Sciuridae density and impacts of forest disturbance in the Sabangau Tropical Peat-Swamp Forest, Central Kalimantan, Indonesia

Charlotte Schep

10,056 words

Thesis submitted for the degree of MSc Conservation,
Dept of Geography,
UCL (University College London)

August, 2014

MSc in Conservation

Please complete the following declaration and hand this form in with your MSc Research Project.

I,

....

hereby declare :

(a)   that this MSc Project is my own original work and that all source material used is acknowledged therein;

(b)   that it has been prepared specially for the MSc in Conservation of University College London;

(c)   that it does not contain any material previously submitted to the Examiners of this or any other University, or any material previously submitted for any other examination.

Signed : ....

Date :   ....

Sciuridae density and impacts of forest disturbance in the Sabangau Tropical Peat-Swamp Forest, Central Kalimantan, Indonesia

Name & Student Number: *Charlotte Schep - 1012214*
Supervisor: *Julian Thompson*

UCL

OuTrop
ORANGUTAN TROPICAL
PEATLAND PROJECT

ABSTRACT

The investigation of aimed to broaden the knowledge of Sciuridae in the Sabangau at the Natural Laboratory of Peat Swamp Forest (NLSPF). The wider surrounding area is known to contain the largest remaining contiguous lowland forest-block on Borneo, which provides a refuge for its high biodiversity as well as threatened endemic species such as the Bornean Orang-utan.

The research compared two sites, one of more pristine and untouched peat-swamp forest and the other more influenced by edge effects, for density and richness of squirrel species. The differences in vegetation structure were investigated using canopy cover and diameter at breast height data and the squirrel density surveys used line-transect (later analysed using the DISTANCE software).

The results confirmed the hypothesized differences between the two sites, with a lower encounter rate and density observed on the outer transects (1.7 sq/km; 0.74) and higher on the inner transects (2.6 sq/km; 0.84). Moreover the results highlighted squirrel preferences for higher and interconnected canopy cover and an increased density of mature fruiting trees.

An analysis of the literature context revealed a lack of research in this area particularly in comparison with other flagship species in Borneo. Available journals were used to compare the results with other density estimates which revealed similar results, confirming the significance of the study. Further analyses also highlighted the need to further examine: possible species-specific differences in density; the roles of larger and more mature trees in recruitment and the presence of fruiting trees in determining squirrel density.

CONTENTS

CONTENTS

LIST OF FIGURES, TABLES & PLATES

FIGURES

LIST OF FIGURES, TABLES & PLATES

TABLES

PLATES

ACKNOWLEDGEMENTS

1 – INTRODUCTION

1.1 – TROPICAL RAINFORESTS OF BORNEO

1.1.1 Biodiversity

Southeast Asia is known today for its long history of colonization and sea trading as well as its rapidly expanding population and economy, but despite widespread human impacts and exploitation, the region still supports a high natural biodiversity for both flora and fauna.

The region's complex geological history coupled with the shifting palaeoclimates caused the isolation of large islands, ultimately facilitating speciation (Meijaard, 2003). Its geographic location and proximity to the equator has propagated extensive humid forests.

Today tropical forests still cover half of the land area, supporting a high diversity of flora and fauna including many endemic species (UNEP, 2009). The area is hence often considered a *hotspot* (see fig1) despite reportedly containing the highest proportion of threatened vascular plant, reptile, bird and mammal species (Sodhi et al., 2010).

Southeast Asia is home to 60% of the world's tropical peatlands, the majority found in Indonesia, which have a surprisingly high species diversity despite the 'extreme' conditions (low pH, low nutrients and anaerobic) (Yule, 2010:394). Recent research from the tropical peat-swamp forests (TPSF), such as those found in central Borneo, confirms their capacity to store carbon and to support significant and highly specialized biodiversity (Yule, 2010).
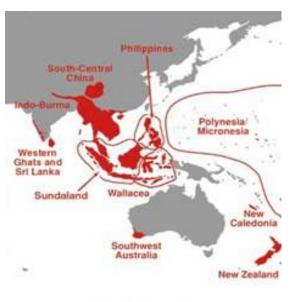
Fig1 – Map of the hotspots Southeast Asia, where hotspot expanses comprise 30-3% of the red areas (SOURCE: Myers et al., 2000)

Borneo is the third largest island on the planet with a landmass of nearly 740,000 square kilometres, with territories belonging to Brunei, Malaysia and Indonesia, the latter split into four administrative provinces – East, South, Central and West Kalimantan (WWF, 2005:8). The forests of Borneo are known for their biodiversity with up to 15,000 different flowering plants, 3,000 species of trees (155 endemic), 37 endemic birds and 44 endemic mammals with new species discovered on scientific expeditions every year (WWF, 2005:10&15). Many of the flagship species, such as the Bornean orang-utan and the Bornean Gibbon, are endemic to the island and are both listed as 'endangered' on the IUCN red list (IUCN, 2014).

1 – INTRODUCTION

About 62% of the world's tropical peatlands are found in the Indo-Malayan region, with the lowlands harboring the largest remaining area of peat swamp rainforest in Borneo, making them particularly unique (Wich et al., 2008; see fig2). In addition to acting as a vital forest habitat for threatened endemic species, peatlands also contain or store 20-35% of the carbon in the terrestrial ecosphere/ soils and play a critical role in natural water regulation and purification (WWF, 2005:62). However, peat-swamp forests have received comparatively little scientific attention to other fragile forest types and hence remain inadequately understood (Posa et al., 2011:15). Perhaps this can be attributed to perceived issues such as difficult accessibility of dense swampy areas and the belief that these areas have low biodiversity (ibid).

Yet these opinions may be misguided as it has since been asserted that peat swamps support a high proportion of specialized, endemic taxa (i.e. terrestrial flora and aquatic invertebrates) (Yule, 2010). It is important to ascertain this biodiversity as well as other qualities, such as vast amounts of carbon storage, in order to elucidate the importance of Borneo's peatlands and their future benefits.
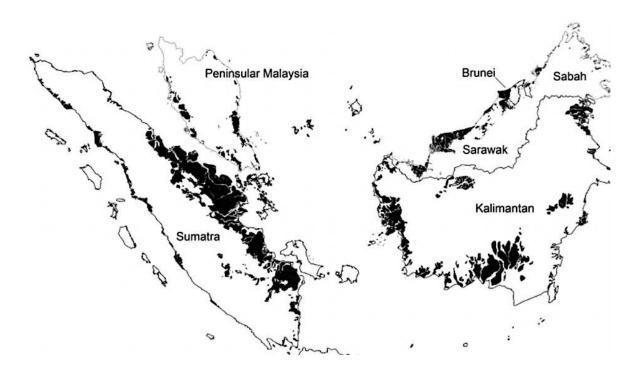
Fig2 – Map of Peninsular Malaysia, Sumatra and Borneo showing the extent of peat swamp forest in 2004 (SOURCE: Posa et al., 2011:51)

1 – INTRODUCTION

1.1.2 Threats faced

Unfortunately the forests of Southeast Asia are disappearing fast with dire impacts to biodiversity (WWF, 2005:10). Prior to 1985 roughly 75% of Borneo was completely covered by forest, however by 2005 this had reduced to 50% and a further reduction by a third is predicted by 2020 (ibid;7). This can be attributed to a variety of factors, including deforestation, degradation, habitat conversion, climate change and fire (Elhers-Smith & Elhers-Smith, 2013; Posa et al., 2011). All are linked to human action, the most detrimental for peat being the draining and logging of vast areas which changes the conditions and 'upsets the balance' so that the forest can no longer recover (Posa et al., 2011:54).
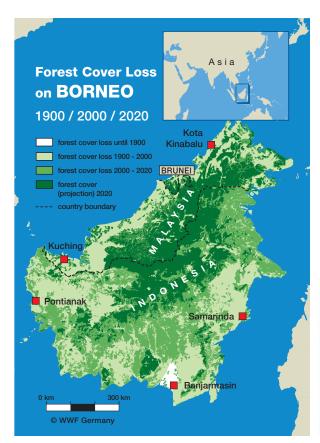
Fig3 – Map of Forest Cover Loss on Borneo in 1900, 2000 and forecasts for 2020 (SOURCE: WWF, n.d)

Fig4 – Map of forest coverage, biodiversity and economic developments on Indonesian Borneo (SOURCE: UNEP, 2009)

The region's rapid expansion of commercial endeavours are widely considered culpable for accelerating deforestation in the 1990s (WWF, 2005:55; fig3). The widespread oil palm (*Elaeis guineenis*) agriculture has been widely documented, with several million hectares of plantations replacing both primary and logged forest over the last two decades (Koh & Wilcove, 2008; Gibbs et al., 2010; Reynolds et al., 2011; fig4).

1 – INTRODUCTION

The detrimental impact to wildlife is considerable, many perish and some are forced to survive in small fragments of forest with reduced interconnectivity and genetic diversity. Moreover, facilitated access to inner forest areas can often enable the growth of illegal activities such as the wildlife trade and further logging.

When peat swamp forests become exposed, the upper layer of the peat dries out and are prone to forest fires which can smoulder beneath the surface for years (WWF, 2005:12). Burning often releases large amounts of particulate matter (CO) into the atmosphere, which is added to the increase of CO_2 emissions when forests are cleared, due to their carbon storage capacity (Slik et al., 2010; Page et al., 2002).

The NLPSF has in the past been affected by forest fires with the most recent in 2006-2007 which affected parts of the edge forest (Harrison et al., 2009). The area was selectively logged under concession until 1997 and then illegally until 2003 (Manduell et al., 2011). The process led to forest degradation through drainage of the swamp via illegal logging canals used to float out timber, resulting in peat degradation, heightened fire risk and tree falls, and forest loss in some areas. Drainage and subsequent fire remain the biggest current threats to the forest.

The *Sabangau*, 568,000 ha of tropical peat-swamp forest, has been exposed to disturbances such as uncontrolled illegal logging and drainage through timber-extraction canals. The affected parts, experience a significant reduction of the water table and more frequent and devastating forest fires (Wosten et al., 2008). Large-scale commercial logging was stopped in the early 2000s by the Centre for International Co-operation in the Management of Tropical Peatland (CIMTROP), after programmes to monitor and patrol the area were implemented. Moreover, nearby 'Taman Nasional Sebangau' was designated a national park in 2004 which increased protection around Sabangau, however the lack of effective logistics and resources mean that it is difficult for the local Forestry Department to fully eradicate illegal timber extraction (Husson et al., 2007) (see fig7).

An example of a failed project with dire consequences is the Mega Rice Project known in Indonesia as *Proyek Lahan Gambut* (PLG) (see fig4), where between 1996 and 1998 around 1 million ha of mostly peatland was deforested and drained for agricultural rice production and settlement (McCarthy, 2001). The 'irrigation system' (consisting of 4,600 km of canals) has destined the area for wasteland unable to support crops and no rice was grown (WWF, 2005:62).

Nevertheless it is important to recognise that the impacts to peat-swamp forests vary according the type and scale of logging and it is important to recognise the differences between subsistence, small-scale profit and commercial endeavours. Selective logging generally has a smaller impact on wildlife and targets trees of a certain age, diameter and species, hence often recognised as more sustainable.

1.2 – SQUIRRELS OF BORNEO

1.2.1 Review of Literature Search

In order to gain an overview of the research conducted in the field, the key scientific databases were searched (see Table1) (different combinations of:- squirrels; disturbance; canopy cover; Borneo and Indonesia).

The more specific the search to the research question, the fewer relevant journals were found. Figure 5 shows an overview of the main topics encountered (see table1; appendix4).The results showed that *very few* studies have been conducted on squirrels in Indonesian-Borneo, particularly when compared to the number of studies conducted on flagship species such as the orang-utan (see table1; fig6).

Koproski regards the lack of literature on arboreal Sciuridae world-wide a 'bleak picture' , with of 13% of known species the subject of ≥1 publication (2005:245).

Other studies also 'suggest a significant dearth of data for tree and flying squirrels', with 0-4 publications published on Borneo (Koprowski & Nandini, 2008:852) (see appendix4).

GENETICS	OVERVIEW / DESCRIPTIVE	BEHAVIOURAL ECOLOGY
molecular dating / speciation	rodentia general background	distribution & ecology mammals Malaysia
molecular dating / speciation	diet / canopy use / body size	diversity in logged / unlogged forest
genetics	nest sites / rodents & tree shrews	competitive exclusion / diet / range
molecular dating / speciation	body size / gliders	logging / borneo mammal overview
	Pleistocene / squirrel species roots	native vs invasive species
	frugivores	wildlife trade / illegal hunting
	seed dispersal / degraded areas	diversity in logged / unlogged forest
	diet / canopy use / body size	logging impacts
	morphology flying squirrels	logging / borneo mammal overview
	skull size / black giant squirrel	commercial forest thinning / flying squirrels / Oregon
	range of diurnal squirrels	forest structure / squirrel responses
	morphometric data / scurid lice	biotic pressures / impact to squirrels
		logging / red squirrels
		forest thinning / opulation dynamics / flying sq & red sq
		forest management / responses of northern flying squirrels

Fig5 – Summary of topics from scientific literature search of 'squirrels; disturbance; canopy cover' (SOURCE: Science Direct, Web of Science and Springer Link)

Fig6 – The number of scientific journals resulting from orangutan vs squirrel searches (SOURCE: Science Direct, Web of Science and Springer Link)

	SCIENTIFIC DATABASE	SEARCH	NUMBER OF RESULTS	TOTAL
1	ScienceDirect		283	
2	Web of Science	squirrel* AND borneo	40	473
3	Springer Link		150	
1	ScienceDirect		637	
2	Web of Science	squirrel* AND indonesia	57	933
3	Springer Link		239	
1	ScienceDirect		1262	
2	Web of Science	orang* AND borneo	388	3557
3	Springer Link		1907	
1	ScienceDirect		4916	
2	Web of Science	orang* AND indonesia	723	10,013
3	Springer Link		4374	

Table1 – The number of results for each search topic within each scientific journal database (SOURCE: Science Direct, Web of Science and Springer Link)

1 – INTRODUCTION

1.2.2 – Species Overview

Squirrels are part of the family Sciuridae, of the order Rodentia, and have been known to occupy a wide range of niches in temperate, subtropical and tropical regions of Southeast Asia, the Americas, Northern Eurasia and Africa. Research in the 1920s proposed six sub-families and the flying squirrels (Pocock, 1923), changed to five in 2003, with the most ancient lineage being the genus *Ratufa* and the *Callosciurinae* constituting the South-east Asian tree squirrels (Thorington et al., 2012:2) (Plate1). The tropical forests of Southeast Asia are the centre of tree squirrel species and endemism with species richness exceeding 50 and substantial endemism (Koprowski & Nandini, 2008). The Rodentia form a large part of the small mammals on Borneo (61 species out of a total of 2000 worldwide) including the 34 known squirrel species (14 nocturnal and rest diurnal) (Meijaard et al., 2005). The Sciuridae can be split into diurnal ground-dwelling, arboreal tree squirrels and nocturnal flying squirrels. The dense cover of high forests of Borneo has led to the evolution of many squirrel species to fill many ecological niches, from the tiny pygmy squirrel (*Nannosciurus melanotis*), to the giant squirrel (*Ratufa affinis*) and 12 known species of flying squirrels (WWF, n.d.).

Due to their excellent vision, squirrels can communicate using posture, foot stamping and tail movements to convey information, dominance and alarm. Calls range from high pitched squeaks and squeals to low-pitched chucks (Thorington et al., 2012:13). Although squirrels are generally thought to be fairly easy to observe and monitor, their identification can present difficulties since some species have extensive variations in colour, particularly in *Callosciurus* (Francis, 2008:328).

 Squirrels often described as opportunistic and typically omnivorous, eating both plants and small invertebrates, however the majority of tree squirrels are granivores or frugivores (Gross-Camp, 2009). Some species are more specialized however, with for instance pygmy squirrels known to be bark gleaners (Emmons, 1980).

1.2.3 – Threats faced

Approximately 74% of the threats small mammals in South-East Asia are habitat-related, with squirrels experiencing habitat loss and fragmentation which has been caused by threats such as logging, agriculture, development, industry and commerce as mentioned previously (CAMP, 2005:41). Tree squirrels across the globe are considered at risk (Koprowski & Steele, 1998). These threats can also reflect in changes in food abundance, increasing inter- and intra-species competition, however squirrels are known for their ability to adapt and exploit other food sources in times of fruit shortage. Forest fires may also have an impact to squirrel populations, where increased predation following burning is believed to drive squirrels to other strata (Dwiyahreni, 2003).

