

Edge Effect on Artificial Nest Predation
in a Tropical Peat Swamp Forest

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Abstract

This study examines the existence or non-existence of an edge effect on artificial nest predation in a Tropical Peat swamp forest.

As a result of logging, fire and land conversion many of the tropics forested landscapes are now heavily fragmented, increasing the amount of edge relative to total area. This study investigates the effects of proximity to edge on avian reproductive success. Nest predation is known to be an important factor in the mortality of birds and though many studies have suggested that predation rates increase towards habitat edges, a large proportion of studies carried out in the tropics do not support this trend.

This study monitored artificial nests placed on an edge to interior gradient of a selectively logged peat swamp forest in Central Kalimantan, Borneo in order to contribute to the currently, small proportion of studies carried out in the tropics. The forest is highly fragmented by canals, railway lines and logging tracks. However, the edges being investigated were two major edges created by logging and fire.

In this study we found no evidence of a relationship between nest predation and distance from the forest edge at either site. This supports the findings of many studies carried out in the tropics and in logged forest. These results challenge the applicability and generality of results achieved in temperate regions to tropical forest ecosystems.

This study is, to my knowledge, the first attempt to investigate nest predation rates in tropical peat swamp forest and may provide an estimation of relative predation rates between sites. The average percent predation of nests was 61.9% at site 1 and 85.7% at site 2. Higher predation rates at site 2 could be indicative of the devastating effect that the annual fires are having on the environment.

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1. Introduction

The world's forests are coming under increasing pressure from the growing human population and the consequent demands for timber and cleared land for agriculture, cash crops and urbanisation. Destruction of species-rich tropical forest is regarded as a major threat to global biodiversity (Turner, 1996) and tropical deforestation rates in Indonesia are among the highest in the world.

In the last decade there has been a significant amount of research conducted into the effects of forest fragmentation and subsequent edge effects on forest biodiversity. A large proportion of studies into edge effect on nest predation rates in temperate forests have shown an increase in predation rates with proximity to the edge (e.g. Gates and Gysel, 1978; Wilcove, 1985; Andrén and Angelstam, 1988). However, the few tropical studies available do not show a clear support for the existence of an edge related increase in predation rates in the tropics (Gibbs, 1991; Burkey, 1993; Carlson and Hartman, 2001).

This study is, to my knowledge, the first to examine artificial nest predation in Indonesian peat swamp forest. Artificial nests were placed on an edge to interior gradient of a selectively logged peat swamp forest in Central Kalimantan, Borneo in order to contribute to the currently, small proportion of studies carried out in the tropics. The forest is highly fragmented by canals, railway lines and logging tracks. However, the edges being investigated were major edges; transitions between two structurally different habitats, created by logging (site 1) and fire (site 2).

The aims of this investigation therefore, are:

- i. To examine how the rate of artificial nest predation varies along a transect extending from the forest edge to the interior;
- ii. To study the rate and overall predation on artificial nests in two sites in mixed swamp forest;
- iii. To assess the influence of canopy cover and predator type on the rates of nest predation.

2. Literature Review

2.1 Tropical forest fragmentation

The world's forests are coming under increasing pressure from the growing human population and the consequent demands for timber and cleared land for agriculture, cash crops and urbanisation.

The occurrence of deforestation and forest fragmentation in the tropics is expected to have serious repercussions on biodiversity, though current knowledge about the relationship between deforestation and species diversity is still relatively poor concerning tropical conditions (Smith *et al.*, 1993 cited in Carlson and Hartman, 2001; Heywood *et al.*, 1994; Turner, 1996).

Southeast Asia is considered to be a region of high biodiversity (Briggs, 1996), despite this tropical deforestation rates in Indonesia are among the highest in the world. Estimates based on satellite-image interpretation show that between 1985 and 1997, the average annual loss was about 10,000 km² (Holmes 2000 cited in Husson *et al.*, 2003), or 14,000 km² / year (FWI/GFW, 2002 cited in Husson *et al.*, 2003). There is a likelihood that the figure is even higher in 2005, due to recent (1997-1998 and 2002) forest fires and unchecked illegal logging (Husson *et al.*, 2003).

Forest fragmentation occurs as continuous forest is converted into landscapes with remnant forest patches in a matrix of non-forest vegetation (Bierregaard *et al.*,

1992; Lovejoy *et al.*, 1986 cited in Cochrane and Laurance, 2002). Habitat fragmentation affects the ecology of tropical forests in many ways, such as altering diversity and composition of biota and changing ecological processes such as pollination and nutrient cycling (Didham *et al.*, 1996; Klein, 1989). Recent evidence indicates that fragmentation also alters rainforest dynamics, causing increased wind turbulence, markedly elevated rates of tree mortality, damage and canopy-gap formation (Laurance *et al.* 2001), and microclimatic changes near fragment edges (Kapos, 1989). This leads to a substantial loss of living biomass in fragments (Laurance *et al.*, 1997; Laurance, 1998*b*).

Many studies have been carried out to examine the effect of deforestation on avian nest predation (Wong *et al.*, 1998; Carlson and Hartman, 2001; Estrada *et al.*, 2002). Research has shown that extinction of local bird species frequently occurs when populations are isolated in forest fragments (Willis, 1974 and 1979 cited in Arango-Vélez and Kattan, 1997; Ambuel and Temple, 1983; Lynch and Whigham, 1984).

2.2 Explaining nest predation rates in fragmented forests

A number of theories have been proposed to explain possible increased rates of nest predation in fragmented forest.

Forest fragmentation exposes the organisms that remain, to conditions of a different surrounding ecosystem (Murcia, 1995 cited in Estrada *et al.*, 2002; Laurence *et al.*, 1997). It is likely that smaller fragments of forest will not be able to support top predators that require a large home range. This disruption of the trophic levels of the

ecosystem allows for smaller predators to increase in activity and population, largely unchecked by predation. Nest predation by these predators will increase as their numbers increase (Terborgh, 1988 cited in Maina and Jackson, 2003).

Similarly, increased nest predation may be due to the fragmentation's impact on the vegetation cover of the habitat. A reduction in low-level vegetation cover will leave the nests of ground-nesting birds more exposed and vulnerable to predation (Matthaie and Stearns, 1981 cited in Maina and Jackson, 2003).

