davies et al. (2001)*	
Marbled cat *(Pardofelis marmorata)*	Martin (1837)*	TRAFFIC (2014)
Masked palm civet *(Paguma larvata)*	Heydon and Bulloh (1996) Syakirah et al. (2000)*	Lee et al. (2004) TRAFFIC (2014)
Pig-tailed macaque *(Macaca nemestrina)*		TRAFFIC (2014)
Malay civet *(Viverra tangalunga)*	Heydon and Bulloh (1996) Syakirah et al. (2000)* Colon (2002)	TRAFFIC (2014)
Hairy-nosed otter *(Lutra sumatrana)*		Wright et al. (2008)
Sunda pangolin *(Manis javanica)*		Meijaard and Sheil (2008) TRAFFIC (2014) Daniel et al. (2014)
Binturong *(Arctictis binturong)*	Heydon and Bulloh (1996) Syakirah et al. (2000)*	TRAFFIC (2014)
Large		
Yellow muntjac *(Muntiacus atherodes)*		

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Sunda clouded leopard *(Neofelis diardi)*	Griffith (1821)*	Garbutt and Prudente, (2008) TRAFFIC (2014)
Red muntjac *(Muntiacus muntjak)*		TRAFFIC (2014)
Sun bear *(Helarctos malayanus)*	Meijaard (1999) (2001) Wong et al. (2005)	TRAFFIC (2014)
Bearded pig *(Sus barbatus)*	Davies et al. (2001)* Wong et al. (2005)	Meijaard et al. (2000)
Borneo orangutan *(Pongo pygmaeus)*	Felton et al. (2003)	Meijaard and Sheil (2008) Meijaard et al. (2011)
Sambar deer *(Rusa unicolor)*		TRAFFIC (2014)