However, although logging impacts to squirrels have been linked to: genetic variation, population densities, home ranges size and reproductive performance, studies have found that responses do not follow a clear pattern with some species notably reduced and others increased. Perhaps a reflection of dietary adaptations or simply normal seasonal effects (Meijaard et al., 2005:78-81).

Moreover *Callosciurus* species are known to be hunted for food in several parts of Southeast Asia, however Bennett and Dahaban (1995) found that certain species (i.e. giant squirrels) can increase in areas subjected to high hunting pressure, perhaps opening up niches (see discussion).

1.2.4 – Conservation status

The 'IUCN Red List' labels many of the Sciuridae in Borneo to be of least concern (IUCN, 2014), and some endemic species of giant and flying squirrels have been elevated to conservation risk with the black giant squirrel and the shrew-faced squirrel near threatened. However most species are so poorly studied and there is so little knowledge of squirrels in tropical forests that accurate assessments cannot be made, for instance the slender-tailed squirrel is data deficient (ibid).

Plate1 – *Callosciurus notatus* at the NLPSF research camp, NLPSF (SOURCE: Joey Markx at OuTrop)

1 – INTRODUCTION

1.2.5 Squirrel population dynamics vs. habitat structure

The relationship between squirrels and plants is often described as 'symbiotic' since they serve as keystone agents of seed dispersal through the consumption of fruiting bodies and dispersal of seeds and spores in subtropical and tropical forests. Hence squirrels act as 'ecosystem engineers', structurally changing the environment and perhaps providing critical ecosystem services (Thorington et al., 2012:17-19).

This close association between squirrel species and a variety forest attributes was discussed by Herbers and Klenner (2007) in terms of the logging of Douglas-fir forests and its impact on 3 species of forest-dwelling sciurids. The study concluded that mature tree removal may have complex impacts to vegetation structure such as increased light penetration to understory plants and trees, which could lead to a change in the microclimate and ultimately a change in species composition (ibid:2659). The diminished number of mature trees, including the seed-producing trees, is linked with a reduction in sciurid numbers (*Glaucomys sabrinus* and *Sciurus vulgaris*).

Prather et al. (2006) also explore squirrel density and recruitment in relation to forest structure and vegetation composition for *Sciurus aberti* . Their results showed that the canopy cover threshold of 40-50% has a large influence on squirrel recruitment and is "probably indicative of the lower thresholds for connectivity in the landscape" (ibid:728).

Koprowski discusses the direct impact that differing forest management strategies have on squirrel populations, with 'clearcut' resulting in a reduction of red squirrel density from 1.2 to 0/ha and 'thinning' from 1.5 to 0.5 squirrels per ha (2005:246). However the study revealed that if management plans involve large connected forests with small and temporary fragmentation in a mosaic form, there may be minimal impact to squirrels.

Apart from vegetation structure, a range of alternative factors may affect squirrel population density, spread and behaviour, such as weather, food availability, and predation, have been shown to impact squirrel populations (Keith 1965). Weather may be a particularly important factor in causing fluctuations in tassel-eared squirrel populations across our study area. For example, Dodd et al. (2006) found that recruitment was positively related to winter–spring precipitation.

1 – INTRODUCTION

1.3 – RESEARCH QUESTION, AIMS & RATIONALE

How does Sciuridae density differ between relatively disturbed and pristine forest transects in the the Sabangau Tropical Peat-Swamp Forest, Central Kalimantan, Indonesia?

The research project is the first of its kind to study the squirrel populations at the Natural Laboratory Peat-Swamp Forest (NLPSF). The main aim was to compare the population density of squirrels between sites of differing forest disturbance in order to investigate potential impacts of vegetation structure to biodiversity.

Along with measurements of distance for density predictions, the study aimed to record other potential variables including activity time, canopy preference, vertical space use and other observed behavioural traits. Additional to these, the temperature and rainfall were to be recorded daily and data of fruit trees from various vegetation plots was to be used as a comparison.

Despite this, smaller mammals fill critical niches in the peat-swamp ecosystem and their shorter breeding cycles and rapid reactions can be advantageous when studying biodiversity and forest quality and health. Past studies, in different biomes, have considered the direct link with squirrel density and habitat quality (Saiful & Nordin, 2004; Cockburn, 1992; Wheatley et al., 2002), food depletion (Herbers & Klenner, 2007) and in terms of breeding rate (Wauters et al., 2001).

Although considerable primate research has been undertaken at the NLPSF research site pivotal for science and conservation of the orang-utan, only few studies have targeted small mammals. Moreover, a comprehensive literature review of all scientific research from Southeast Asia and Borneo revealed a lack of papers with a specific focus on squirrels (see table 1; appendix4).

In general, further knowledge of coexistence patterns and roles of small mammal in their ecosystems and their ability to cope with habitat changes is vital with the rising impacts of habitat loss and fragmentation in tropical rain forests worldwide (Wells et al., 2004).

The study therefore recognized the need to expand research on squirrels in Borneo and paired this with an investigation into potential patterns of forest structure and degradation in the NLPSF.

1 – INTRODUCTION
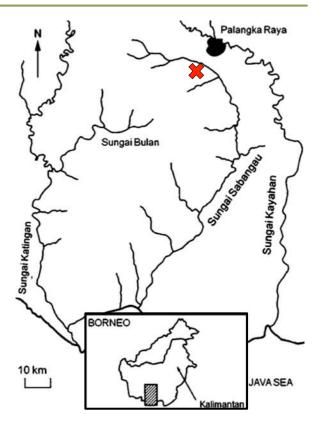
1.4 – HYPOTHESES

The main hypothesis considers the impacts of 'edge effects' on squirrel density in the outer forest of the Natural Laboratory of the study of Peat Swamp Forest (NLPSF). It assumes that this area is more degraded and that squirrel density will be negatively impacted. The different variables examined can form additional hypotheses in order to test other potential impacts to squirrel populations.

- ❖ There will be a *lower canopy cover* at edge of forest transects than inner forest transect since the trees are less developed / less mature in the NLPSF.

- ❖ There will be *fewer mature animal-dispersed trees* in the vegetation plots located nearer to the edge of the forest than the inner forest in the NLPSF.

- ❖ Squirrel populations will be *less dense* and *lower species richness* at edge of forest transects than inner forest transects in the NLPSF.

2 – METHODOLOGY
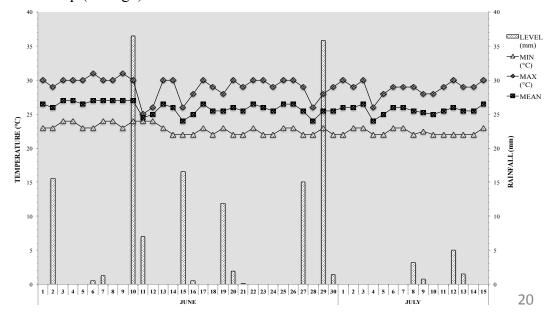
2.1 – GEOGRAPHICAL LOCATION

This research was carried out as part of the OuTrop multi-disciplinary research project in collaboration with CIMTROP. The data was conducted during the months of June/July 2014 in the Sabangau Forest Central Kalimantan province of Indonesian Borneo, 20km south-west of the provincial capital Palangka Raya (see fig7). More specifically, the NLPSF covers 500 km^2 out of the total Sabangau forest area (stretching south from Palangka Raya to the coast and from the east R.Kahayan to the west R.Katingan, ~9,200 km^2) and can be found at (21°18'58.21" S, 113°54'26.94" E). The field station borders the Sabangau river and the high water tables in the forest itself causes flooding of the peat-swamp in the wet-season, and run-off in the dry season (June – October). The tropical climate is generally hot and humid, attributable to its proximity to the equator and during the research period rainfall and temperature were recorded each day at 06:00 and 18:00 using a minimum-maximum thermometer and a rain-gauge situated at the research camp (see fig8).

Fig7 – The Sabangau Forest within Kalimantan (see inset), where 'X' marks the study area at NLPSF (SOURCE: Cheyne & Macdonald, 2011)

Fig8 – Climate graph of temperature and rainfall during the June/July data collection period

2 – METHODOLOGY

2.2 – FIELD DATA COLLECTION

2.2.1 Line-Transect Surveys

In order to explore the population abundance and density of squirrels in the NLPSF, a variety of data was collected using line-transect surveys in both the representative locations, inner (*Transect A and C*) and outer forest or forest edge (*Transect Secret East - SE and Secret West - SW*). The transects were located at least 500m apart to reduce the amount of overlap. The mixed-swamp forest has burnt in recent years, with the edge forest being generally more susceptible to the ignited fires. A delineated section on the transect SE (±550-750m), burnt in 2006-2007, was so different in vegetation structure and type from the rest of the transect that data would not be representative and this section was therefore excluded (see yellow box – fig9).
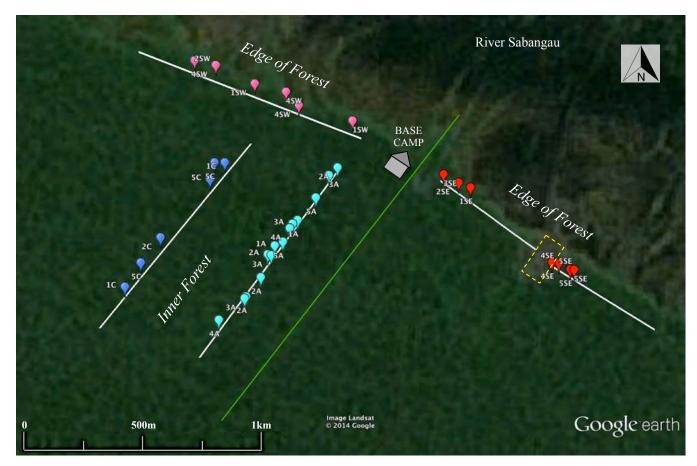
Fig9 – The GPS results (appendix3) from each sighting and the location of the line-transects walked, where: Transect A (light blue), Transect C (dark blue), Transect Secret East (red) & Transect Secret West (pink). The location of the NLPSF is shown as well as the burnt area on transect secret east delineated by a yellow box (SOURCE: Google Earth)

2 – METHODOLOGY

2.2.1 Canopy Cover

An estimation of canopy cover at three height ranges: *<10m, 10m – 20m* and *>20m*, was made every 50m along each line in the inner and outer transects in order to build up a picture of the forest structure and density. A *densiometer* was used, with the blocked squares counted (obscured by vegetation) at the different levels and later a percentage cover calculated (see fig10).

This method is also referred to as 'canopy closure' and defined it as "the proportion of sky hemisphere obscured by vegetation when viewed from a single point" (Jennings et al., 1999:62).

The techniques was also used to take a spot estimate at each squirrel sighting along the line transects.
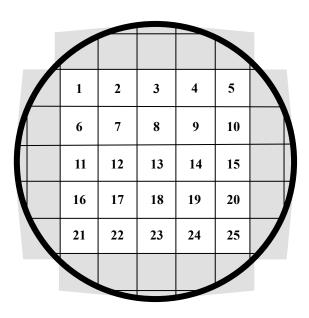
Fig10 – A visualization of the densiometer used to estimate canopy cover, with the number of squares counted

2 – METHODOLOGY

Due to limiting factors, such as difficult working conditions and limited days available for data collection, surveying was limited to two contrasting areas (see fig9). The surveys were conducted in June and July of 2014 (the late wet to early dry season) with generally low forest flood waters at both sites of the NLPSF, and some patchy dry areas in the edge-of-forest transects.

The method is based on that described in Buckland et al. (2001 & 2010) and Thomas et al. (2010), with the data collected in order to estimate population density, using the principles of the software 'Distance' (see p.26). This sampling technique is today widely employed in the tropics for both larger animals, such as Red Langurs (Elhers-Smith & Elhers-Smith, 2013) and also smaller animals, such as Buffy-tufted-ear Marmosets (Norris et al., 2011).

The line transects were surveyed by two people simultaneously, the researcher and an assistant (±10 years of experience working at research site), this technique allowed a higher detection rate (particularly of *still* squirrels) and was maintained for all transects. Often the squirrels' rapid movements in the vegetation provoked a sighting, and only rarely an individual was spotted still (resting or eating) or visually detected after hearing the sound of its call (chattering or long-calling) (see p.36; plate3).

Figure 11 helps to illustrate that some points off the line go undetected (do not have a perpendicular line) however points *on* the line itself are always detected. Also, those at greater distances away have a lower probability of being detected (Burnham et al., 1980). In order to avoid restricting the number of observations we did not limit *w* in practice (see fig12), however naturally the distance is impeded by clear vision and obstruction by dense vegetation.
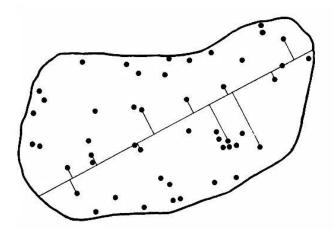

Fig11 – A diagrammatic representation an aerial view of detected points and their distance to the transect within a census area (SOURCE: Burnham et al., 1980)

2 – METHODOLOGY

The transects, 1 km each in length, were surveyed at approximately 250m per hour. The length of daily transects was restricted by the difficult terrain and conditions, with long transects compromising the ability of the researchers to detect animals. The number of sightings obtained was of importance, since 40 were necessary to estimate parameters reliably from distance sampling (Buckland et al., 2001). In order to increase the number of detections the four transects which (2 inner and 2 outer see fig9) were each surveyed 5 times (total effort expended, *20km*).

Upon detecting a squirrel, basic information was noted (i.e. date, start time, location and transect name), then the transect was traversed at a slow but fairly constant walking pace (often 5-10 steps and then a pause of 5/10 seconds – to confirm that a squirrel species rather than another small mammal). At the moment of sighting, the following data was collected from the point of sighting (R) (see fig12) (bold refers to key):

- time of day;
- geographical coordinates (using GPS);
- height of the squirrel (using clinometer, degrees(°) and estimated height, metres);
- bearing to the squirrel (the angle in degrees(°), **Θ**);
- distance from researcher to squirrel (metres, **y**);
- perpendicular distance from squirrel to transect (metres, **x**);
- species & behavioural data;
- canopy cover at squirrel sighting

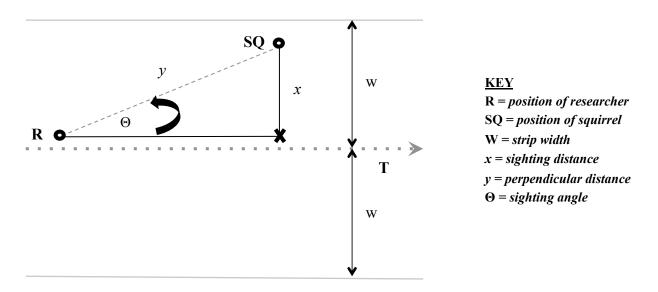

KEY
R = *position of researcher*
SQ = *position of squirrel*
W = *strip width*
x = *sighting distance*
y = *perpendicular distance*
Θ = *sighting angle*

Fig12 – The transect line survey method (SOURCE: Buckland et al., 2001)

2 – METHODOLOGY

2.2.3 Diameter at Breast-Height (DBH) of animal dispersed trees

Vegetation plots conducted in June 2013 by the Orangutan Tropical Peatland Project (OuTrop) as part of the on-going research at NLPSF investigating the differences of fruit and flower availability at increasing distances from the river. The a snapshot of this data from four plots, named 0.4, 1A, 1C and pH, formed a comparison in order to test differences between inner and outer forest plots for this project. Each plot is divided into two parts (see fig13), "Sub-plot 0" (300 x 5m, total 0.9 ha) and "Plot 1" (500 x 5m, total 1.5 ha), where the smaller sub-plot to the north of the transect measured all alive trees ≥6cm DBH and the plot to the south trees ≥ 20 cm DBH. This sampling method was employed to facilitate spatial analysis of differences and set templates for later temporal analyses, it was also designed for the logistical restrictions. (Harrison, 2009:59; Harrison et al., 2010)
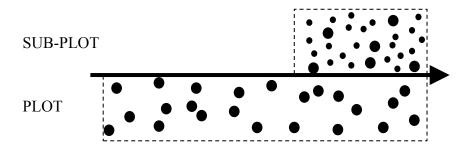

Fig13 – A visualization of the trees sampled in the vegetation plots

The dataset from the plots was truncated for ease of analysis, with only animal-dispersed trees since this was relevant to squirrel populations and also a 20-cm minimum DBH limit for trees was imposed since the majority of the sightings were in larger trees with wide trunks (>20cm) (appendix8).