The nests of smaller birds, such as passerines may suffer predation from species that thrive in fragmented forest. Research in the United States has suggested that certain vertebrate nest predators, especially corvids, attain greater population densities where forest has been fragmented, such as along roads (Robinson *et al.*, 1995 cited in Cooper and Francis, 1998).

It has been suggested that the type of matrix surrounding the remaining forest is more important than fragment size in determining predation. A high-productivity matrix, such as agricultural land, would support a higher number of generalist predators than pasture for example (Angelstam, 1986 cited in Arango-Vélez and Kattan, 1997).

2.3 Edge effects in fragmented forest

Arango-Vélez and Kattan, (1997) remark that some studies have found that increased predation rates in small fragments are the result of an edge effect; that predation rates are higher at the edge than in the forest interior (Gates and Gysel,

1978; Wilcove *et al.*, 1986; Andrén and Angelstam, 1988). High predation rates in small fragments may result from an increased exposure to the edge. Small fragments have a large perimeter-to-area ratio, and thus generalist predators from the surrounding habitat are able to penetrate deep into the forest fragment and reach a greater fraction of its area (Gates and Gysel, 1978; Andrén *et al.*, 1985; Wilcove *et al.*, 1986; Andrén and Angelstam, 1988; Paton, 1994). If the forest fragment is very small, the whole area may be vulnerable to invasion by generalist predators, which could be abundant in the surrounding habitat (Paton, 1994; Murcia, 1995).

‘The “Edge effect” refers to the physical and biotic changes associated with remnant forest margins. In a continuous forest, habitat edges are rare, typically limited to small internal clearings created by landslides, river meanders or other natural disturbances. The margins of forest fragments are usually abrupt, delineating a sudden transition from forests to pastures, crops, or other modified habitats’ (Laurance and Bierregaard, 1997).

Edge effects have been shown to exist in forests in the tropics, though relatively little research has been carried out on edge effects in tropical peat swamp forest. In rainforests, physical edge effects can include elevated wind turbulence and temperature variability, lateral light penetration, and reduced humidity, all of which result from the close proximity of a harsh external climate in the surrounding matrix. Biotic effects can include the proliferation of secondary vegetation along forest margins, invasion of generalist plants and animals, and alteration of ecological processes such as nutrient cycling and energy flows (Laurance and Bierregaard, 1997).

Mechanisms such as negative edge effects have been cited as possible causes for the deterioration in isolated fragments of tropical forest. An example of negative edge effects would be that the internal microclimate of the forest becomes hotter, drier and brighter near the edge, causing increases in tree mortality that adversely affect forest species (Turner and Corlett, 1996; Sodhi *et al.*, 2003).

Of the two sites being investigated in this study, site 1 is an old edge created when the riverine forest was felled. The edge at site 2 would be classed as new; it was created by fire in 1997 and has been renewed annually by preceding fires. Kapos *et al.*, (1997) measured microclimatic changes associated with margins of forest fragment in central Amazonia and found that for the newly cut edge, air humidity and soil moisture increased along simple gradients with distance into the forest, but in the older edge the patterns were far more complex. Older forest edges may tend to be “sealed” by a wall of proliferating second growth, reducing the influence of edge on forest microclimate. They also found that there was an increased frequency of tree-fall gaps within 70m of forest margins, demonstrating that wind damage is unlikely to be ameliorated by older edges. These effects could also be expected in the research sites in this study.

One questionable issue is the extent to which edge effects can be expected to have influence within the forest. Of studies carried out on physical processes and edge effects (Kapos *et al.*, 1997; Turton and Freiburger, 1997; Didham, 1997; and Laurance, 1997), microclimatic changes seem mainly limited to a zone within 15-60 m of edges, but some biotic changes can penetrate much farther than this. For example, the functional assemblages of invertebrates may be altered up to 200m

from edges, while in some regions, elevated wind damage and related changes in forest composition appear detectable within several hundred meters of edges (Laurance and Bierregaard, 1997).

Studies of edge effects on tropical forest fauna found that faunal populations often respond rapidly to habitat fragmentation. Invertebrate communities, in particular can change very quickly, both because of their short generation times, which lead to rapid population changes, and because of their small size and endothermic nature, which probably render them sensitive to environmental changes within the fragments (Brown and Hutchings, 1997; Weishampel, Shugart and Westman, 1997). Vertebrate populations may also change with surprising rapidity as illustrated in studies in recently fragmented forests (Bierregaard and Stouffer, 1997) and newly isolated islands (Lynham, 1997; Terborgh *et al.*, 1997). Endothermic vertebrates such as birds and mammals have substantial area and energy needs, often rendering them vulnerable to habitat insularisation. Many smaller species are sensitive to changes in the forest microclimate and may respond strongly to edge effects and other ecological changes in fragments (Laurance and Bierregaard, 1997).

To date, edge effects in Amazonian forests, such as alterations in microclimate, forest dynamics and faunal communities, have been shown to penetrate from 10-400 m into fragment interiors (Bierregaard *et al.* 1992; Laurance *et al.*, in press; Lovejoy *et al.*, 1986 cited in Cochrane and Laurance 2002). Preliminary evidence, however suggests that some edge-related changes in tropical forests could penetrate much further than this, perhaps as far as several kilometres into the fragment interiors (Curran *et al.*, 1999; Laurance, 2000 cited in Cochrane and

Laurance, 2002).

2.4 Previous nest predation studies

Nest predation experiments have been extensively conducted in almost every type of forested landscape (Janzen, 1978; Wilcove, 1985; Yahner and Cypher, 1987; Nour *et al.*, 1993; Paton, 1994; Yahner and Mahan, 1996 cited in Sodhi *et al.*, 2003). However, an extensive search found no studies of nest predation in peat swamp forests.

A large proportion of studies into edge effect on nest predation rates in temperate forests have shown an increase in predation rates with proximity to the edge (Gates and Gysel, 1978; Chasko and Gates, 1982; Bringham and Temple, 1983; Andrén *et al.*, 1985; Wilcove *et al.*, 1986; Andrén and Angelstam, 1988; Burger, 1988; and Moller, 1989 cited in Estrada *et al.* 2002). However, studies in the tropics do not always support this trend (Gibbs, 1991; Wong *et al.*, 1998; Carlson and Hartman, 2001).