2.2.4 – Other data

Other data were also recorded, while completing each transect, including: time sighted; substrate; height; squirrel species & behaviour. These data were visually assessed, estimated and categorized using designed keys (Table2).

In some cases sightings were so fleeting that species and behaviours were non-identifiable.

SUBSTRATE		SPECIES		BEHAVIOUR	
A	liana	PL	plantain	F	feeding
B	branch	SL	slender	FO	foraging
C	stem	LO	lows	TR	travelling
D	trunk	SH	shrew-faced	C	calling
E	other	PY	black-eared pygmy	S	sleeping
		FL	flying (red/whiskered)	ST	still
		n/a	non-identifiable	FI	fighting
				M	mating
				O	other

Table2 – The key table used in the line-transect methodology

2 – METHODOLOGY

2.3 – STATISTICAL ANALYSES

2.3.1 Statistical Software

The statistical analyses of central tendency was explored using Microsoft Excel for Mac 2011 version 14.2.3 and the analysis of variance (ANOVA) was examined using the 'two-sample t-test' in SPSS Statistics Desktop (V22.0).

In order to investigate the squirrel abundance and density, DISTANCE version 6.0 was used with the methodology described by Buckland et al (2004) and Thomas et al (2002).

The perpendicular distances were analysed using a probability density function that models the decrease in sightings of animals with distance from the centre line of the transect. This function is then used to calculate a density of groups with standard error and 95% confidence limits (Plumptre, 2000; Buckland et al. 1993). The method looks at the effective strip half-width μ, with the density calculated using the equation:

$$\hat{D} = \frac{n}{2\hat{\mu}L}$$

The constant (μ) is the total area under the detection function which estimates how wide the strip width would be if every organism was seen and none were missed (fig14 and table9).

3 – RESULTS & ANALYSIS

2.3.2 Assumptions in Distance software

According to the methodology of Buckland et al. (2001:9), a series of assumptions were made for the use of the DISTANCE software in the abundance analyses:

1. No animals directly on the transect line went undetected (detection probability or $g(0)=1$)
2. No movement occurred prior to detection
3. The data were free of measurement error (with no measurement error and no rounding errors)
4. Sightings of individual animals were independent events

Another assumption outlined by Welsh (2002) is of uniformity, where the software assumes the items being sampled are distributed at random in the landscape and that the probability of detection falls the further away the animal is from the line transect baseline (fig14&15).
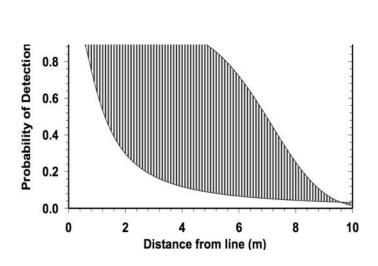
Fig14 – An example detection function, where the area under the function represents the items counted and the area above the function represents the items missed (Burnham et al., 1980:189)
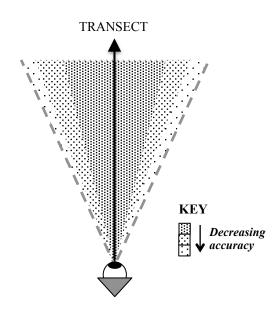
Fig15 – A basic visualization of decreasing accuracy of sightings, assuming all squirrels on the line detected
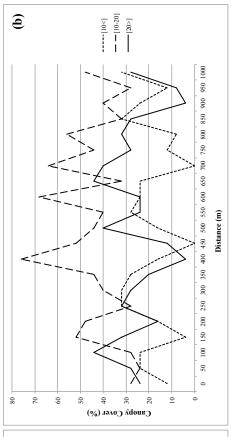
27

3 – RESULTS & ANALYSIS

3.1 – DATA ANALYSIS
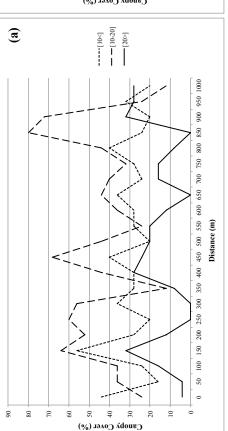
3.1.1 Canopy Cover
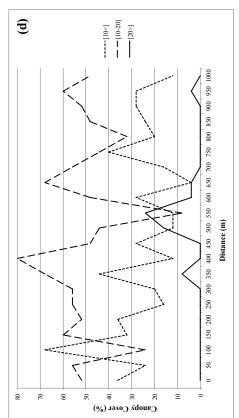
The photographs taken in around the NLPSF research camp visually show differences in the vegetation structure between sites. Photographs a & b show the affect of the 2006 forest fire creating a wide open space with few trees; c & d, taken on the inner transects, show a denser and darker transect in comparison with e & f, taken on the outer transects, more open and sparsely vegetated.

Plates 2a to 2f – Photos from June/July at the NLPSF where: (a) forest fire in 2006 (SOURCE: OuTrop, 2006); (b) transect SE at burnt area; (c) transect A; (d) transect C; (e & f) transect SW

Figs 16a to 16d – Percentage Canopy Cover along the line-transect, where: (a) transect A; (b) transect C; (c) transect secret east and (d) transect secret west
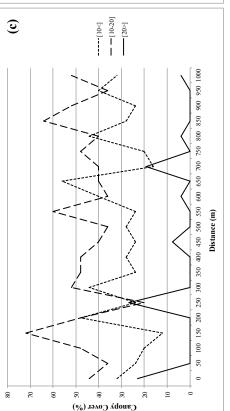
3 – RESULTS & ANALYSIS

The changes in canopy cover along the transect, estimated using a densiometer, are displayed in line graphs of percentage canopy cover (CC) for each level – 10<, 10 – 20 and 20>. The canopy cover along the transect is described in terms of the general trend and outliers (see table3).

	A	C
10<	•Fairly stable •Fluctuate between 40 – 20%	•Fluctuate a fair amount, between 30 – 10% •Interspersed with 0% coverage
10 – 20	•Spots of very high coverage •Large fluctuation along transect, between 70 – 20%	•Fairly high fluctuation, between 60 – 30% •Interspersed with very high coverage, 70%
20>	•Lower coverage with smaller fluctuation 30 – 10% •Interspersed with areas of 0% coverage	•Fairly high coverage with small fluctuation 40 – 20% •Interspersed with lower coverage 0 – 5%

	SE	SW
10<	•Fairly high fluctuation between 50 – 20%	•Fairly low, with a high fluctuation, between 30 – 10% •Interspersed with a high spot at 65%
10 – 20	•Lower fluctuation, mainly between 50 – 40%	•Very high fluctuation, between 70 – 50% •Interspersed with extreme high and low, spots of coverage at 80% & 10%
20>	•Very low coverage and low fluctuation between 10 – 0% •Interspersed with areas of 20%	•Very low coverage, generally at 0% •Interspersed with a high spot at 20%

Table3 – Summary of changes in the percentage Canopy Cover trend along each transect

Generally, all the transects show a large fluctuation in CC at all levels, however some areas have no (or very low) percentages of CC at >20m (i.e. TA 250-300m), with some of these spots correlating with a higher percentage of CC at <10m (i.e. TSW 100m). These areas were often at or near natural clearances with many fallen trees, perhaps the open vegetation structure and more light to the understory facilitates the growth of younger trees.

In contrast, some spots along the outer forest transects showed spots of low percentage CC at <10m and 10-20m paired with a higher CC at 20m> (i.e. TSE 250m and TSW 550m). This may indicate a less dense vegetation structure with few younger trees and a lack of understory.

Differences were also detected between the inner and outer transects, the most evident being the CC of over 20m which is lower in TSE & TSW than TA and TC.

The data revealed that average tree height is slightly lower in the outer transects with taller, mature trees more sparsely dispersed. These results correlate with visual cues observed whilst walking the transects at the edge of the forest (see plates 2e & f) since some areas appeared more open and degraded in this area.

At the point of each individual at each sighting, canopy cover was also estimated along with the height of the squirrel on the tree. The data was grouped into categories for facilitated analyses (fig17); the percentages of CC seem to show a normal distribution pattern with a slight negative skew. Although the CC was estimated as a percentage, the coverage is unlikely to reach either one hundred or zero percent CC owing to the vegetation structure of the peat swamp forest which is generally dense with natural gaps in the tree canopy.

Most squirrels are found between 36 and 63 percent CC, a peak in number of sightings at 45 to 54, hence the majority were sighted in areas of denser canopy coverage and therefore may reflect squirrel preference. The clear drop to in sightings at 63 to 72 percent CC may be influenced by both the improbability of these sites having a very high CC (nature of the tree canopy) and the poor visibility due to forest density restricting the number of sightings (see limitations). Nevertheless the results may also reflect lesser preference for exceptionally low and high canopy cover.
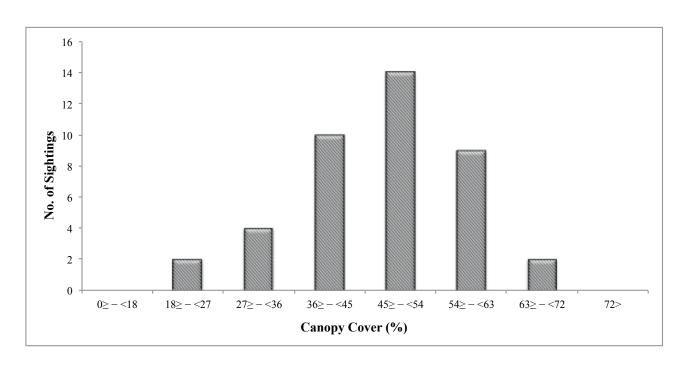

Fig17 – Number of sightings recorded at each percentage Canopy Cover for all transects

3.1.2 Vertical Space Use

The canopy cover data can be compared with other relevant data, including the *vertical space use* of the squirrels, measured by the estimated height sighted on the tree, and the diameter at breast-height (DBH) of trees in plot close to the inner and outer forest edge transects.

The sighting heights were grouped into categories to facilitate analysis. The general pattern shows fewer sightings at lower and more at higher tree heights, with the majority sighted at a height of between 14 to 24 metres (see fig18).

The data could reflect a preference of the squirrels for taller trees, particularly since most of were observed foraging and collecting fruit at the leafy upper canopy (appendix7). In turn, this could correlate with a higher number of sightings at a higher canopy cover.
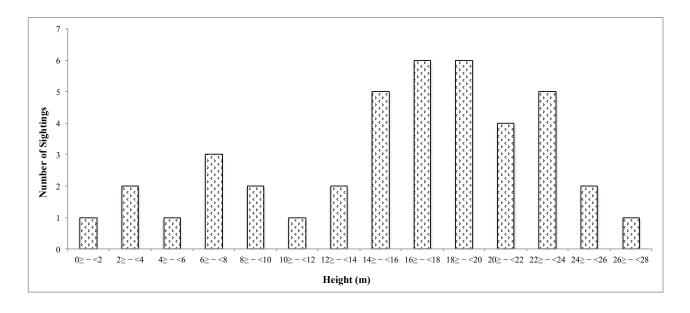

Fig18 – Number of sightings recorded at each height category for all transects

3 – RESULTS & ANALYSIS

3.1.3 Diameter at Breast-Height

The data on DBH, collected from four plots, 0.4, 1A, 1C & pH, were analysed and truncated to show fruit trees at >20cm diameter . The graphs compare the plots nearer the inner forest and edge forest with the data grouped into categories to facilitate analysis (see fig19a&b). The animal-dispersed trees seem to be more numerous in the 0.4 and 1A plots and show a wider spread of data with the majority of tree DBH falling between 20 and 32cm. In contrast, the 1C and pH plots have significantly fewer animal dispersed trees >20cm DBH.

In all plots the majority of trees have a DBH of below 34cm which suggests that older trees with wide trunks (100cm) are very sparsely distributed throughout the forest.
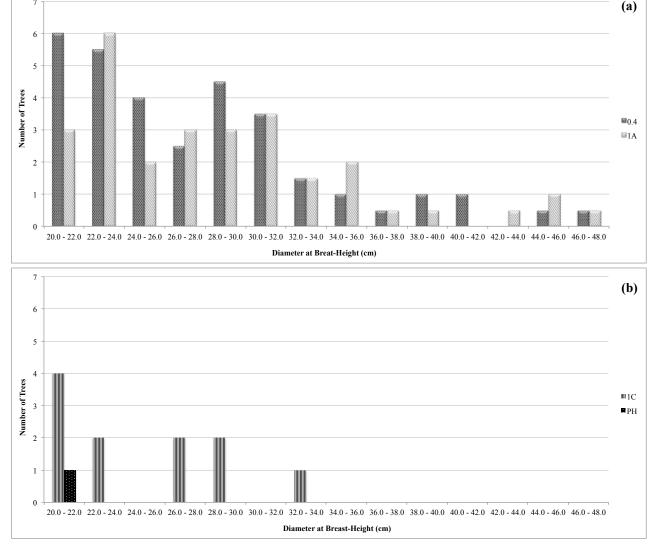

Fig19 a & b – The tree diameter at breast-height for animal-dispersed trees >20cm in plots 0.4, 1A, pH and 1C (SOURCE: OuTrop, unpublished data)

3 – RESULTS & ANALYSIS

Plots 0.4 and 1A have a fairly similar distribution of DBH in each of the classes, yet perhaps 0.4 has more trees at lower DBH between 20 and 26cm (see fig19a). While plot 1C seems to show a similar data spread to plots 0.4 and 1A but with far fewer trees, the plot pH only has one animal-dispersed tree. The latter two plots have comparatively fewer fruit trees and less older and mature trees. However the truncation of the data excluded very young trees, with DBH <20cm, which may have been more abundant in the outer transects.

Table 4 shows the *density of large trees* per ha, with a lower density of larger trees in the pH and 1C plots which correlates with the assumptions drawn from the data sets.

PLOT	AREA (ha)	NUMBER OF TREES > 20 dbh	DENSITY OF LARGE TREES / ha
0.4	0.40	115	287.5
1A	0.40	105	262.5
1C	0.15	29	193.3
PH	0.15	16	106.7

Table4 – The density (number of trees per hectare) of large trees in each of the vegetation plots

3 – RESULTS & ANALYSIS

3.1.4 Squirrel species and behaviour

At the squirrel sighting, identification was attempted, with many species distinguished for their unique features (i.e. the Plantain squirrel has a bright orange belly and a black and white stripe) (appendix9).

ORDER / FAMILY	LATIN NAME	ENGLISH NAME	♯
RODENTIA, Sciuridae	*Callosciurus notatus*	Plantain squirrel	23
	Sundasciurus tenuis	Slender squirrel	9
	Callosciurus prevostii	Prevost's squirrel	2
	Nannosciurus melanotis	Black-eyed pigmy squirrel	2
	Rhinosciurus laticaudatus	Shrew-faced ground squirrel	2
	Sundasciurus hippurus	Horse-tailed squirrel	1
	n/a	n/a	2

Table5 – The Latin name and the total number of the species encountered along the transects
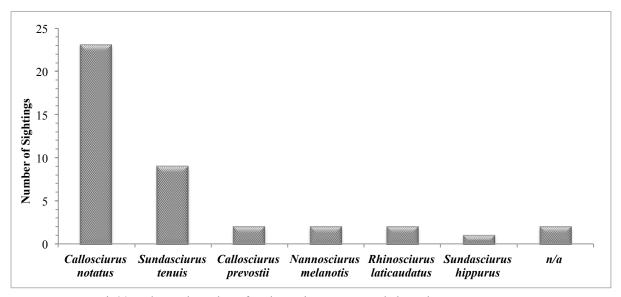

Fig20 – The total number of each species encountered along the transects

A total 6 species from 4 genera (*Callosciurus*, *Sundasciurus*, *Nannosiurus* and *Rhinosciurus*) were recorded (Table5). The majority of the squirrels sighted across all transects were *Callosciurus notatus* and *Sundasciurus tenuis*, this pattern was noted both in the inner and outer transects (fig20). However the more 'rare' species, such as *Rhinosciurus laticaudatus* and *Sundasciurus hippirus* were only spotted in the dense inner forest. Perhaps this pattern reflects the species which have the ability to adapt and take advantage of different habitats with varying levels of fruit availability.

3 – RESULTS & ANALYSIS

The squirrel behaviours were often only fleetingly observed along the line-transects, with the majority of the individuals rapidly travelling or foraging through the forest canopy. Rarely, squirrels were observed marking territory by calling or fighting (see table6).

BEHAVIOUR	♯
TRAVELLING	16
FORAGING	17
FIGHTING	2
EATING	2
FORAGING/FIGHTING	2
CALLING/FORAGING	1
STILL	1

Table6 – The total number of squirrels sighted for each time-of-day category
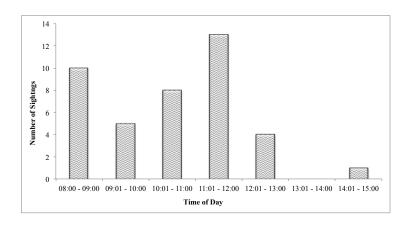
Fig21 – The total number of squirrels sighted for each time-of-day category

Plates3 a, b and c – Photographs of a calling plantain squirrel (vocalizations included clicking sounds in 2-beat patterns combined with up and down tail movements)

Additionally, the time of day was noted at every sighting, showing a peaks in the early and late morning and a clear drop in the afternoon (fig21). This could be attributed to the increase of temperatures at midday which may be less preferable for squirrels.

3 – RESULTS & ANALYSIS

3.2 – STATISTICAL ANALYSES

3.2.1 Central Tendency

The distribution of the data was studied using the sample *mean ($\bar{x}$)* and the statistical dispersion was analysed using *standard deviation (s)* and *variance (s^2)*. The mean of each canopy cover layer, summarized in table 7 and figure 22, shows that each transect layer has its lowest values for 20m and above and the highest percentage cover between 10 and 20m.

The difference between the inner and outer forest transects is evident when comparing the 20m values, in which transects A and C are significantly higher than SE and SW (i.e. for transect SW the canopy cover is ten times lower in <20m than 10-20m canopy level).
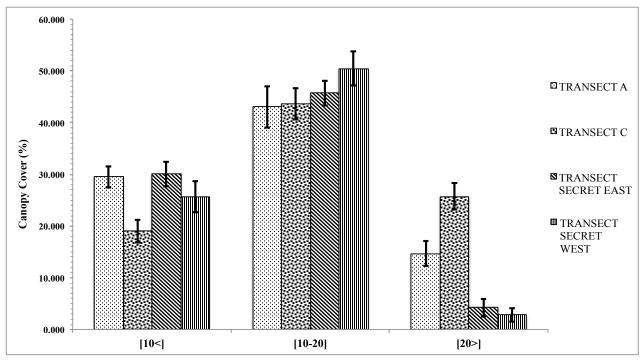
Fig22 – The mean percentage Canopy Cover at less than 10m, between 10 and 20m and above 20m for each transect

The error bars were added from the standard error to test how certain the mean values are, with most showing a small bar and therefore a fairly high confidence. However the error bars are slightly higher transect A and SW at 10 to 20m which could show a larger spread in the variability of the data.

The variance and standard deviation (*s*) in table 7 show the spread of data away from the mean. The *s* varies between 6 and 18 variance for all the canopy layers however the total *s* for all layers across each transect is very similar. This indicates that the data is similarly clustered around the mean.

		TRANSECT A		TRANSECT C		TRANSECT SECRET EAST		TRANSECT SECRET WEST	
Mean	[10<]	29.524		19.04761905		30.0952381		25.714	
	[10-20]	43.048		43.61904762		45.71428571		50.476	
	[20>]	14.667		25.71428571		4.212454212		2.857	
Variance	[10<]	89.107		104.9977324		121.324263		194.395	
	[10-20]	338.141		193.3786848		121.2517007		226.249	
	[20>]	117.841		133.4421769		64.67281193		36.789	
Standard Deviation	[10<]	9.440		10.24684012		11.01472937		13.943	
	[10-20]	18.389		13.90606648		11.011435		15.042	
	[20>]	10.855		11.55171749		8.041940806		6.065	
Standard Error	[10<]	2.060		2.236043832		2.403611004		3.043	
	[10-20]	4.013		3.034552488		2.402892113		3.282	
	[20>]	2.369		2.520791418		1.754895356		1.324	
Confidence Intervals		U.L.	L.L	U.L.	L.L	U.L.	L.L	U.L.	L.L
	[10<]	33.561	25.486	23.430	14.665	34.806	25.384	31.678	31.678
	[10-20]	50.913	35.183	49.415	37.823	50.424	41.005	56.910	56.910
	[20>]	19.310	10.024	30.655	20.774	7.652	0.773	5.451	5.451

Table7 – The mean, variance, standard deviation, standard error and confidence intervals for percentage Canopy Cover for each transect

3.2.2 Analysis of variance (ANOVA)

ANOVA was used as a statistical model to analyse the differences between group means. The 'two sample t-test' was used to reveal whether each of the transect datasets were significantly different from each other, where: the null hypothesis (H_0) states there is *no* significant difference between the two canopy cover transects (Sig.>0.05) and the alternative hypothesis (H_1) states there *is* a significant difference (Sig.<0.05) (see appendix10-15 for SPSS outputs).

(a)

	A	C	SW	SE
A		1	2	3
C	1		4	5
SW	2	4		6
SE	3	5	6	

(b & c)

The results were tested against a 5% significance level and it was deduced that the majority of the tests at 20m> canopy are significantly different. While tests amongst the inner and outer transects (see 1 & 6 – table8b) showed no significant difference between canopy cover, tests that compare the outer and inner transects (see 2, 3, 4 & 5) showed some significantly different datasets.

In particular, transect A and SE (3) show significant differences at the medium and higher canopy layers.

		[10<]	[10-20]	[20>]
1	*A & C*	0.347	0.247	0.879
2	*A & SW*	0.196	0.229	0.002
3	*A & SE*	0.380	0.039	0.042
4	*C & SW*	0.504	0.855	0.011
5	*C & SE*	0.968	0.229	0.015
6	*SW & SE*	0.550	0.487	0.316

		[10<]	[10-20]	[20>]
1	*A & C*	NS	NS	NS
2	*A & SW*	NS	NS	S
3	*A & SE*	NS	S	S
4	*C & SW*	NS	NS	S
5	*C & SE*	NS	NS	S
6	*SW & SE*	NS	NS	NS

Table8 a, b & c – The ANOVA two-sample t-test (b) and the significant, *S*, and not-significant, *NS*, difference in canopy cover (c)

3 – RESULTS & ANALYSIS

3.2.4 Squirrel Population Analysis

A total of 41 sightings were made across all transects, 26 sighted in A & C and 15 in SE & SW (see table9). The majority of sightings consisted of a single squirrel, although in intermittent cases either 2 or none were encountered on the transect.

As an initial estimate using the raw data, *2.05 individuals per km* were encountered over the total 20 km of line-transect surveys, which could perhaps represent a rough index for total density in the area. The DISTANCE software provided a more thorough test of squirrel density, using data from distance-sampling in the field to investigate any differences between the inner and outer transects.

Frequently, investigations into density of wildlife populations begin by truncating the dataset in order to remove extreme outliers which may impact the results and make the data more difficult to model (Ruette, Stahl & Albaret, 2003). However after deliberation, the squirrel dataset was not truncated since there were no obvious outliers in terms of distances (all widths 19m and under), angles or number of squirrels. Furthermore a reduction in the numbers of sightings would have been detrimental to the data analysis since the recommended minimum is of 40 sightings (required to estimate parameters reliably from distance sampling) was only just achieved (Buckland et al., 2001). The Generalized Linear Models (GLM) generated were tested for best fit both visually and using the Akaike's Information Criterion (AIC) to identify the variables that affect the perpendicular sighting distances collected in the inner and outer TPSF transects at the squirrel sightings (appendix16&17). The *Hazard Rate - Cosine* model was chosen, generating histograms with detection curves revealing the probability that animals were detected ('not missed') at different distances from the transect line (figs23 a to d).

The output of the DISTANCE software resulted in various detection probability graphs displaying the results but with larger and smaller distance intervals to reveal more detail for facilitated interpretation. The inner transects show a high probability of detection close to the transect which drops fairly consistently as you move away from the transect, with about 85% detection from 0 to 5.5m and 20% detection at 19m (see fig23b). The outer transects generally show more fluctuation in results and a less regular histogram shape with a very high detection close to the transect, around 60% detection from 3 to 5m, 90% detection from 8 to 12m and then 50% detection at 15m.
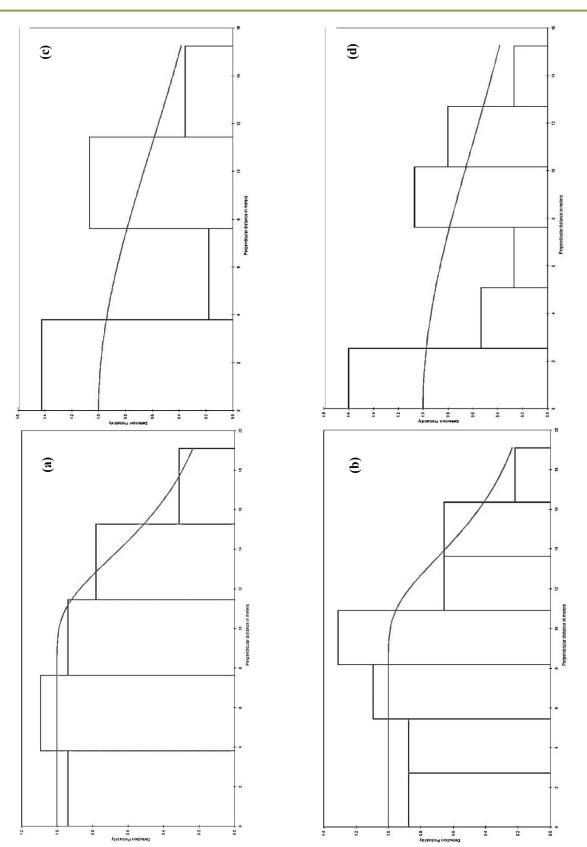
Fig23a to d – The detection probability plots, where: (a & b) represent transects A and C and (c & d) represent transect secret east and west

3 – RESULTS & ANALYSIS

According to Buckland et al (2001:3-5) a proportion of objects within distance w of the line go undetected which is the reason why the software measures the 'effective strip half-width' μ. This is lower in the outer forest transects than the inner transects, correlating with the detection probabilities. The number of sightings, n, for the inner and outer transects was fairly low (owing to time restrictions etc. – see limitations) however the DISTANCE analysis was nevertheless performed (see table9). The *chi square* probability value for both the inner and outer transects is higher than 0.05, which indicates a reasonable fit of data to the model (see appendix18). The *coefficient of variation* was calculated to compare the level of variation relative to the mean, with both data sets showing low variation but A & C showing a better overall model fit.

The *encounter rate* provided an impression of the number of squirrels per kilometer, with a clear difference in values – the researcher was 60% more likely to encounter a squirrel on the inner transects (2.6/km) than the outer transects (1.7/km). Moreover the *density*, based on the hazard cosine model, is 0.84 squirrels/ha (8.4/km^2) for the inner transects and 0.74 squirrels/ha (7.4/km^2) for the outer transects, hence notably lower for the more disturbed habitat.

	Effort (L, Km)	Number of Sightings (n)	Effective Strip Width (μ, m)	Encounter Rate (n/L, Squirrels/km)	Density	Coefficient of Variation (CV, %)	Chi-square (P[b])
A & C	10	26	15.511	2.60	0.84	14.47	0.84
SE & SW	10	17	11.529	1.70	0.74	22.69	0.24

Table9 – A summary of the DISTANCE outputs, including: effort, number of sightings, encounter rate, density. Coefficient of variation and chi-square

3 – RESULTS & ANALYSIS

3.2.3 Other Density Studies

Meijaard et al. (2005) examines the studies on different squirrel species in Borneo, from which a comparison of population densities was created (table10).

		LATIN NAME	REFERENCE	DENSITY (individulals/km2)	LOCATION
1	Plantain Squirrel	*Callosciurus notatus*	Saiful & Nordin, 2004 Yeager, 1999	5.35 8.1	Ule Mudah Forest reserve, Malaysia Kayan Mentarang National Park, Indonesia
2	Prevost's Squirrel	*Callosciurus prevostii*	Saiful & Nordin, 2004	3.29	Ule Mudah Forest reserve, Malaysia
3	Three-striped Ground Squirrel	*Lariscus insignis*	Harrison, 1969	6.0 - 19.0	n/a, Borneo
4	Four-striped Ground Squirrel	*Lariscus hosei*		no available information	
5	Red Giant Flying Squirrel	*Petaurista petaurista*		limited available information	
6	Pale Giant Squirrel	*Ratufa affinis*	MacKinnon et al., 1996 Saiful & Nordin, 2004	11 1.3	n/a, Borneo Ule Mudah Forest reserve, Malaysia
7	Horse-tailed Squirrel	*Sundasciurus hippurus*	Saiful & Nordin, 2004	3.93	Ule Mudah Forest reserve, Malaysia
8	Low's Squirrel	*Sundasciurus lowii*	Saiful & Nordin, 2004	13	Ule Mudah Forest reserve, Malaysia
9	Slender Squirrel	*Sundasciurus tenuis*		no available information	
10	Shrew-faced Ground Squirrel	*Rhinosciurus laticaudatus*		no available information	

Table10 – A comparison between individual squirrel species density within various locations on Borneo (SOURCE: Meijaard et al., 2005)

The studies used the DISTANCE software to investigate densities of individual species, revealing a variation in the densities of the different squirrel species in different regions of Borneo. In comparison with the density estimates for the NLPSF (8.4 and 7.4/km^2), some squirrels were observed at a higher density such as *Sundasciurus lowii* (13) and some much lower *Sundasciurus hippurus* (3.93). With the most abundant species in the NLPSF the *Callosciurus notatus*, the density estimates are comparatively lower in the Malaysian reserve but very similar in the Indonesian national park (Yeager, 1999).

These studies reveal population numbers may be significantly different for each species in a described area. Perhaps climatic, anthropogenic and other more nuanced impacts either negatively or positively affect different species (i.e. some species taking advantage of more open areas).

The comparative review by Meijaard et al. (2005) also reveals the limited number of squirrel density studies in Borneo, with many suffering from a lack of data to make accurate estimates.

4 – DISCUSSION

4.1 – Canopy cover

In order to test the first hypothesis, canopy cover changes along the transect (fig16) were examined for differences in the vegetation structure of the inner and outer forest areas. The technique provided an efficient way of comparing the three different canopy heights. The key difference between sites was the reduced upper canopy cover at the forest edge. This revealed that the forest structure along the secret east and west transects contained proportionally fewer taller, more mature trees, which correlated with visual observations (see plates 2e &f) as well as the statistical analyses. The results of *central tendency* tests confirmed a difference between the mean canopy cover of the inner and outer transect, and the *ANOVA* tests showed statistically different results in the upper canopy layer when comparing all inner and outer transects.

The results also analysed the vertical space use, which revealed a squirrel preference for taller and more mature trees, as well as the majority of observed behaviour consisting of foraging in the canopy (fig18). Moreover, the data reflected a generally high canopy cover at each squirrel sighting (fig17) and therefore could reflect a squirrel preference for a more dense vegetation structure. The importance of the canopy to small mammals may be attributed to the higher presence of foliage and fruits, often labelled as most productive rain forest layer (Wells et al., 2004). For instance, Dodd et al. (2006) draw attention to the importance of interlocking canopy and overstory 'clumpiness' for the density and recruitment of tassel-eared squirrel (*Sciurus aberti*) at the patch scale.

A high fluctuation of canopy cover across all transects at the medium and lower canopy heights (figs16) may reflect a normal variance in canopy structure as well as tree-fall clearances and other disturbances in the NLPSF. The graphs also show that certain areas with reduced percentage upper canopy had a higher percentage lower canopy and visa-versa. For instance at 100m on secret west, a peak of lower canopy and a lack of upper canopy may reflect a previously disturbed area, resulting in more 'open' conditions. Hence it could be a disruption in the natural successional processes that prevents a climax community of mature trees to be reached, instead facilitating growth and competition of younger and smaller trees.

Canopy gap formations, such as a reduced upper canopy in the NLPSF, may be attributed to random natural disturbances as well as various anthropogenic disturbances (Felton et al., 2006). The peat-swamp forests experience mainly small-scale internal or *endogenous* disturbances, with the 'uprooting' and weakening of trees attributable to anything from death, insect/fungus/disease, fire or stormy weather (rain and wind) (Schaetzl, 1989) to human-influenced disturbances such as erosion, peat-drainage, selective logging and fire (Felton et al., 2006).

4 – DISCUSSION

Natural disturbances are frequent in the wet tropics (Webb, 1958), a regime that is often argued to be central for the maintenance of tree diversity with gaps changing micro-climatic conditions (light, temperature and moisture levels) allowing pioneers to reach the canopy. However the disturbances which impact tree canopy structure and connectivity in forests can have a significant impact on the recruitment of small mammal populations. Many squirrel species favour a high canopy stratification and few gaps (Carey et al., 1999), with canopy continuity being a key factor for ease of movement through the arboreal pathway as well as nesting. Squirrel nest density has been found to be higher near clumps of trees with interlinking crowns and lower near disturbances such as human forest-use and road construction in riverine forests in central India (Datta & Goyal, 1996).