Identifying predation rates on nests is a reasonable means for testing the stability of the bird populations in an area (Maina and Jackson, 2003). Research conducted in both temperate and tropical forests has identified nest predation by vertebrates as one of the major influences limiting forest bird populations, with composition of the nest predator communities and vegetation structure of the study site emerging as the two main determinants of nest predation rates (Telleria and Diaz, 1995 cited in Cooper and Francis, 1998).

The combined results of previous studies suggest that larger and more pristine forests may be better for avian survival rates, however pinpointing the variables affecting artificial nest predation may be difficult (Sodhi *et al.* 2003).

Fragmentation is a system-level phenomenon, therefore assessing its effects is done based on the assumption that we know how the intact system operates; otherwise no effect can be estimated. Such understanding is often undeveloped, especially in the case of tropical forests where even simple species inventories are difficult to achieve. This is not such a problem for academic ecology, but may become an issue when offering management advice (Crome, 1997).

3. Site Description

The peat swamp of Central Kalimantan covers an area of approximately 30,000 km², which is one of the largest unbroken tropical peatland areas in the world. Peat swamp forest is among the earth's most endangered and least known ecosystems (Rieley *et al.*, 1996 cited in Boehm and Siegert, 2001). This habitat is relatively inaccessible, yet remarkably diverse and of global importance. It regulates hydrology over vast areas, has a huge carbon storage capacity and is extremely fragile and liable to disturbance (Page and Rieley, 1998 cited in Boehm and Siegert, 2001; Morrogh-Bernard *et al.*, 2004). Temperatures within the forests are moderate and under closed canopy, seldom exceed 28 °C. The peatland is located mainly on quartz sand (podzol), extending from the Java sea and up to the Heath forest belt in the northern area, covering a peat swamp forest belt of approximately 150km to 200km (Sieffermann *et al.*, 1988 cited in Boehm and Siegert, 2001).

The Sebangau catchment, located between the Katingan and Kahayan rivers,

encompasses a continuous forested area of some 6,000km² (Morrogh-Bernard *et al.* 2004). The entire area has been logged under the concession system in the past; the regime was finished by 1997. Since then, illegal logging has become ubiquitous and a dense network of small canals has been established. These are draining the swamp in the dry season leading to degradation of peat, high tree mortality and increased risk of forest fires (Husson *et al.*, 2003). Approximately 10-15% of the forest was burnt in the 1997-98 fires (Morrogh-Bernard *et al.*, 2004).

The Sebangau forest supports a huge diversity of plant life including important timber species such as Ramin (*Gonystylus bancanus*), and the commercially valuable species *Dyera costulata* (Jeluton) from which the sap is used to make latex. The forest supports eight species of primate, over 200 species of bird and a large and diverse invertebrate community. This includes several species listed in the IUCN (International Union for Conservation of Nature and Natural Resources) Red Data Book of threatened species of plants and animals (Morrogh-Bernard *et al.*, 2004).

This area has been of recent interest for research into the effects of the fires, such as carbon release (Boehm and Siegert 2001*b*), and the ecological impact of the Indonesian government's giant land use conversion project; the Mega Rice project, which began in 1996 (Boehm and Siegert 2001*a*). In the area surrounding site 1, research into orang-utan (*Pongo pygmaeus*) distribution and density; forest and peat structure; ecology; and biodiversity has been ongoing since 1993, carried out under the auspices of the Center for International Co-operation in Management of Tropical Peatland (CIMTROP), University of Palangkaraya. Further research has been carried out by the Orang-utan Tropical peatland Project (OuTrop) over the past five years, within a 500km² protected area known as the "National Laboratory for the study of Peat Swamp

Ecology” (NAMTROP). The National Laboratory was established by the Indonesian Ministry of Forestry in conjunction with the Ministry of Research and Technology (BPPT), the Provincial Government of Central Kalimantan and the University of Palangkaraya, in 1999 (Morrogh-Bernard *et al.*, 2004). This site is part of 5,680 km² of peat swamp forest in this area that was designated National Park status in October 16th 2004.

4. Method

4.1. Study Sites

Two sites were selected in mixed peat swamp forest for placement of artificial nests.

Site 1 was in the vicinity of the Setia Alam Field Station, which is situated 20 km southwest of Palangkaraya in the upper reaches of the Sebangau River. The Sebangau catchment is a large area of peat swamp forest, of which 5,782 km² is currently still under forest (see fig.4.1 A). The entire area has been logged under the concession system in the past until 1997 and has suffered extensive illegal logging since. The forest has become fragmented by a dense network of small canals, logging tracks and a disused railway line. Setia Alam Field Station is sited just inside the edge of the forest on the site of the former logging concession (see fig. 4.1 B). Here there is an abrupt edge between the forest and the sedge swamp habitat that borders the river. The area that is now sedge swamp was once covered in riverine forest but this has all been felled.

Site 2 was placed in Block C of the former 'Mega Rice Project'. Between 1996 and 1998 the Indonesian authorities set about clearing the area of forest, between the Kahayan and Kapuas catchments, in order to convert the land to rice fields. First a network of massive canals was constructed in order to drain the peat then the commercially valuable timber species were removed. However, during the 1997-98 El Niño event the area caught fire and the project was abandoned. In total one million hectares were cleared of forest and the area continues to burn annually (Morrogh-Bernard *et al.*, 2004).

Site 1 consisted of six transects that were cut from transect 0 of the research grid used by the Orang-utan Peatland Project (OuTrop), north to meet the sedge swamp edge. This allowed easy access to the transects through the forest.

Site 2 consisted of only three transects, this was due to the difficulty in accessing the site and the limited time we had in which to place out and check the nests. These transects were cut from the edge of the forest to 250m in.