Nevertheless, habitat use strongly depends on the squirrel species, since some species prefer a more open canopy structure and move through the lower canopy heights. For instance, a study argued that larger squirrel species generally used higher strata of lianas and branches (*Ratufa bicolour* and *Callosciurus erythraeus*) whilst the smaller species foraged more at lower levels using the main trunk or ground (*Callosciurus pygerythrus and Tamiops macclellandi*) (Datta & Goyal, 2008).

4.2 – Mature animal-dispersed trees

The second hypothesis tested the *diameter at breast-height* to analyse vegetation structure and the number of mature animal-dispersed trees in plots close to the inner and outer transects. Some argue that the composition of tree species is more influential than canopy structure on the density and demography of a small mammals (Adler, 2000). The overall pattern showed a higher number of trees in the inner forest plots with more trees at a higher DBH. Hence a higher number of tall and mature feeding trees are available to provide a higher amount of forage, attracting more squirrels to the area. With this information, in the outer forest plots disturbances may have caused "a few large trees [to be] replaced with more small trees" often increasing the species diversity in the patch (Denslow et al., 1995:962). Such a loss of large trees may have a significant impact on small mammal density. These old and large trees have been described as 'keystone' structures since they play crucial roles for both arboreal and terrestrial mammals in forest ecosystems (Lindenmayer et al., 2012). Mature trees can provide distinctive ecological features which younger and smaller trees cannot, including (and not limited to): large internal cavities, complex branching patterns, idiosyncratic canopy architecture and abundant fruits, flowers, foliage, and nectar (ibid:1305). The higher density of mature trees may result in more fruit since the fecundity of a tree has been shown to be related to its size. These attributes are essential for cavity-using invertebrates like squirrels.

It has also been argued that the late stages of forest development provide a habitat structure that attracts squirrels due to the increased variety in fruit production (Carey et al., 1999:64).

4 – DISCUSSION

DBH has not only been used as an indicator of tree size but also to reflect the tree's ability to produce fruit. Datta & Goyal (1996) compared large fruiting trees in relatively disturbed and undisturbed sites and the impact on the Indian Giant Squirrel, *Ratufa indica*. The species had a preference for larger food and nest trees (≥12 metres), and a dependence on canopy continuity. Nevertheless the study acknowledges that the species may be able to adapt to disturbed forests (ibid:394).

Lastly, as well as the forest structure influencing squirrel density, squirrel density may also influence the NLPSF. It has been argued that small neotropical mammal species foraging within the crowns of mature trees may be key in the their maintenance (through pollination and seed dispersal) hence forest structure may be vulnerable species' preferences and range etc. (Nason & Hamrick, 1997).

4.3 – Squirrel density and Species richness

The use of line transect technique allowed a detailed population analysis using the DISTANCE software which generated detection probability histogram plots. These showed generally high numbers of detections between 0 and 10m after which detection rapidly decreased, with the furthest sighting at 19m. This pattern corresponds with Burnham et al.'s detection function (fig14). The drop in sightings in the outer transects between 3 and 7m could reflect an anomaly or may be an discrepancy due to the small sample size (limited number of sightings at the forest edge). Equally the small sample size may have had an impact on the Effective Strip Width (ESW), with some studies pooling all results in order to avoid unrealistic estimates. The data shows a lower ESW for the outer than inner transects reveals that more squirrels seen at far distances in the inner transects. Although this may have been caused by the lower density of squirrels in this area, the result is contrary to the other data collected on the outer transects which indicate a more open and bright forest structure with increased visibility.

The *encounter rate* is approximately 30% higher in the inner than the outer transects and moreover the *density* is higher in A and C than SE and SW. These data all point to a higher density and species richness of squirrels in the inner forest. Although there were very few density studies to compare with, the research by Saiful and Nordin (2004) obtained very similar densities for *C. notatus*.

The species richness analyses revealed that the highest number of squirrels encountered were of *C. notatus,* followed by *S. tenuis*, and the lowest number of *S. hippurus*. This suggests that certain species are more abundant in the outer forest regions and are hence able to populate more disturbed areas. Species such as *C. notatus* have been described as 'generalist' or 'opportunist' and are able to adapt to different niches and use the characteristics to their advantage (Charles & Ang, 2010). For instance a recently disturbed habitat may experience an absence of large-bodied predators, which in turn can open up niches for insect-fruit-vegetable feeders like *C. notatus* (ibid:556).

4 - DISCUSSION

This can be contrasted with species that are more sensitive to changes in habitat structure and impacts of disturbance, such as *S. hippurus* and *R. laticaudatus*, two species often described as rare (ibid:549). As described earlier fruit-abundance may be a key determinant of species richness and can reveal the sensitivity of certain species of squirrels to disturbances. For instance, studies discuss the ecological stratification of squirrels in terms of density after logging, where species with more selective feeding and behavioural habits (i.e. insectivorous and terrestrial) are less dense (Meijaard & Sheil, 2008). This could correlate with the few sightings of *R. laticaudatus* and *S. hippirus* in the outer transects. The study also remarks that *S. lowii* is negatively impacted by logging with a decline in numbers observed after logging as well as higher numbers in primary compared to secondary forest (ibid:23). This species-specific response of squirrels to logging is also noted in other studies, where although some generalists are described as 'thriving' in disturbed areas, it is emphasized that many other species experience reduced numbers or total absence altogether. This is linked to factors such as the reduced canopy cover, tree density and basal area in logged forest and the low tree species diversity and structural complexity (Datta & Goyal, 2008:901).

One extreme example of a squirrel species thriving in disturbed environments is the Indian Giant Squirrel *Petaurista philippensis* in Western Ghats, where encounter rates were found to be highest at the forest edge (Nandini & Parthasarathy, 2008). The explanation given for this was that the species was able to opportunistically exploit food resources and that the exposure of the edge to light increased productivity and higher food availability (ibid:1555).

5 – CONCLUSION

5.1 – AUTOCRITIQUE – limitations and improvements

The following limitations, in no particular order, were encountered during the study:

- *Rain & Wind* – although recording was stopped when rain was torrential, it was impossible to stop during short and light rain bouts, however it may have an impact on squirrel activity either during or after the rain bout. Equally rain during the night may cause increased activity the morning after due to need for foraging and the decreased temperatures

- *Time of day* – the start times were determined by the logistical restrictions involved for the assistant to reach camp. Perhaps for instance two different starts in the early morning and early afternoon may have increased sightings, following the squirrel peak activity.

- *Length of transect* – the lengths of the transects were limited by the physically difficult conditions of working in the forest (often hot, waterlogged and with many fallen trees etc.)

- *Vigilance / Experience / Tiredness* – with light-levels increasing as the transects were walked, it may have been easier to spot squirrels, however energy-levels decreased as the researchers walked along the transect and hence it is possible that less were spotted near the ends of the transects. Equally, the researcher had no previous experience and the assistant had many years of experience at the NLPSF but had little specific experience in spotting squirrels, hence signs of squirrels may have been missed – and may have improved with time at the NLPSF (i.e. calls).

- *Denseness of forest* – the density of the vegetation may have also impacted visibility and hence the number of sightings, hence perhaps more squirrel sightings in/near natural clearances.

- *Time of year* – the time of year may have an impact on the number of fruit trees or the vegetation structure present and therefore attract more or less squirrels to certain areas

- *Noise disturbance* – the disturbance caused by walking along transects in a peat swamp forest may impact the number of squirrels seen

5 – CONCLUSION

The limitations encountered reveal that further research may improve this study through for instance lengthening transects and doing more repeat surveys. This will enable a larger area to be surveyed and perhaps lead to a higher number of sightings – 60–80 observations allows better precision when using the DISTANCE software (Buckland et al., 2001).

Also, due to the difference in wet and dry season, comparison surveys could be made at different times of year to test for differences in squirrel abundance and the impact of weather/flooding. Equally the level of disturbance could be investigated and a comparison performed for squirrel abundance between different sites (i.e. include squirrel abundance at Mega Rice, highly deforested). Different types of disturbance could also be investigated, for instance the difference in squirrel abundance between site affected by erosion, fire and agriculture.

In the future, knowledge on species-specific densities should be increased since some species may be negatively impacted by disturbances while others may be taking advantage of habitat changes. Also surveys should compare fruiting tree abundance and diversity to squirrel density and richness which may be a key determinant. Lastly studies on large and mature tree density in comparison with squirrel density and richness should be increased, with older trees attract the more threatened and 'rare' squirrel species.

5 - CONCLUSION

5.2 – SUMMARY

The research project has highlighted that squirrels perform important ecosystem services, including seed planting and dispersal, pollination, influencing plant form and function and fungal spore dispersal. Many studies now recognise the benefits of surveying the rapid responses of small animals to disturbances and the use of squirrel species as 'indicators' for forest structure and health.

Despite the limitations to study, the data analysis confirmed the hypothesized differences in habitat structure and squirrel density between the more pristine inner forest and the more disturbed outer forest. The increased squirrel density and richness showed a positive correlation with other factors, in particular high canopy cover and increased density of fruit trees and diameter at breast-height. From this it may be deduced that squirrel preferences were for more dense and connected canopy and large fruiting trees, ideas which were supported by various literature studies.

However other research also highlighted the importance of studying species-specific density since certain species are more disturbance-proof due to their generalist diet. Some results even revealed that species such as *C. notatus* can increase in disturbed edge habitats since they are able to benefit from less competition in the niche habitat and perhaps lesser predation.

The research project has contributed to furthering the knowledge of Sciuridae in Borneo as well as starting an investigation into the negative impacts of disturbances on squirrel populations. This is particularly important in the knowledge that anthropogenic threats to peat-swamp forests worldwide are rapidly increasing, encroaching on their habitats. In Borneo the threats of oil palm plantations cannot be underestimated in terms of the knock-on impacts to the ecological ecosystem. Even though the disturbances may be deemed minimal, this study shows that impacts may be distinct and particularly recognizable when studying the rapid responses of small mammals. It is therefore crucially important to continue research into this area of conservation and I hope that investigations will continue by OuTrop at the NLPSF.

6 – REFERENCES

ONLINE SOURCES

OuTrop. (2014). *Orangutan Tropical Peatland Project.* [LINK: http://www.outrop.com/]

DISTANCE. (2014). *Information on the development of Distance and Distance-related R packages.* [ACCESSED: 28/07/14] [LINK: http://www.distancesampling.org/]

WWF. (n.d.). *Borneo Mammals*. About the Heart of Borneo, Borneo Forests. [SOURCE: 04/08/14] [LINK: http://wwf.panda.org/what_we_do/where_we_work/borneo_forests/about_borneo_forests/borneo_animals/borneo_mammals/]

JOURNALS, TEXTS & REPORTS

Adler, G. H. (2000). *Tropical tree diversity, forest structure and the demography of a frugivorous rodent, the spiny rat (Proechimys semispinosus)*. Journal of Zoology, 250(01), 57-74.

Bennett, E. L. and Z. Dahaban. (1995). *Wildlife responses to disturbances in Sarawak and their implications for forest management*. Pages 66-86 in R. B. Primack, and T. E. Lovejoy, editors. Ecology, conservation and management of South-East Asian rainforests. Yale University Press, New Haven, USA & London, UK.

Buckland, S. T., Anderson, D. R., Burnham, K. P., & Laake, J. L. (1993). *Distance sampling: estimating abundance of biological populations*. Chapman & Hall.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). *Introduction to distance sampling: Estimating abundance of biological populations*. Oxford University Press.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. & Thomas, L. (2004). *Advanced distance sampling*. Oxford University Press Inc., New York.

Buckland, S. T., Plumptre, A. J., Thomas, L., & Rexstad, E. A. (2010). *Line transect sampling of primates: can animal-to-observer distance methods work?*. International Journal of Primatology, 31(3), 485-499.

Burnham, K. P., Anderson, D. R., & Laake, J. L. (1980). *Estimation of density from line transect sampling of biological populations*. Wildlife monographs, 3-202.

CAMP. (2005). Molur, S., Srinivasulu, C., Srinivasulu, B., Walker, S., Nameer , P. O. and Ravikumar, L.. (Eds.). *Status of South Asian Non-volant Small Mammals*. Conservation Assessment & Management Plan (CAMP) Workshop Report. Zoo Outreach Organisation in collaboration with Wildlife Information & Liaison Development Society. [ACCESSED: 10/01/14] [LINK: http://www.zooreach.org/downloads/ZOO_CAMP_PHVA_reports/2005%20Rodent%20CAMP%20report.pdf]

Carey, A. B., Kershner, J., Biswell, B., & de Toledo, L. D. (1999). *Ecological scale and forest development: squirrels, dietary fungi, and vascular plants in managed and unmanaged forests*. Wildlife Monographs, 3-71.

Charles, J. K., & Ang, B. B. (2010). *Non-volant small mammal community responses to fragmentation of kerangas forests in Brunei Darussalam*. Biodiversity and conservation, *19*(2), 543-561.

Cheyne, S. M., & Macdonald, D. W. (2011). *Wild felid diversity and activity patterns in Sabangau peat-swamp forest, Indonesian Borneo*. Oryx, 45(01), 119-124.

Cockburn, A. (1992). *Habitat heterogeneity and dispersal: environmental and genetic patchiness*. In: Animal Dispersal. Small Animals as a Model (Ed. by N. C. Stenseth & W. Z. Lidicker), pp. 65–95. London: Chapman & Hall.

6 – REFERENCES

Datta, A., & Goyal, S. P. (1996). *Comparison of forest structure and use by the Indian giant squirrel (Ratufa indica) in two riverine forests of Central India*. Biotropica, 394-399.

Datta, A., & Goyal, S. P. (2008). *Responses of diurnal tree squirrels to selective logging in western Arunachal Pradesh*. Curr Sci, 95(7), 895-902.

Denslow, J. S. (1995). *Disturbance and diversity in tropical rain forests: the density effect*. Ecological applications, 5(4), 962-968.

Dodd, N. L., Schweinsburg, R. E., & Boe, S. (2006). *Landscape-Scale Forest Habitat Relationships to Tassel-Eared Squirrel Populations: Implications for Ponderosa Pine Forest Restoration*. Restoration Ecology, 14(4), 537-547.

Dwiyahreni, A. A. (2003). *The effects of forest fire on the squirrel and tree shrew community dynamic in southern Sumatra*. In Abstract Booklet 3rd International Colloquium in the ecology of tree squirrels. 7th European squirrel workshop. Ford Castle, Northumberland, UK. 26th-30th May 2003

Edwards, F. A., Edwards, D. P., Larsen, T. H., Hsu, W. W., Benedick, S., Chung, A., ... & Hamer, K. C. (2014). Does logging and forest conversion to oil palm agriculture alter functional diversity in a biodiversity hotspot?. *Animal Conservation*, *17*(2), 163-173.

Ehlers-Smith, D. A., & Ehlers-Smith, Y. C. (2013). *Population density of red langurs in Sabangau tropical peat-swamp forest, Central Kalimantan, Indonesia*. American journal of primatology, 75(8), 837-847.

Emmons, L. H. (1980). *Ecology and resource partitioning among nine species of African rain forest squirrels*. Ecological Monographs, 31-54.

Felton, A., Felton, A. M., Wood, J., & Lindenmayer, D. B. (2006). *Vegetation structure, phenology, and regeneration in the natural and anthropogenic tree-fall gaps of a reduced-impact logged subtropical Bolivian forest*. Forest Ecology and management, 235(1), 186-193.

Francis, C. M. (2008). *A field guide to the mammals of South-East Asia*. New Holland Publishers.

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). *Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s*. Proceedings of the National Academy of Sciences, 107(38), 16732-16737.

Gross-Camp, N. D., Mulindahabi, F., & Kaplin, B. A. (2009). *Comparing the Dispersal of Large-seeded Tree Species by Frugivore Assemblages in Tropical Montane Forest in Africa*. Biotropica, 41(4), 442-451.