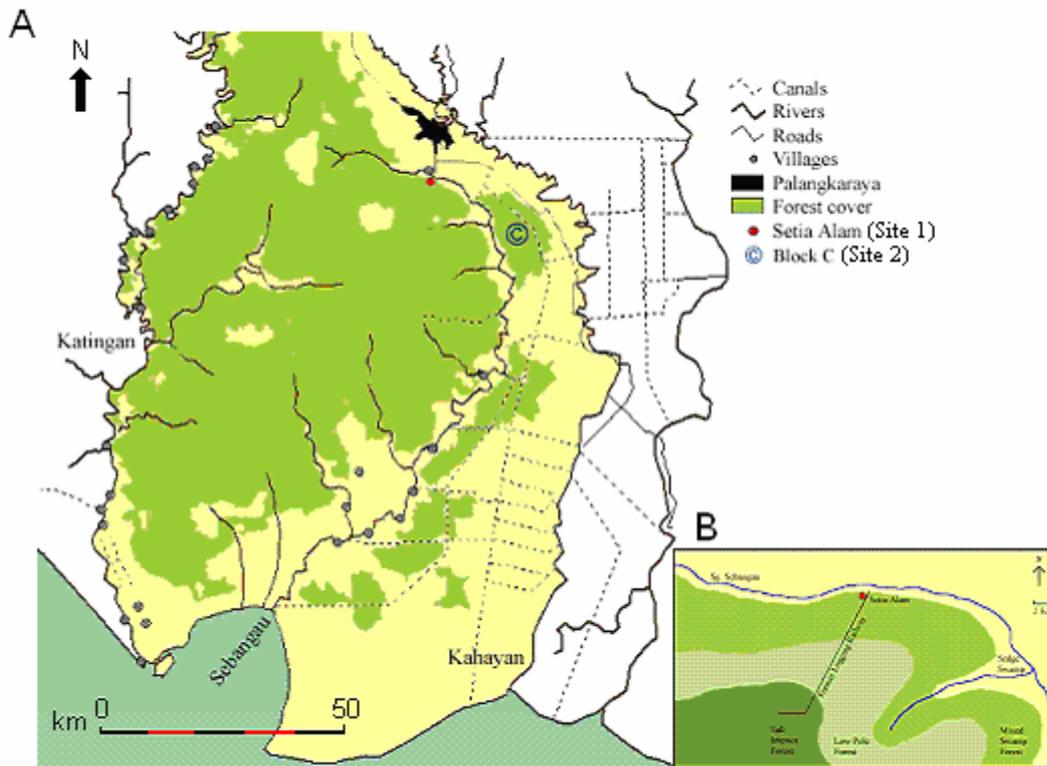


Figure 4.1: Site map of the Sebangau Catchment (A) and Setia Alam field station (B) (Husson, ca. 2004 and Morrogh-Bernard *et al.*, 2004 respectively)

4.2 Demarcation and layout of transects

For both sites, transects stretched 250m running perpendicular to the forests edge and were placed 250m apart. The forest edge was measured from the point where canopy cover became greater than 50%. Though a more common method, such as that used by Maina and Jackson (2003), is to define the edge of the forest as being where the canopy tree trunks of the forest reach the forest margin, this would have meant that the first 50m of the transect was transitional scrub habitat.

Because of the difficulties in operating in the peat swamp forest, the transects were cut using parang (short, straight-edged knives) to create a pathway through the

forest. Stations were placed along the transects following a modified Fibonacci series, with 'stations' at 10, 25, 35, 60, 95, 155, and 250m from the forest edge. This concentrates sampling closer to the edge where the effects are likely to be most pronounced if edge effects occur. This method was also used by Maina and Jackson (2003). Stations were marked with red raffia tied round the nearest tree and yellow wax marked the distance along the transect.

4.3 Materials

Nest predation is a good indicator of edge effects as eggs are a non-specific food source and are predated by opportunist predators in any forest habitat. As a result, they can be used as a constant method in forests in all habitats and climates, which is beneficial when making comparisons between edge effect studies. Identifying predation rates on nests is also a reasonable means for testing the stability of the bird populations in an area.

One major methodological challenge in studies of nest predation, especially in tropical forests, is finding enough natural nests to generate meaningful sample sizes (Darveau *et al.*, 1997). Therefore, artificial nests were used, which is a method that has been widely used to investigate nest predation in the tropics (Maina and Jackson, 2003; Cooper and Francis, 1998; Carlson and Hartman, 2001). Artificial nests can be placed in high concentrations in an area along transects and in set quantities for good scientific comparison between two areas in a way that hunting for real nests would not allow. It is then possible to limit some of the variations in nest features which can also affect nest predation rates such as nest size, nest structure and egg size (Yahner and Wright, 1985; Telleria and Diaz, 1995; Major and Kendal,

1996 cited in Estrada *et al.*, 2002).

Though this technique does rely on the assumption that predators search for, encounter, and respond to artificial nests in the same manner as natural nests, no assumption is being made that predation rates on artificial nests are indicative of actual predation rates.

Fresh quails eggs (*Coturnix coturnix*), purchased locally, were used to represent the eggs of typical forest birds. Plastercine eggs were used to determine the type of predator that attacked the eggs by the marks left in the plastercine, they were hand-moulded and painted with poster paint so as to closely resemble quails eggs. Numerous researchers have used quail eggs in nest predation studies (Nilsson *et al.* 1985; Wilcove, 1985; Small and Hunter, 1988 cited in Sodhi *et al.* 2003) and the use of plasticine eggs to identify predators by the imprints left in the eggs has been used in a number of studies (Wong *et al.*, 1998; Estrada *et al.*, 2002; Maina and Jackson, 2003).

4.4 Nests and nest placement

In order to test that the methodology of this experiment would function satisfactorily, four nests were placed out in the forest near the base camp of Setia Alam for four nights before the experiment was begun. The nests and the eggs that were contained therein remained in place, which was our main concern. However, these nests were not predated.

The nests were made from rattan baskets (approx. 100mm diameter, 60mm depth)

and following the methods used by Arango-Vélez and Kattan, 1996, were camouflaged with mosses taken from the forest the day before the nests were set out. The nests were placed at random angles, between 1-2m from the station, the exact position of each nest depending on the availability of a suitable substrate. However, the plastercine nests were always west of the transect, and the quail eggs always to the east. The nests were tied to trees at approximately 1m from the ground with wire, a height typical of many forest passerines. This may be an important consideration on comparison with other studies where ground nests were used. Predation of artificial nests by birds has been reported to be higher in above ground nests than on ground nests in Amazonian and Puerto Rican rainforest (Latta *et al.*, 1995; Telleria and Diaz, 1995 cited in Estrada *et al.* 2002), however, Arango-vélez and Kattan (1996) found no significant difference in predation rates between ground and off-ground nests. Once the nests were in place, 3 eggs were placed in the nest, either plastercine or quails eggs. It was important to attempt an equal amount of concealment of the nests as predation rates by visual predators have been found to fall with increased levels of nest concealment (Martin, 1993 cited in Cooper and Francis, 1998).

Rubber gloves were used at all times when handling the nests and the eggs. However the plastercine eggs were moulded by hand without gloves and the quails eggs would have been handled before purchase.

The experiment was conducted over a 13 day period for each site, a length of time representing the incubation period for most passerines (Kieth *et al.*, 1992; Urban *et al.*, 1992 cited in Maina and Jackson, 2003). The nests were monitored on day 1 (the day following their placement in the forest) and then every 3 days. On day 13 all

remaining nests were collected.

4.5 Classification of damages

Following the methodology of Arango-Vélez and Kattan (1996), a nest was considered predated upon if at least one egg had disappeared or was broken. The nests were recorded as successful if all eggs remained intact. This method was considered to be most exact because in life it is common for the mother to abandon a tampered nest preventing the survival of the whole nest. Nests containing plastercine eggs were considered predated if a mark was found in at least one egg that was judged to be the result of predation. In some cases pock marks appeared in plastercine eggs; presumed to be the results of ants or weathering and though this was recorded the nest was recorded as unpredated.

Predators of plastercine eggs were divided into the following groups; Rodent; Bird; primate; Reptile; and Other. Confirmation of predation classification of the eggs was carried out by Tris Allinson (OuTrop), Dr. David Bilton, (Biological Department, University of Plymouth), John Bull (School of Earth, Ocean and Environmental Sciences, University of Plymouth) and Laura D'Arcy (OuTrop). Reptile predation was held as a possibility by Dr. Colin McCarthy of the Natural History Museum of London (identified from photographs of eggs grouped as predated by reptiles, see appendix III).

4.6 Measurement of Variables

Canopy cover was measured at each site using a spherical densitometer, a method also used by Wong *et al.*, (1998). At each distance demarcation of the transects, canopy cover readings were taken at the positions that the quails egg nest had been situated in. This was carried out to identify whether increased visibility of the eggs had an effect on the nests; whether a less dense canopy would let in more light and increase the visibility of the nests to predators.

Being able to identify the predators responsible for predation of experimental nests can reveal the impact that fragmentation of a forest is having on the predators of the nests, for example if predation is by a native species of the forest, or a predator from the surrounding matrix which may not have access to the forest interior. Plastercine eggs were used to identify potential predators by beak or bite marks revealing the proportion of primates, rodents, reptiles or birds responsible for predation.

5. Results

5.1 Canopy Cover

No significant difference was found ($p > 0.05$) in the canopy cover of the individual stations or the mean cover of the transects at either site at the 95% confidence level (Kruskall-Wallis test). However, there is statistically significant difference among the standard deviations of the mean cover of the transects of site 2 at the 95% confidence level (smallest of p -values 0.025). This invalidates the results of the standard statistical tests for the mean transect data of site 2. There is not a statistically significant difference in canopy cover between the two sites. This suggests that Canopy cover is unlikely to be a significant factor in the predation of

artificial nests in this investigation.

5.2 Combining stations and transects

The data has been divided into four groups of nests: Site 1 quail nests; site 1 plastercine nests; site 2 quail nests; and site 2 plastercine nests. The Kruskal-Wallis test found no significant difference between the median predation rates in site 1 plastercine nests; site 2 quails nests; or site 2 plastercine nests between transects at the 95% confidence interval so the transects within these groups could be combined.

Significant difference at the 95% confidence interval was found between the predation rates of transects of quail nests at Site 1; transect BB has a high rate of survival for quail eggs and station 155 in transect DD is also statistically significantly different at the 95% confidence interval from the other stations for quail nests because it was predated on the first day. This is most likely due to chance events, however, these data points were considered as possible outliers when analysing relationships between the data sets.

5.3 Relationship between distance from edge and predation

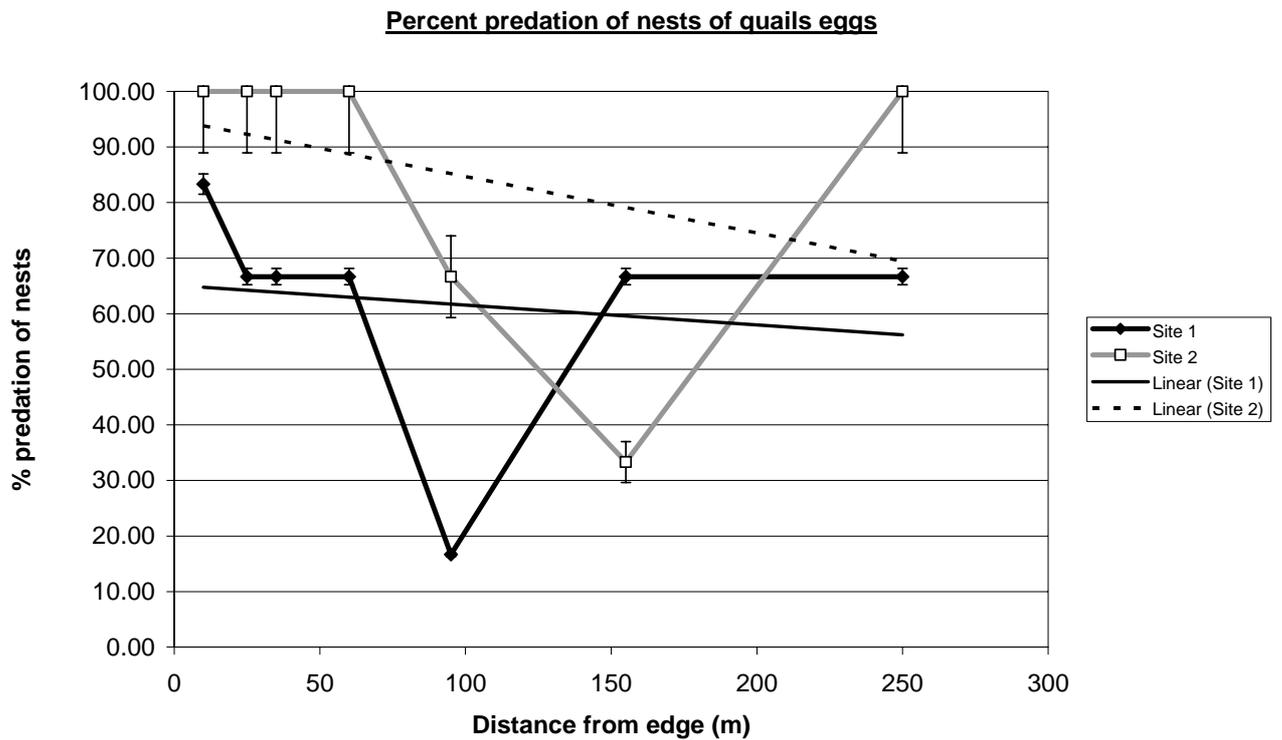
The percentage of artificial quail nests that were predated in the 13 day period were assessed to find whether predation was related to distance from the edge. A linear regression analysis showed that there is no statistically significant relationship between distance from forest edge and predation of nests at site 1 (p -value = 0.753, r^2 = 2.2%) or site 2 (p -value = 0.466, r^2 = 11.06%) at the 90% or above confidence