Harrison, J. L. (1969). *The abundance and population density of mammals in Malayan lowland forests*. Malayan Nature Journal 34:174-178

Harrison, M. E., Cheyne, S. M., Sulistiyanto, Y. and Rieley, J. O. (2007). *Biological effects of smoke from dry-season fires in non-burnt areas of the Sabangau peat swamp forest, Central Kalimantan, Indonesia*. In: Rieley J. O. Banks C. J. and Radjagukguk B. (Eds). Carbon-climate-human interaction on tropical peatland. Proceedings of The International Symposium and Workshop on Tropical Peatland,Yogyakarta, 27-29 August 2007, EU CARBOPEAT and RESTORPEAT Partnership, Gadjah Mada University, Indonesia and University of Leicester, United Kingdom. [LINK: www.geog.le.ac.uk/carbopeat/yogyaproc.html]

6 – REFERENCES

Harrison, M. E. (2009). *Orang-utan feering behavior in Sabangau, Central Kalimantan.* PH.D., University of Cambridge, the United Kingdom.

Harrison, M. E., Page, S. E., & Limin, S. H. (2009). *The global impact of Indonesian forest fires*. Biologist, 56(3), 156.

Harrison, M. E., Morrogh-Bernard, H. C., & Chivers, D. J. (2010). *Orangutan energetics and the influence of fruit availability in the nonmasting peat-swamp forest of Sabangau, Indonesian Borneo*. International Journal of Primatology, 31(4), 585-607.

Herbers, J., & Klenner, W. (2007). *Effects of logging pattern and intensity on squirrel demography*. The Journal of Wildlife Management, 71(8), 2655-2663.

Husson, S., Morrogh-Bernard, H., D'Arcy, L., Cheyne, S. M., Harrison, M. E., & Dragiewicz, M. (2007, August). *The importance of ecological monitoring for habitat management-A case study in the Sabangau forest, Central Kalimantan, Indonesia*. In: Carbon-Climate-Human Interaction on Tropical Peatland. Proceedings of The International Symposium and Workshop on Tropical Peatland, Yogyakarta (pp. 27-29).

IUCN. (2014). *The IUCN Red List of Threatened Species*. Version 2014.2. [ACCESSED: 02/08/14] [LINK: www.iucnredlist.org]

Jennings, S. B., Brown, N. D., & Sheil, D. (1999). *Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures*. Forestry, 72(1), 59-74.

Jones, C. B. (2012). *Robustness, plasticity, and evolvability in mammals: a thermal niche approach*. Springer.

Keith, J. O. (1965). *The Abert squirrel and its dependence on ponderosa pine*. Ecology, 150-163.

Koh, L. P., & Wilcove, D. S. (2008). *Is oil palm agriculture really destroying tropical biodiversity?*. Conservation letters, 1(2), 60-64.

Koprowski, J. L. (2005). *Management and conservation of tree squirrels: the importance of endemism, species richness, and forest condition*. Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II *(GJ Gottfried, BS Gebow, LG Eskew, and CB Edminster, comps.)*. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, 245-250.

Koprowski, J. L., & Nandini, R. (2008). *Global hotspots and knowledge gaps for tree and flying squirrels*. Current Science, 95(7), 851-856.

Koprowski, J. L., & Steele, M. A. (1998). *Future directions: research on the ecology of tree squirrels*. Ecology and evolutionary biology of tree squirrels (M. Steele, JF Merritt, and DA Zegers, eds.). Virginia Museum of Natural History, Martinsville, 309-310.

Lindenmayer, D. B., Laurance, W. F., & Franklin, J. F. (2012). *Global decline in large old trees*. Science, 338(6112), 1305-1306.

Lurz, P. W. W., Garson, P. J., & Wauters, L. A. (1997). *Effects of temporal and spatial variation in habitat quality on red squirrel dispersal behaviour*. Animal Behaviour, 54(2), 427-435.

MacKinnon, K., G. Hatta, H. Halim, and A. Mangalik. (1996). *The ecology of Kalimantan*. Periplus Editions, Singapore.

6 – REFERENCES

Manduell, K., Morrogh-Bernard, H., & Thorpe, S. (2011). *Locomotor behavior of wild orangutans (pongo pygmaeus wurmbii) in disturbed peat swamp forest, Sabangau, central Kalimantan, Indonesia*. American Journal of Physical Anthropology, 145(3), 348-359. doi: 10.1002/ajpa.21495

McCarthy J.F. (2001). *Decentralisation and Forest Management in Kapuas District, Central Kalimantan*. Center for International Forestry Research

Meijaard, E. (2003). *Mammals of south-east Asian islands and their Late Pleistocene environments*. J Bio-geogr 30:1245-1257.

Meijaard, E. (Ed.). (2005). *Life after logging: reconciling wildlife conservation and production forestry in Indonesian Borneo*. Cifor.

Meijaard, E., & Sheil, D. (2008). *The persistence and conservation of Borneo's mammals in lowland rain forests managed for timber: observations, overviews and opportunities*. Ecological Research, 23(1), 21-34.

Morrogh-Bernard, H., Husson, S., Page, S. E., & Rieley, J. O. (2003). *Population status of the Bornean orang-utan Pongo pygmaeus in the Sebangau peat swamp forest, Central Kalimantan, Indonesia*. Biological Conservation, 110(1), 141-152.

Myers, N., Mittermeier, R. A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000). *Biodiversity hotspots for conservation priorities*. Nature 403:853–858.

Nason, J. D., & Hamrick, J. L. (1997). *Reproductive and genetic consequences of forest fragmentation: two case studies of neotropical canopy trees*. Journal of Heredity, 88(4), 264-276.

Nandini, R., & Parthasarathy, N. (2008). *Food habits of the Indian giant flying squirrel (Petaurista philippensis) in a rain forest fragment, Western Ghats*. Journal of Mammalogy, 89(6), 1550-1556.

Norris, D., Rocha-Mendes, F., Marques, R., de Almeida Nobre, R., & Galetti, M. (2011). *Density and spatial distribution of buffy-tufted-ear marmosets (Callithrix aurita) in a continuous Atlantic Forest*. International Journal of Primatology, 32(4), 811-829.

Page, S. (2006). *The biodiversity of peat swamp forest habitats in SE Asia; impacts of land-use and environmental change; implications for sustainable ecosystem management*. STRAPEAT Project.

Prather, J. W., Dodd, N. L., Dickson, B. G., Hampton, H. M., Xu, Y., Aumack, E. N., & Sisk, T. D. (2006). *Landscape models to predict the influence of forest structure on tassel-eared squirrel populations*. Journal of Wildlife Management, 70(3), 723-731.

Pocock, R. I. (1923, June). *The Classification of the Scinridæ*. In Proceedings of the Zoological Society of London (Vol. 93, No. 2, pp. 209-246). Blackwell Publishing Ltd.

Posa, M. R. C., Wijedasa, L. S., & Corlett, R. T. (2011). *Biodiversity and conservation of tropical peat swamp forests*. BioScience, 61(1), 49-57.

Plumptre, A. J. (2000). *Monitoring mammal populations with line transect techniques in African forests*. Journal of Applied Ecology, 37(2), 356-368.

Reynolds, G., Payne, J., Sinun, W., Mosigil, G., & Walsh, R. P. (2011). *Changes in forest land use and management in Sabah, Malaysian Borneo, 1990–2010, with a focus on the Danum Valley region*. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1582), 3168-3176.

6 – REFERENCES

Routledge, R. D., & Fyfe, D. A. (1992). *Confidence limits for line transect estimates based on shape restrictions*. The Journal of wildlife management, 402-407.

Ruette, S., Stahl, P., & Albaret, M. (2003). *Applying distance -sampling methods to spotlight counts of red foxes*. Journal of Applied Ecology, 40(1), 32-43.

Saiful, A. A. and M. Nordin. (2004). *Diversity and density of diurnal squirrels in a primary hill dipterocarp forest, Malaysia*. Journal of Tropical Ecology 20:45-49

Schaetzl, R. J., Burns, S. F., Johnson, D. L., & Small, T. W. (1989). *Tree uprooting: review of impacts on forest ecology*. Vegetation, 79(3), 165-176.

Slik, J., Aiba, S., Brearley, F.Q., Cannon, C.H., Forshed, O., Kitayama, K., Nagamasu, H., Nilus, R., Payne, J. & Paoli, G. (2010). *Environmental correlates of tree biomass, basal area, wood specific gravity and stem density gradients in Borneo's tropical forests*. Global Ecol. Biogeogr. 19, 50–60.

Sodhi, N. S., Posa, M. R. C., Lee, T. M., Bickford, D., Koh, L. P., & Brook, B. W. (2010). *The state and conservation of Southeast Asian biodiversity*. Biodiversity and Conservation, 19(2), 317-328.

Thomas, L., Buckland, S. T., Burnham, K. P., Anderson, D.R., Laake, J. L., Borchers, D.L. & Strindberg, S. (2002). *Distance sampling*. In El- Shaarawi AH, Piegorsch WW (eds) Encyclopedia of environmetrics. John Wiley & Sons, Chinchester, p 544–552

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., ... & Burnham, K. P. (2010). *Distance software: design and analysis of distance sampling surveys for estimating population size*. Journal of Applied Ecology, 47(1), 5-14.

Thorington, Jr, R. W., Koprowski, J. L., Steele, M. A., & Whatton, J. F. (2012). *Squirrels of the World*. The Johns Hopkins University Press.

Wauters, L. A., Gurnell, J., Preatoni, D. and Tosi, G. (2001). *Effects of spatial variation in food availability on spacing behaviour and demography of Eurasian red squirrels*. Ecography, 24: 525–538.

Webb, L. J. (1958). *Cyclones as an ecological factor in tropical lowland rain-forest, North Queensland*. Australian Journal of Botany, 6(3), 220-228.

Wells, K., Pfeiffer, M., Lakim, M. B., & Linsenmair, K. E. (2004). *Use of arboreal and terrestrial space by a small mammal community in a tropical rain forest in Borneo, Malaysia*. Journal of Biogeography, 31(4), 641-652.

Welsh, A. H. (2002). *Theory & Methods: Incomplete detection in enumeration surveys: Whither distance sampling?*. Australian & New Zealand Journal of Statistics, 44(1), 13-22.

Wheatley, M., Larsen, K. W., & Boutin, S. (2002). *Does density reflect habitat quality for North American red squirrels during a spruce-cone failure?*. Journal of Mammalogy, 83(3), 716-727.

Wich, S. A., Meijaard, E., Marshall, A. J., Husson, S., Ancrenaz, M., Lacy, R. C., ... & Singleton, I. (2008). *Distribution and conservation status of the orang-utan (Pongo spp.) on Borneo and Sumatra: how many remain?*. Oryx, *42*(03), 329-339

6 – REFERENCES

WWF. (2005). *Borneo: Treasure Island at Risk. Status of Forest, Wildlife and related Threats on the Island of Borneo*. Germany WWF. Frankfurt am Main. [ACCESSED: 09/08/14] [LINK: http://assets.wwf.org.uk/downloads/treasureisland_0605.pdf]
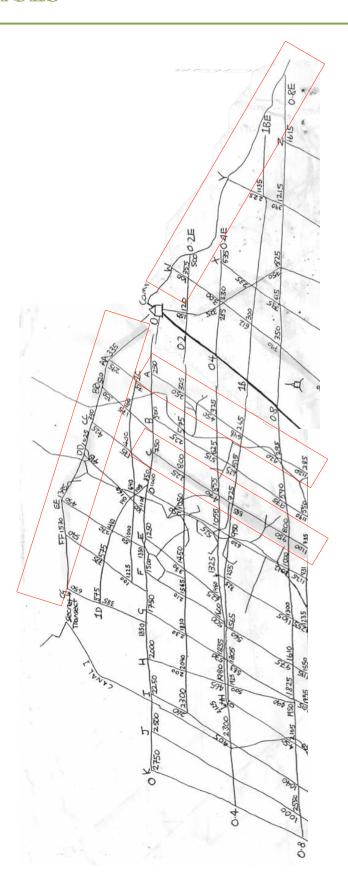
Yeager, C. (1999). *Research report Lalut-Birai Field Station 1997-1999*. WWF Indonesia, Kayan-Mentarang National Park Project, Jakarta, Indonesia

Yule, C. M. (2010). *Loss of biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests*. Biodiversity and Conservation, 19(2), 393-409.

UNEP. (2009). *The forests of Southeast Asia – UNEP*. Vital forest graphics, pp.42-43 [ACCESSED: 04/08/14] [LINK: http://www.unep.org/vitalforest/Report/VFG_full_report.pdf]

7 – APPENDICES

APPENDIX 1

Transects Map NLPSF

7 – APPENDICES

APPENDIX 2

Temperature and Rainfall

		TEMPERATURE			TOTAL RAINFALL
		MIN (°C)	MAX (°C)	MEAN	LEVEL (mm)
JUNE	1	23	30	26.5	0
	2	23	29	26.0	15.5
	3	24	30	27.0	0
	4	24	30	27.0	0
	5	23	30	26.5	0
	6	23	31	27.0	0.5
	7	24	30	27.0	1.3
	8	24	30	27.0	0
	9	23	31	27.0	0
	10	24	30	27.0	36.5
	11	24	25	24.5	7
	12	24	26	25.0	0
	13	23	30	26.5	0
	14	22	30	26.0	0
	15	22	26	24.0	16.5
	16	22	28	25.0	0.5
	17	23	30	26.5	0
	18	22	29	25.5	0
	19	23	28	25.5	11.9
	20	22	30	26.0	1.9
	21	22	29	25.5	0.1
	22	23	30	26.5	0
	23	22	30	26.0	0
	24	22	29	25.5	0
	25	23	30	26.5	0
	26	23	30	26.5	0
	27	22	29	25.5	15
	28	22	26	24.0	0
	29	23	28	25.5	35.8
	30	22	29	25.5	1.4
JULY	1	22	30	26.0	0
	2	23	29	26.0	0
	3	23	30	26.5	0
	4	22	26	24.0	0
	5	22	28	25.0	0
	6	23	29	26.0	0
	7	23	29	26.0	0
	8	22	29	25.5	3.2
	9	22.5	28	25.3	0.8
	10	22	28	25.0	0
	11	22	29	25.5	0
	12	22	30	26.0	5
	13	22	29	25.5	1.5
	14	22	29	25.5	0
	15	23	30	26.5	0

7 – APPENDICES

APPENDIX 3

GPS COORDINATES

#	Transect	Elevation	Southings	Eastings
[001]	C (1)	58	02°19'00.3"	113°54'02.5"
[002]	C (2)	71	02°19'18.0"	113°58'49.8"
[003]	C (3)	83	02°19'11.0"	113°58'54.3"
[004]	C (4)	82	02°19'46.9"	113°58'31.3"
[005]	SW	(-)78	02°18'53.7"	113°54'19.4"
[006]	SW	62	02°18'49.1"	113°54'06.0"
[007]	A	43	02°19'07.8"	113°54'12.6"
[008]	A	45	02°19'11.4"	113°54'09.7"
[009]	A	73	02°19'00.3"	113°54'17.7"
[010]	A	79	02°19'12.7"	113°54'08.3"
[011]	A	68	02°19'15.9"	113°54'08.0"
[012]	A	77	02°19'18.6"	113°54'06.2"
[013]	A	79	02°19'01.4"	113°54'16.5"
[014]	A	81	02°19'08.3"	113°54'12.0"
[015]	A	67	02°19'12.8"	113°54'09.3"
[016]	A	65	02°19'18.9"	113°54'06.0"
[017]	SW	62	02°19'46.3"	113°53'57.7"
[018]	SE	63	02°19'02.3"	113°54'35.7"
[019]	SW	64	02°13'51.9"	113°54'12.0"
[020]	SW	86	02°13'50.1"	113°54'10.2"
[021]	SW	82	02°13'46.8"	113°54'00.6"
[022]	SE	43	02°19'01.6"	113°54'34.1"
[023]	SE	43	02°19'00.6"	113°54'32.0"
[024]	A	60	02°19'09.0"	113°54'11.6"
[025]	A	69	02°19'22.0"	113°54'02.6"
[026]	SE	70	02°19'12.1"	113°54'47.2"
[027]	C	69	02°19'00.3"	113°54'01.1"
[028]	C	74	02°19'02.7"	113°54'00.6"
[029]	C	68	02°19'14.6"	113°58'51.8"
[030]	SE	44	02°19'12.2"	113°54'48.1"
[031]	SE	44	02°19'13.0"	113°54'49.7"
[032]	SE	49	02°19'13.0"	113°54'50.2"
[033]	A	67	02°19'04.6"	113°54'14.9"
[034]	A	72	02°19'10.9"	113°54'10.8"

7 – APPENDICES

APPENDIX 4   Literature search

REFERENCE	TOPIC	QUOTE	PAGE

1

SCIENTIFIC DATABASE ScienceDirect
SEARCH squirrel AND borneo
NUMBER OF RESULTS 280

#	REFERENCE	TOPIC	QUOTE	PAGE
1	den Tex, R. J., Thorington, R., Maldonado, J. E., & Leonard, J. A. (2010). *Speciation dynamics in the SE Asian tropics: Putting a time perspective on the phylogeny and biogeography of Sundaland tree squirrels, Sundasciurus*. Molecular Phylogenetics and Evolution, 55(2), 711-720.	molecular dating / speciation	"Cytochrome b sequences from the squirrel genus Callosciurus were selected as the most appropriate outgroup…"	713
2	Dieterlen, F. (2005). Rodents. *Ecosystems of the world, 14*, 383-400.	rodentia general background	"Three rodent sub-orders and four families inhabit the rain forest: Sciuromorpha with Sciuridae (squirrels)"	383
3	Cranbrook, E., & Furtado, J. I. (1988). *Key Environments Malaysia*.	distribution & ecology mammals Malaysia	"native wild species…Rodents 54/14"	146
4	Wilson, W. L., & Johns, A. D. (1982). *Diversity and abundance of selected animal species in undisturbed forest, selectively logged forest and plantations in East Kalimantan, Indonesia*. Biological Conservation, 24(3), 205-218.	diversity in logged / unlogged forest	"gradual shift in species composition and dominance among flying squirrels (Petauristinae) from primary forest through partially logged to secondary forest"	216

SCIENTIFIC DATABASE Web of Science
SEARCH squirrel AND borneo
NUMBER OF RESULTS 40

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Beaudrot, L., Struebig, M. J., Meijaard, E., van Balen, S., Husson, S., & Marshall, A. J. (2013). *Co-occurrence patterns of Bornean vertebrates suggest competitive exclusion is strongest among distantly related species*. Oecologia, 173(3), 1053-1062.	competitive exclusion / diet / range	"relative intensity of potential competition within and between species of primates, birds, bats and squirrels."	1055
2	Beaudrot, L., Struebig, M. J., Meijaard, E., Van Balen, S., Husson, S., Young, C. F., & Marshall, A. J. (2013). *Interspecific interactions between primates, birds, bats, and squirrels may affect community composition on Borneo*. American journal of primatology, 75(2), 170-185.	diet / canopy use / body size	"species presence–absence data on bats, birds, primates, and squirrels"	172
3	den Tex, R. J., Thorington, R., Maldonado, J. E., & Leonard, J. A. (2010). *Speciation dynamics in the SE Asian tropics: Putting a time perspective on the phylogeny and biogeography of Sundaland tree squirrels, Sundasciurus*. Molecular Phylogenetics and Evolution, 55(2), 711-720.	molecular dating / speciation	"Cytochrome b sequences from the squirrel genus Callosciurus were selected as the most appropriate outgroup…"	713
4	Musser, G. G., Durden, L. A., Holden, M. E., & Light, J. E. (2010). *Systematic review of endemic Sulawesi squirrels (Rodentia, Sciuridae), with descriptions of new species of associated sucking lice (Insecta, Anoplura), and phylogenetic and zoogeographic assessments of sciurid lice*. Bulletin of the American Museum of Natural History, 339(1), 1-260.	morphometric data / scurid lice	"Analyses of fur color patterns, morphometric data derived from external, cranial, and dental dimensions…… revision of Sulawesi's endemic squirrel fauna"	4
5	Wells, K., Lakim, M. B., & Pfeiffer, M. (2006). *Nest sites of rodents and treeshrews in Borneo*. Ecotropica, 12, 141-149.	nest sites / rodents & tree shrews	"The scansorial squirrel *Sundasciurus lowii* nested both in tree cavities and in nests made of plant fiber"	141
6	Dial, R. (2003). *Energetic savings and the body size distributions of gliding mammals*. Evolutionary ecology research, 5(8), 1151-1162.	body size / gliders	"allometric relationships to determine an upper limit for body mass in mammalian gliders (flying squirrels, marsupial gliders, colugos and anomalurids)."	1151
7	Oshida, T., Fujita, Y., Lin, L. K., & Masuda, R. (2001). *A preliminary note on the phylogenetic position of the lesser giant flying squirrel Petaurista elegans, inferred from mitochondrial cytochrome b gene sequence*. Mammal Study,26(2), 149-152.	genetics	"female lesser giant squirrel was captured…on Sumatra Island..total DNA was extracted from skin tissue…cytochrome b gene"	149

SCIENTIFIC DATABASE Springer Link
SEARCH squirrel AND borneo
NUMBER OF RESULTS 150

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Meijaard, E., & Sheil, D. (2008). The persistence and conservation of Borneo's mammals in lowland rain forests managed for timber: observations, overviews and opportunities. *Ecological Research, 23*(1), 21-34.	logging / borneo mammal overview	"terrestrial, largely insectivorous squirrels seemed least able to adapt to conditions in logged forests."	23
2	Lane, D. J. W. (2010). *Late Quaternary turnover of mammals in Borneo: the zooarchaeological record*. In Biodiversity and conservation (Vol. 19, No. 2, pp. 373-391). Springer.	Pleistocene / squirrel species roots	"subspecies of Prevost's squirrel Callosciurus prevostii are best explained by immigration during the terminal Pleistocene from Sumatra to western Borneo via the Karimata land bridge."	378
3	Wells, K., Lakim, M. B., & O'Hara, R. B. (2014) *Shifts from native to invasive small mammals across gradients from tropical forest to urban habitat in Borneo*. Biodiversity and Conservation, 1-15.	native vs invasive species	"Most of them comprised species of native rats, squirrels…recorded as the most commonly trapped species in near-natural rainforests in Borneo"	2296
4	Shanahan, M., & Compton, S. G. (2001). *Vertical stratification of figs and fig-eaters in a Bornean lowland rain forest: how is the canopy different?*. In Tropical Forest Canopies: Ecology and Management (pp. 121-132). Springer Netherlands.	frugivores	"Malaysian forests… squirrels all appear to have habitat preferences that partition their environment in the vertical dimension"	122

2

SCIENTIFIC DATABASE ScienceDirect
SEARCH squirrel AND indonesia
NUMBER OF RESULTS 614

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Lee, R. J., Gorog, A. J., Dwiyahreni, A., Siwu, S., Riley, J., Alexander, H., ... & Ramono, W. (2005). *Wildlife trade and implications for law enforcement in Indonesia: a case study from North Sulawesi*. Biological Conservation, 123(4), 477-488.	wildlife trade / illegal hunting	"Trade in two non-protected groups, large bats and squirrels…"	482
2	Blackham, G. V., Thomas, A., Webb, E. L., & Corlett, R. T. (2013). *Seed rain into a degraded tropical peatland in Central Kalimantan, Indonesia*. Biological Conservation, 167, 215-223.	seed dispersal / degraded areas	"A review of seed dis- persers in degraded areas of tropical Asia recognised…squirrels (Sciuridae), the majority of which consume only relatively small- fruited, small-seeded fruits…"	216
3	Wilson, W. L., & Johns, A. D. (1982). *Diversity and abundance of selected animal species in undisturbed forest, selectively logged forest and plantations in East Kalimantan, Indonesia*. Biological Conservation, 24(3), 205-218.	diversity in logged / unlogged forest	"gradual shift in species composition and dominance among flying squirrels (Petauristinae) from primary forest through partially logged to secondary forest"	216

SCIENTIFIC DATABASE Web of Science
SEARCH squirrel AND indonesia
NUMBER OF RESULTS 56

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Beaudrot, L., Struebig, M. J., Meijaard, E., Van Balen, S., Husson, S., Young, C. F., & Marshall, A. J. (2013). *Interspecific interactions between primates, birds, bats, and squirrels may affect community composition on Borneo*. American journal of primatology, 75(2), 170-185.	diet / canopy use / body size	"species presence–absence data on bats, birds, primates, and squirrels"	172
2	den Tex, R. J., Thorington, R., Maldonado, J. E., & Leonard, J. A. (2010). *Speciation dynamics in the SE Asian tropics: Putting a time perspective on the phylogeny and biogeography of Sundaland tree squirrels, Sundasciurus*. Molecular Phylogenetics and Evolution, 55(2), 711-720.	molecular dating / speciation	"Cytochrome b sequences from the squirrel genus Callosciurus were selected as the most appropriate outgroup…"	713
3	Musser, G. G., Durden, L. A., Holden, M. E., & Light, J. E. (2010). *Systematic review of endemic Sulawesi squirrels (Rodentia, Sciuridae), with descriptions of new species of associated sucking lice (Insecta, Anoplura), and phylogenetic and zoogeographic assessments of sciurid lice*. Bulletin of the American Museum of Natural History, 339(1), 1-260.	morphometric data / scurid lice	"Analyses of fur color patterns, morphometric data derived from external, cranial, and dental dimensions…… revision of Sulawesi's endemic squirrel fauna"	4
4	Rasmussen, N. L., & Thorington Jr, R. W. (2008). Morphological differentiation among three species of flying squirrels (Genus Hylopetes) from Southeast Asia. *Journal of Mammalogy, 89*(5), 1296-1305.	morphology flying squirrels	"Understanding the zoogeographic patterns of these flying squirrels and the rest of the Sunda fauna…"	1296
5	Endo, H., Kimura, J., Oshida, T., Stafford, B. J., Rerkamnuaychoke, W., Nishida, T., ... & Hayashi, Y. (2004). *Geographical variation of skull size and shape in various populations in the black giant squirrel Ratufa macroura in south India*. The Journal of veterinary medical science/the Japanese Society of Veterinary Science,66(10), 1213-1218.	skull size / black giant squirrel	"the feeding pattern and locomotion tendencies were diverged…did not observe differences of adaptational strategy among populations of the black giant squirrel."	1217
6	Whitten, J. E. (1981). *Ecological separation of three diurnal squirrels in tropical rainforest on Siberut Island, Indonesia*. Journal of Zoology, 193(3), 405-420.	range of diurnal squirrels	"ecological separation of diurnal squirrels on Siberut Island"	405
7	Wilson, C. C., & Wilson, W. L. (1975). *The influence of selective logging on primates and some other animals in East Kalimantan*. Folia Primatologica,23(4), 245-274.	logging impacts	"low squirrel score….reflects the habitat disruption from selective logging"	262

SCIENTIFIC DATABASE Springer Link
SEARCH squirrel AND indonesia
NUMBER OF RESULTS 239

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Meijaard, E., & Sheil, D. (2008). The persistence and conservation of Borneo's mammals in lowland rain forests managed for timber: observations, overviews and opportunities. *Ecological Research, 23*(1), 21-34.	logging / borneo mammal overview	"terrestrial, largely insectivorous squirrels seemed least able to adapt to conditions in logged forests."	23

3

SCIENTIFIC DATABASE Springer Link
SEARCH squirrel AND disturb* AND canopy
NUMBER OF RESULTS 846

#	REFERENCE	TOPIC	QUOTE	PAGE
1	Manning, T., Hagar, J. C., & McComb, B. C. (2012). *Thinning of young Douglas-fir forests decreases density of northern flying squirrels in the Oregon Cascades*. Forest Ecology and Management, 264, 115-124.	commercial forest thinning / flying squirrels / Oregon	"Thinning decreased density of northern flying squirrels, and squirrel densities were significantly lower in heavily thinned stands than in more lightly thinned stands."	115
2	Carey, A. B. (2001). *Experimental manipulation of spatial heterogeneity in Douglas-fir forests: effects on squirrels*. Forest Ecology and Management,152(1), 13-30.	forest structure / squirrel responses	"Three species of indigenous squirrels would each respond differently in the short-term to remove trees and the collateral damage to plants, fungi, and other habitat elements"	15
3	Joshua, J., & Johnsingh, A. J. T. (1994). *Impact of biotic disturbances on the habitat and population of the endangered grizzled giant squirrel Ratufa macroura in south India*. Biological conservation, 68(1), 29-34.	biotic pressures / impact to squirrels	"squirrel population did not show a decline during annual counts over three years but these disturbances resulted in loss of cover, food trees and nesting sites"	29
4	Allard-Duchêne, A., Pothier, D., Dupuch, A., & Fortin, D. (2014). *Temporal changes in habitat use by snowshoe hares and red squirrels during post-fire and post-logging forest succession*. Forest Ecology and Management, 313, 17-25.	logging / red squirrels	"effects that post-disturbance vegetation may impose on populations of snowshoe hare (Lepus americanus Erxleben) and red squirrel (Tamiasciurus hudsonicus L.)"	17
5	Ransome, D. B., Lindgren, P. M., Sullivan, D. S., & Sullivan, T. P. (2004). *Long-term responses of ecosystem components to stand thinning in young lodgepole pine forest. I. Population dynamics of northern flying squirrels and red squirrels*. Forest Ecology and Management, 202(1), 355-367.	forest thinning / opulation dynamics / flying sq & red sq	"Sciurids fulfill an important ecological role. Northern flying squirrels (Glaucomys sabrinus) consume primarily the fruiting bodies of ectomycorrhizal fungi"	356
6	Holloway, G. L., Smith, W. P., Halpern, C. B., Gitzen, R. A., Maguire, C. C., & West, S. D. (2012). *Influence of forest structure and experimental green-tree retention on northern flying squirrel (Glaucomys sabrinus) abundance*. Forest Ecology and Management, 285, 187-194.	forest management / responses of northern flying squirrels	"treatment-unit basal area and amount of surrounding mature (>80-year-old) forest, suggesting that squirrel abundance was influenced by local structure and landscape-scale variables"	187

7 – APPENDICES

APPENDIX 5

Canopy Cover along transect

Transect A

DISTANCE	# of squares		
	[10<]	[10-20]	[20>]
0	11	6	1
50	4	9	1
100	6	9	4
150	14	16	8
200	7	13	3
250	5	15	0
300	9	14	0
350	7	3	2
400	7	11	7
450	10	17	6
500	5	11	5
550	7	6	5
600	7	9	3
650	9	11	0
700	6	10	4
750	7	8	4
800	10	11	2
850	6	20	0
900	5	18	8
950	8	6	7
1000	5	3	7
MEAN	7.4	10.8	3.7

Transect C

DISTANCE	# of squares		
	[10<]	[10-20]	[20>]
0	3	7	6
50	6	6	7
100	6	7	11
150	1	13	8
200	4	12	4
250	8	7	8
300	8	10	7
350	7	11	5
400	4	19	1
450	0	13	3
500	4	11	10
550	7	10	6
600	6	17	6
650	6	8	11
700	0	16	10
750	3	11	7
800	2	14	8
850	8	8	7
900	6	10	1
950	3	7	2
1000	8	12	7
MEAN	4.8	10.9	6.4

Transect Secret East

DISTANCE	# of squares		
	[10<]	[10-20]	[20>]
0	8	11	6
50	6	9	0
100	5	12	0
150	3	18	0
200	12	12	0
250	6	5	7
300	11	13	0
350	6	12	0
400	7	12	0
450	6	10	2
500	7	9	0
550	6	15	0
600	10	9	1
650	14	10	0
700	4	10	5
750	5	12	0
800	11	10	1
850	7	16	0
900	6	13	0
950	10	9	0
1000	8	13	1
MEAN	7.5	11.4	1.1

Transect Secret West

DISTANCE	# of squares		
	[10<]	[10-20]	[20>]
0	9	13	0
50	6	14	0
100	17	6	0
150	8	15	0
200	9	13	0
250	4	14	0
300	5	14	0
350	11	17	2
400	3	20	0
450	7	12	0
500	3	11	4
550	3	2	6
600	7	12	1
650	1	17	1
700	4	14	0
750	10	11	0
800	5	8	0
850	6	12	0
900	7	13	0
950	7	15	1
1000	3	12	0
MEAN	6.4	12.6	0.7

7 – APPENDICES

APPENDIX 6 & 7

Canopy Cover at squirrel sighting

Number of squares blocked by canopy	% coverage	Number of Sightings
1 − 3	0≥ − <9	0
4 − 6	0≥ − <18	0
7 − 9	18≥ − <27	2
10 − 12	27≥ − <36	4
13 − 15	36≥ − <45	10
16 − 18	45≥ − <54	14
19 − 21	54≥ − <63	9
22 − 24	63≥ − <72	2
25 − 27	72>	0
28 − 30	81≥ − <90	0
31 − 33	90>	0

Height of squirrel at sighting

Height (m)	Number of Sightings
0≥ − <2	1
2≥ − <4	2
4≥ − <6	1
6≥ − <8	3
8≥ − <10	2
10≥ − <12	1
12≥ − <14	2
14≥ − <16	5
16≥ − <18	6
18≥ − <20	6
20≥ − <22	4
22≥ − <24	5
24≥ − <26	2
26≥ − <28	1