level. No relationship between distance from forest edge and artificial nest predation was found to exist.

The linear regression analysis was used to assess the rate of predation; a comparison of the percentage of days survived by the quail egg nests with distance from the edge was carried out. No statistically significant relationship was found for site 1 (p -value = 0.71, r^2 = 3.04 %) or site 2 (p -value = 0.237, r^2 = 26.5 %) at the 90% or above confidence level. Therefore we should accept the null hypothesis; that no statistically significant relationship exists between distance from forest edge and rate of predation of artificial nests.

To ensure that the possible outliers in the site 1 data (transect BB; and station 155 of transect DD) were not having a significant impact on the data analysis, they were removed for a repeat of the assessment. A linear regression analysis of predation and predation rate related to distance from edge still found no statistically significant relationship (p -value = 0.6705 and 0.861 respectively) at the 90% or above confidence level.

Graph 5.1 shows the mean predation on nests of quail's eggs at both sites, plotted against distance from forest edge in metres. A standard linear regression graph for both sites and percent variability of y as R^2 is also displayed. Predation rates on quail nests are highest in the first 10m for site 1 and 10– 50m from the edge for site 2. However, this is a weak trend and could be a chance event as statistical tests do not find this to be significant. When displayed on a graph, it is visually apparent that there does not appear to be a clear relationship between predation and distance from edge. It is possible that other factors are influencing the data here.



Graph 5.1: The mean predation on nests of quail's eggs at both sites is plotted against distance from forest edge. A standard linear regression graph for both sites is also displayed and percent variability of y as R^2 is shown in error bars.

Predation of nests of plastercine eggs was also analysed for both sites. The ANOVA table did not reveal a statistically significant relationship between total predation and distance from edge at site 1 or 2 (p -value = 0.79 and 0.47 respectively); or predation rate and distance from edge for site 1 or 2 (p -value = 0.76 and 0.237 respectively) at the 90% confidence level.

5.4 Comparison between predation rates between sites

The average percent predation of nests was found to be 61.9% at site 1 and 85.7% at site 2. There is not a statistically significant difference between site 1 and 2 in total predation on nests of quail or plastercine eggs. Though the Mann-Whitney

W test suggests a statistically significant difference in quail nest predation, this difference is not evident once the outliers have been removed. Neither is there a statistically significant difference in the rate of predation between site 1 and 2 quail predation (see table 5.1).

<u>Comparisons between sites 1 and 2</u>	Total predation or rate of predation (%)		Kolmogorov-Smirnov test <i>p</i> -value	Mann-Whitney (Wilcoxon) W test <i>p</i> -value	T- test <i>p</i> -value
	Site 1	Site 2			
Quail predation	61.91 %	85.70 %	<i>0.056</i>	0.023	<i>0.085</i>
Quail predation after removal of outliers	68.57 %	/	<i>0.056</i>	<i>0.124</i>	<i>0.238</i>
Quail rate of predation	67.52 %	51.02 %	<i>0.204</i>	<i>0.366</i>	<i>0.109</i>
Quail rate of predation after removal of outliers	64.60 %	/	<i>0.559</i>	<i>0.307</i>	<i>0.207</i>
plastercine predation	61.90 %	85.73 %	<i>0.056</i>	0.018	0.021
plastercine rate of predation	70.07 %	48.97 %	0.012	0.049	0.024

Table 5.1 The results of statistical analyses of the null hypothesis; that there is no statistically significant difference in predation rates between the two sites at the 95% confidence level. Where the *p*-value for the tests is less than 0.05 we can reject the null hypothesis in favour of the alternative; that there is a statistically significant difference in predation rates at the 95% confidence level.

Predation on nests of plastercine eggs between sites was also analysed. The T-test and the Mann-Whitney W test show statistically significant difference in total predation between the two sites and there appears to be significant difference in

rate of predation between sites. The total predation is greater at site 2; however, predation occurs more rapidly at site 1.

5.5 Predators related to distance from edge

Predators of plastercine eggs were divided into the following groups; Rodent; Bird; Primate; Reptile; and Other. Simple Regression Analysis on each group of predators in relation to distance from edge showed no statistically significant relationship for any of the groups at site 1 (lowest p -value = 0.742) or site 2 (lowest p -value = 0.235).

5.6 Comparison in predator groups

On comparing the sites; predation on nests of plastercine eggs by primates was found to be significantly higher at site 1 by the Kolmogorov-Smirnov test (p -value = 0.0117), but not for the T-test or the Mann-Whitney W test. Predation by reptiles was considered to be significantly higher at site 2 for all three tests (K-S p -value = 0.0117). There is not a statistically significant difference in predation between sites by rodent, bird or other (K-S test p -values = 0.204) at the 95% confidence level (see table 5.2).

		Rodent	Bird	Primate	Reptile	Other	Total predated
Site 1	%	25	14.3	7.1	1.2	14.3	61.9
	ratio	21	12	6	1	12	
Site 2	%	19	11.9	2.4	33.3	19	85.6
	ratio	8	5	1	14	8	

Table 5.2 Percentage of nests of plastercine eggs predated by group, and ratio of predator dominance in nest predation.

6. Discussion

In this study no edge effect was found to impact predation of artificial nests in peat swamp forest. This is consistent with other studies, in a variety of habitat types, that have also failed to find increased predation rates at the forest edge in comparison with the interior (Yahner and Wright, 1985; Angelstam, 1986; Gibbs, 1991; Santos and Tellería, 1992 all cited in Arango-Vélez and Kattan, 1996. Ratti and Reese, 1988; Small and Hunter, 1988; Nour *et al.*, 1993; Hanski *et al.*, 1996 all cited in Wong *et al.*, 1998).

Wong *et al.* (1998) suggests that though at edges there is often higher predation by avian predators, this may be compensated for by a rise in mammalian predation in interiors of heavily fragmented landscapes; as the mammals become confined to the forest fragment and competition for food is greater. Thus, in most studies predation rates remained relatively constant and no edge effect was detected. This has been supported by previous assertions that predation of nests by small mammals is proportionately more common than predation by nest-robbing birds or reptiles in the forest interior than near the edges (Burkey, 1993; Telleria and Diaz, 1995 cited in Cooper and Francis, 1998). However, in this study plastercine egg predation by avian predators was not found to be significantly higher at the forest edge, and predation by mammals was not higher in the interior. No statistically significant relationship was found for any of the predator groups in relation to distance from the edge at either site. It would be appropriate to carry out an investigation into whether an edge effect on the density of the groups of predators identified in this experiment exists using a different methodology to nest predation.

Of the few nest predation studies that have been carried out in logged forested landscapes, as in this one, most have shown no increase in predation with distance towards the forest edge (Yahner and Wright, 1985; Ratti and Reese, 1988; Storch, 1991; Rudnicky and Hunter, 1993; Hanski *et al.*, 1996 cited in Bayne and Hobson, 1997). Bayne and Hobson, (1997) make an appropriate explanation for this based on the ideas of Rudnicky and Hunter (1993); Angelstam (1986) and Hanski *et al.* (1996): The absence of an edge effect in landscapes fragmented by logging is due to predator communities and predator densities being typically different in landscapes fragmented by logging compared to those fragmented by agriculture. In agricultural landscapes, human activities provide a permanent change in the landscape structure and an increased food supply (crops and refuse) that may lead to higher densities of generalist predators such as corvids, particularly along edges. In contrast, logged edges provide little in the way of increased food and may be too short-lived to allow colonization by generalist predators adapted to more open fragmented habitats. This theory is a far more appropriate justification of the results obtained in this study.

The level of predation of artificial nests in the tropical peat swamp forest appears to be significantly higher than in temperate forest (see table 6.1). That artificial nest studies display higher predation rates in the tropics compared to temperate regions has become a common trend. This may be because survival in the tropics is reliant on predation as the primary limiting factor for population growth contrasting with the temperate zones where resource abundance, as a result of temperature and sunlight, is primarily limiting.

Predation at site 1 appears representative of tropical, artificial predation rates; while,

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site 2 received unusually high predation compared to other studies. However it is difficult to make an accurate comparison as the methodology for these experiments differs considerably in the length of the experiment, types of eggs and style of nest used, for example.

<u>Forest type</u>	<u>Predation rate</u>	<u>Author</u>
Peat swamp forest	62%	This study site 1
Peat swamp forest	86%	This study: site 2
Tropical Lowland Rainforest	80.5%	Wong <i>et al.</i> 1998
Tropical Lowland Rainforest	62%	Sodhi <i>et al.</i> 2003
Tropical Rainforest	70.6% (interior)	Estrada <i>et al.</i> 2002
Tropical Rainforest	76.2% (edge)	Estrada <i>et al.</i> 2002
Tropical Montane forest	49% (interior)	Carlson and Hartman, 2001
Tropical Montane forest	30% (edge)	Carlson and Hartman, 2001
Temperate forest	45% (interior)	Carlson and Hartman, 2001 calculated from Patton, 1994
Temperate forest	56% (edge)	Carlson and Hartman, 2001 calculated from Patton, 1994

Table 6.1 This table makes a comparison between the predation rates at the two study sites and those found in previous studies.

Though statistical tests show there to be no significant difference, a comparison between the mean quail predation rates of the two sites does nevertheless appear to have implications; the total nest predation at site 2 is 23.8% higher than at site 1. Statistical tests did find significant difference between predation on plastercine eggs at the two sites. A repeat of the experiment with 9 transects at each site could be valuable to confirm, or reject the possibility that predation is significantly higher at site 2.

Analysis of predators found no significant difference between predation on nests of plastercine eggs between sites by rodent, bird or other. Predation by primates was higher for site 1, and predation by reptiles was significantly higher for site 2, this may be an effect of the frequent fires at site 2. The risk of fire may have had a negative effect on primate population density in this area. It is possible that reptiles are more adaptable to the fires and their effects; this would provide them with an advantage over other generalist predators. Research into the effect of the fires at site 2 on reptiles and primates could increase our understanding of the reasons for these results.

6.1 Limitations

Though this study failed to find the existence of an edge effect on artificial nest predation, there may be an edge effect that remained undetected because of the limitations in this study.

The main disadvantage with using artificial nests for nest predation studies is that artificial nests may not be a true indication of what real bird populations are experiencing. An issue noted by Cooper and Francis (1998) is the absence of an adult bird to guard the nest from predators especially during nocturnal raids by small mammals. Therefore, we might expect predation rates to be higher in this study than in life. Some authors such as Haskell, (1995) have questioned the suitability of using quail eggs in nest predation studies. Because of their larger size and harder shell they are often considered as poor substitutes for passerine eggs. However, this should not create such a discrepancy as predators of eggs will be generalists and

should not be affected by this.

There are a large number of variables in ecology studies that cannot be controlled. It would be ideal to have been able to monitor far more variables to note correlation with nest predation, such as predator abundance, edge/area ratio and light intensity, for example. Unfortunately the resources available did not allow for this. Other studies have attempted to monitor some of these variables. Wong *et al.*, (1997) found no significant correlations between predation rates and the following variables; fragment area, edge/area ratio, isolation index and canopy density. Estrada *et al.*, (2002) determined predator abundance, visual exposure of the nests (light intensity), and vegetation type. No significant relationship was found for vegetation type, however, the amount of light penetrating to the ground was found to be closely related to predation rate. It would be desirable to repeat this study, while monitoring and taking into account more of the variables that have been found to affect nest predation.