7 – APPENDICES

APPENDIX 8

Diameter at Breast-Height in plot and sub-plots

Diameter at Breast-Height (cm)	SUB-PLOT (0)				PLOT (1)	
	0.4	1A	1C	PH	0.4	1A
20.0≥ − <22.0	7	3	4	1	5	3
22.0≥ − <24.0	4	5	2	0	7	7
24.0≥ − <26.0	1	1	0	0	7	3
26.0≥ − <28.0	3	4	2	0	2	2
28.0≥ − <30.0	4	3	2	0	5	3
30.0≥ − <32.0	1	3	0	0	6	4
32.0≥ − <34.0	2	0	1	0	1	3
34.0≥ − <36.0	1	1	0	0	1	3
36.0≥ − <38.0	1	1	0	0	0	0
38.0≥ − <40.0	1	0	0	0	1	1
40.0≥ − <42.0	1	0	0	0	1	0
42.0≥ − <44.0	0	1	0	0	0	0
44.0≥ − <46.0	0	0	0	0	1	2
46.0≥ − <48.0	0	0	0	0	1	1

7 – APPENDICES

APPENDIX 9

Species Identification table
(Darker/shaded the one seen in camp NLPSF)

	LATIN NAME	ENGLISH NAME
1	*Aeromys tephromelas*	Black flying squirrel
2	*Aeromys thomasi*	Thomas's flying squirrel
3	*Callosciurus adamsi*	Ear-spot squirrel
4	*Callosciurus baluensis*	Kinabalu squirrel
5	*Callosciurus notatus*	Plantain squirrel
6	*Callosciurus orestes*	Bornean black-banded squirrel
7	*Callosciurus prevostii*	Prevost's squirrel
8	*Dremomys everetti*	Bornean mountain ground squirrel
9	*Exilisciurus exilis*	Plain pigmy squirrel
10	*Exilisciurus whiteheadi*	Whitehead's pigmy squirrel
11	*Glyphotes simus*	Red-bellied sculptor squirrel
12	*Hylopetes lepidus*	Grey-cheeked flying squirrel
13	*Hylopetes spadiceus*	Red-cheeked flying squirrel
14	*Iomys horsfieldii*	Horsfield's flying squirrel
15	*Lariscus hosei*	Four-striped ground squirrel
16	*Lariscus insignis*	Three-striped ground squirrel
17	*Nannosciurus melanotis*	Black-eared pigmy squirrel
18	*Petaurillus emiliae*	Lesser pigmy flying squirrel
19	*Petaurillus hosei*	Hose's pigmy flying squirrel
20	*Petaurista elegans*	Spotted giant flying squirrel
21	*Petaurista petaurista*	Red giant flying squirrel
22	*Petinomys genibarbis*	Whiskered flying squirrel
23	*Petinomys hageni*	Hagen's flying squirrel
24	*Petinomys setosus*	Temminck's flying squirrel
25	*Petinomys vordermanni*	Vordermann's flying squirrel
26	*Pteromyscus pulverulentus*	Smoky flying squirrel
27	*Ratufa affinis*	Giant squirrel
28	*Rheithrosciurus macrotis*	Tufted ground squirrel
29	*Rhinosciurus laticaudatus*	Shrew-faced ground squirrel
30	*Sundasciurus brookei*	Brooke's squirrel
31	*Sundasciurus hippurus*	Horse-tailed squirrel
32	*Sundasciurus jentinki*	Jentink's squirrel
33	*Sundasciurus lowii*	Low's squirrel
34	*Sundasciurus tenuis*	Slender squirrel

APPENDIX 10

SPSS – ANOVA analyses (A/C)

/CRITERIA CI(.95).

→ **T-Test**

[DataSet0]

10m<

Group Statistics

	AC	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	29.5238	9.67274	2.11076
	2.00	21	19.0476	10.49989	2.29126

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.905	.347	3.363	40	.002	10.47619	3.11532	4.17989	16.77249
	Equal variances not assumed			3.363	39.734	.002	10.47619	3.11532	4.17858	16.77380

Group Statistics

	AC	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	43.0476	18.84271	4.11182
	2.00	21	43.6190	14.24948	3.10949

10 – 20m

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	1.380	.247	-.111	40	.912	-.57143	5.15519	-10.99045	9.84760
	Equal variances not assumed			-.111	37.238	.912	-.57143	5.15519	-11.01458	9.87172

Group Statistics

	AC	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	14.6667	11.12355	2.42736
	2.00	21	25.7143	11.83699	2.58304

20m>

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.024	.879	-3.117	40	.003	-11.04762	3.54460	-18.21152	-3.88372
	Equal variances not assumed			-3.117	39.846	.003	-11.04762	3.54460	-18.21238	-3.88286

APPENDIX 11

SPSS – ANOVA analyses (A/SE)

➔ **T-Test**

[DataSet0]

10m<

Group Statistics

	ASE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	29.5238	9.67274	2.11076
	2.00	21	30.0952	11.28674	2.46297

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.787	.380	-.176	40	.861	-.57143	3.24369	-7.12718	5.98432
	Equal variances not assumed			-.176	39.084	.861	-.57143	3.24369	-7.13197	5.98911

10 – 20m

Group Statistics

	ASE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	43.0476	18.84271	4.11182
	2.00	21	45.7143	11.28336	2.46223

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	4.532	.039	-.556	40	.581	-2.66667	4.79266	-12.35300	7.01967
	Equal variances not assumed			-.556	32.709	.582	-2.66667	4.79266	-12.42071	7.08737

[DataSet0]

Group Statistics

	ASE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	14.6667	11.12355	2.42736
	2.00	21	4.2381	8.22742	1.79537

20m>

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	4.413	.042	3.454	40	.001	10.42857	3.01918	4.32659	16.53055
	Equal variances not assumed			3.454	36.842	.001	10.42857	3.01918	4.31026	16.54689

APPENDIX 12

SPSS – ANOVA analyses (A/SW)

▸ **T-Test**

[DataSet0]

3 – ASW

Group Statistics

	ASW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	29.5238	9.67274	2.11076
	2.00	21	25.7143	14.28686	3.11765

10m<

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	1.731	.196	1.012	40	.318	3.80952	3.76498	-3.79978	11.41883
	Equal variances not assumed			1.012	35.152	.319	3.80952	3.76498	-3.83261	11.45166

Group Statistics

	ASW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	43.0476	18.84271	4.11182
	2.00	21	50.4762	15.41304	3.36340

10 – 20m

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	1.491	.229	-1.398	40	.170	-7.42857	5.31220	-18.16493	3.30779
	Equal variances not assumed			-1.398	38.487	.170	-7.42857	5.31220	-18.17809	3.32095

[DataSet0]

Group Statistics

	ASW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	14.6667	11.12355	2.42736
	2.00	21	2.8571	6.21519	1.35627

20m>

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	11.376	.002	4.247	40	.000	11.80952	2.78056	6.18980	17.42925
	Equal variances not assumed			4.247	31.379	.000	11.80952	2.78056	6.14130	17.47774

APPENDIX 13

SPSS – ANOVA analyses (C/SE)

→ **T-Test**

[DataSet0]

Group Statistics

	CSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	19.0476	10.49989	2.29126
	2.00	21	30.0952	11.28674	2.46297

10m<

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.002	.968	-3.284	40	.002	-11.04762	3.36394	-17.84640	-4.24884
	Equal variances not assumed			-3.284	39.793	.002	-11.04762	3.36394	-17.84750	-4.24774

Group Statistics

	CSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	43.6190	14.24948	3.10949
	2.00	21	45.7143	11.28336	2.46223

10 – 20m

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	1.105	.299	-.528	40	.600	-2.09524	3.96630	-10.11143	5.92095
	Equal variances not assumed			-.528	38.003	.600	-2.09524	3.96630	-10.12457	5.93409

Group Statistics

	CSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	25.7143	11.83699	2.58304
	2.00	21	4.2381	8.22742	1.79537

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
20m> Canopy	Equal variances assumed	2.749	.105	6.827	40	.000	21.47619	3.14571	15.11848	27.83390
	Equal variances not assumed			6.827	35.668	.000	21.47619	3.14571	15.09434	27.85804

APPENDIX 14

SPSS – ANOVA analyses (C/SW)

➡ **T-Test**

[DataSet0]

Group Statistics

	CSW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	19.0476	10.49989	2.29126
	2.00	21	25.7143	14.28686	3.11765

10m<

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.455	.504	-1.723	40	.093	-6.66667	3.86906	-14.48633	1.15299
	Equal variances not assumed			-1.723	36.726	.093	-6.66667	3.86906	-14.50810	1.17477

Group Statistics

	CSW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	43.6190	14.24948	3.10949
	2.00	21	50.4762	15.41304	3.36340

10 – 20m

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.034	.855	-1.497	40	.142	-6.85714	4.58055	-16.11477	2.40049
	Equal variances not assumed			-1.497	39.756	.142	-6.85714	4.58055	-16.11654	2.40226

Group Statistics

	CSW	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	25.7143	11.83699	2.58304
	2.00	21	2.8571	6.21519	1.35627

20m>

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	7.064	.011	7.835	40	.000	22.85714	2.91746	16.96074	28.75355
	Equal variances not assumed			7.835	30.249	.000	22.85714	2.91746	16.90095	28.81333

7 – APPENDICES

APPENDIX 15

SPSS – ANOVA analyses (SW/SE)

▸ **T-Test**

[DataSet0]

Group Statistics

	SWSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	25.7143	14.28686	3.11765
	2.00	21	30.0952	11.28674	2.46297

10m<

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.363	.550	-1.103	40	.277	-4.38095	3.97315	-12.41099	3.64909
	Equal variances not assumed			-1.103	37.966	.277	-4.38095	3.97315	-12.42441	3.66251

Group Statistics

	SWSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	50.4762	15.41304	3.36340
	2.00	21	45.7143	11.28336	2.46223

10 – 20m

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	.491	.487	1.142	40	.260	4.76190	4.16834	-3.66262	13.18643
	Equal variances not assumed			1.142	36.654	.261	4.76190	4.16834	-3.68665	13.21046

Group Statistics

	SWSE	N	Mean	Std. Deviation	Std. Error Mean
Canopy	1.00	21	2.8571	6.21519	1.35627
	2.00	21	4.2381	8.22742	1.79537

Independent Samples Test

20m>

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Canopy	Equal variances assumed	1.033	.316	-.614	40	.543	-1.38095	2.25007	-5.92851	3.16661
	Equal variances not assumed			-.614	37.219	.543	-1.38095	2.25007	-5.93912	3.17722

APPENDIX 16

DISTANCE – inner transects output

Detection Fct/Global/Chi-sq GOF Test 2

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	3.82	6	6.40	0.025
2	3.82	7.64	7	6.40	0.056
3	7.64	11.5	6	6.30	0.014
4	11.5	15.3	5	4.61	0.033
5	15.3	19.1	2	2.28	0.035

Total Chi-square value =   0.1627 Degrees of Freedom = 2.00

Probability of a greater chi-square value, P = 0.92186

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Density Estimates/Global

```
Effort      :   10.00000
# samples   :   10
Width       :   19.10000
# observations:  26
```

Model 1
   Hazard Rate key, $k(y) = 1 - Exp(-(y/A(1))**-A(2))$

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	0.83811	0.20144	24.03	0.51103	1.3745

Measurement Units

Density: Numbers/hectares
   ESW: meters

Component Percentages of Var(D)

Detection probability   : 36.3
Encounter rate   : 63.7

Estimation Summary - Detection probability

		Estimate	%CV	df	95% Confidence Interval	
Hazard/Cosine						
	m	2.0000				
	LnL	-75.199				
	AIC	154.40				
	AICc	154.92				
	BIC	156.91				
	Chi-p	0.83928				
	f(0)	0.64470E-01	14.47	24.00	0.47896E-01	0.86780E-01
	p	0.81210	14.47	24.00	0.60332	1.0000
	ESW	15.511	14.47	24.00	11.523	20.879

Detection Fct/Global/Chi-sq GOF Test 3

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	2.73	4	4.57	0.072
2	2.73	5.46	4	4.57	0.072
3	5.46	8.19	5	4.57	0.040
4	8.19	10.9	6	4.53	0.478
5	10.9	13.6	3	3.83	0.179
6	13.6	16.4	3	2.48	0.108
7	16.4	19.1	1	1.44	0.135

Total Chi-square value =   1.0844 Degrees of Freedom = 4.00

Probability of a greater chi-square value, P = 0.89674

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Goodness of Fit Testing with some Pooling

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	2.73	4	4.57	0.072
2	2.73	5.46	4	4.57	0.072
3	5.46	8.19	5	4.57	0.040
4	8.19	10.9	6	4.53	0.478
5	10.9	13.6	3	3.83	0.179
6	13.6	19.1	4	3.92	0.002

Total Chi-square value =   0.8425 Degrees of Freedom = 3.00

Probability of a greater chi-square value, P = 0.83928

Estimation Summary - Encounter rates

		Estimate	%CV	df	95% Confidence Interval	
	n	26.000				
	k	10.000				
	L	10.000				
	n/L	2.6000	19.19	9.00	1.6911	3.9974
	Left	0.0000				
	Width	19.100				

Estimation Summary - Density&Abundance

		Estimate	%CV	df	95% Confidence Interval	
Hazard/Cosine						
	D	0.83811	24.03	19.76	0.51103	1.3745

APPENDIX 17

DISTANCE – outer transects output

Detection Fct/Global/Chi-sq GOF Test 2

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	3.81	8	5.51	1.123
2	3.81	7.62	1	4.90	3.104
3	7.62	11.4	6	3.87	1.172
4	11.4	15.2	2	2.72	0.190

Total Chi-square value = 5.5874 Degrees of Freedom = 2.00

Probability of a greater chi-square value, P = 0.06119

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Detection Fct/Global/Chi-sq GOF Test 3

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	2.54	6	3.72	1.405
2	2.54	5.08	2	3.52	0.659
3	5.08	7.62	1	3.17	1.487
4	7.62	10.2	4	2.71	0.616
5	10.2	12.7	3	2.19	0.296
6	12.7	15.2	1	1.69	0.279

Total Chi-square value = 4.7432 Degrees of Freedom = 4.00

Probability of a greater chi-square value, P = 0.31468

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Goodness of Fit Testing with some Pooling

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	2.54	6	3.72	1.405
2	2.54	5.08	2	3.52	0.659
3	5.08	7.62	1	3.17	1.487
4	7.62	10.2	4	2.71	0.616
5	10.2	15.2	4	3.88	0.004

Total Chi-square value = 4.1716 Degrees of Freedom = 3.00

Probability of a greater chi-square value, P = 0.24352

Density Estimates/Global

```
Effort         :    10.00000
# samples      :    10
Width          :    15.25000
# observations:    17
```

Model 1
  Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	0.73728	0.20184	27.38	0.42370	1.2829

Measurement Units

Density: Numbers/hectares
    ESW: meters

Component Percentages of Var(D)

Detection probability : 68.7
Encounter rate   : 31.3

Estimation Summary - Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	17.000				
k	10.000				
L	10.000				
n/L	1.7000	15.31	9.00	1.2047	2.3990
Left	0.0000				
Width	15.250				

Estimation Summary - Detection probability

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
m	1.0000				
LnL	-45.724				
AIC	93.448				
AICc	93.715				
BIC	94.282				
Chi-p	0.24352				
f(0)	0.86739E-01	22.69	16.00	0.63940E-01	0.13948
p	0.76599	22.69	16.00	0.47012	1.0000
ESW	11.529	22.69	16.00	7.1694	18.539

Estimation Summary - Density&Abundance

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
D	0.73728	27.38	24.76	0.42370	1.2829

7 – APPENDICES

APPENDIX 18

DISTANCE – Chi square and ESW

Estimation Summary - Detection probability

AC

		Estimate	%CV	df	95% Confidence Interval	
Hazard/Cosine						
	m	2.0000				
	LnL	-75.199				
	AIC	154.40				
	AICc	154.92				
	BIC	156.91				
	Chi-p	0.83928				
	f(0)	0.64470E-01	14.47	24.00	0.47896E-01	0.86780E-01
	p	0.81210	14.47	24.00	0.60332	1.0000
	ESW	15.511	14.47	24.00	11.523	20.879

Estimation Summary - Detection probability

SESW

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	m	1.0000				
	LnL	-45.724				
	AIC	93.448				
	AICc	93.715				
	BIC	94.282				
	Chi-p	0.24362				
	f(0)	0.86739E-01	22.69	16.00	0.53940E-01	0.13948
	p	0.76699	22.69	16.00	0.47012	1.0000
	ESW	11.529	22.69	16.00	7.1694	18.539