It is possible that the positions of the nests may have an effect on predation if some were more visible than others. Stations were marked with red raffia tied round the tree and yellow wax marked the distance along the transect. It is possible that visual predators may be able to use this as a visual indicator of the presence of a nest. Cooper and Francis (1998) also noted that real nests are not arranged in linear transects. The high density of nests in such a small area may be an explanation for such high predation rates, however, this is an issue faced in all artificial nest predation studies.

Human disturbance in this area of peat swamp forest is comparatively high; this is

an expected anthropogenic edge effect. Loggers, bat collectors and Jeluton latex harvesters have access to more of the forest with the existence of logging tracks and a dismantled railway. Site 1 is assumed not to be a route used by bat collectors or rubber tappers. This area is an established site of research for many organisations (e.g. OuTrop, CIMTROP), however, the transects used in this site were only used for orang-utan follows during the period of the study, which is a relatively low impact activity in terms of disturbance. The transects at site 2 crossed with transects of other researchers and they may have received some interference during the study. The most significant human interference in the areas of study would have been from us. Because of the difficulties in operating in the peat swamp forest, the transects were cut using parang to create a pathway through the forest; this will have caused significant disturbance initially and could have scared off some potential predators for a period. The transects would also have suffered disturbance on the days that the nests were checked. We aimed to minimise the impact of this at site 1 by only passing down transects in one direction and returning to base through the sedge swamp. Unfortunately, this became impossible at the end of the experiment when the water level rose. It was not possible to avoid walking the transect twice per check at site 2.

Human scent left on checks of the nests and possible scent contamination of the nests despite use of rubber gloves may have altered the behaviour of some predators. The plastercine eggs were handled without gloves during painting and moulding, it was hoped that the smell of plastercine and paint would mask any human scent. However, it is possible that this unfamiliar smell may also influence the behaviour of certain types of predators (Rangen *et al.* 2000 cited in Estrada *et al.*, 2002).

Quail eggs being purchased from the local market would have been handled without gloves before purchase leaving a trace of human scent. We have assumed that the quail eggs were relatively fresh on the day that they were placed in the forest; however, we cannot be sure of this.

It is possible that more data was required to find a trend. Site 2 only had three transects, which may not have provided enough room for error in the data. Transects of 250m may not run far enough into the interior to display an end to the edge effect. It would be desirable to recreate the study with a greater number of longer transects, however, the difficulties of operating in peat swamp forest would require a large team to check the nests if this extended study was to be carried out.

6.2 Implications

This study is, to my knowledge, the first attempt to investigate nest predation rates in tropical peat swamp forest and is valuable in making comparisons with the pressure experienced by passerines in other habitats. However, because of the limitations in artificial nest predation studies, the predation rates revealed in this study may not be comparable to what the peat swamp forest's birds are experiencing. This study is only based on artificial predation rates, and it is not known to what extent the results are indicative of natural predation rates. This experiment is likely to determine predation pressure by generalist predators and thus is suitable for a comparison of nest vulnerability between sites (Seiving, 1992).

Hence, higher predation at site 2 could be indicative of the devastating effect that fire created edges are having on passerine survival in the habitat.

The research that has been carried out in the Sebangau catchment over the past few years has brought it global recognition as a valuable habitat of exceptional biodiversity, encouraging it's designation of National Park status. However, this does not offer the area complete security and the problems of illegal logging and peat drainage will not disappear immediately, subsequently, it is important to monitor the success of the national park in conserving biodiversity to support the conservation of this important global resource. The effects of the 'mega rice project' have had a devastating impact on the peat swamp forest at site 2. Continuation of research into the effect of the fires and logging on biodiversity is necessary to draw attention to this issue and encourage action to be taken to mitigate further damage.

This study examines the little understood, highly complex system of peat swamp forest. It relies on the response to a variable being demonstrated in animal behaviour; yet predator behaviour is affected by countless factors that have not been monitored in this study. The study is based on the response of not just one species, but a whole range of generalist predators. The study aims to prove or disprove the existence of a complex process; edge effects, which is not yet fully understood and varies in effect and distance from edge. Such limited methodology cannot be expected to yield infallible results. However, this study was as complex as the resources available allowed and reveals the need for further study in this area to prove or disprove the existence of an edge effect on artificial nest predation in peat swamp forest.

7. Conclusion

In this study we found no evidence of edge effects. There appears to be no significant relationship between distance from forest edge and total predation or rate of predation of artificial nests at either site. This challenges the applicability and generality of results achieved in temperate regions to tropical forest ecosystems and is supported by many studies carried out in logged forest and in the tropics that have also failed to find an edge effect on nest predation.

Because of the limitations in artificial nest predation studies, it is not known to what extent these results are indicative of natural predation rates. This experiment is likely to determine predation pressure by generalist predators and thus is suitable for comparison of nest vulnerability between sites. Higher predation at site 2 could be indicative of the devastating effect that fire created edges are having on passerine survival in the habitat.

From a conservation standpoint, more research into the effect of fragmentation of peat swamp forest on biodiversity is necessary in this area. Extensive research into the effects of the fires, illegal logging and the peat drainage is urgently needed. Attention needs to be drawn to these issues to encourage better management and protection of this area.

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Database

STATIGRAPHICS Plus 5.1 (1994-2001) Statistical Graphics Corp.

10. Appendices

Appendix I

General Risk Assessment Form

Area: Tropical peat swamp forest, Central Kalimantan, Indonesia.

Nr. Palangkaraya.

Activity being assessed: Research for ENV316 final project module.

Ref No.	Hazards	Probability	Severity	Risk Factor	Controls in place / Action to be taken
1.	Sunburn	3	2	6	Wear appropriate clothing inc. hat and use of sunscreens.
2.	Biting Insects	3	1	6	Wear appropriate clothing and use of insect repellents and net.
3.	Dehydration	3	2	6	Regular intake of non-alcoholic drinks. Carry supply of water at all times when leaving the field station.

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4.	Wild animals	2	2	4	Wild animals should never be touched. Never enter forest alone. Seek local expertise on animal behaviour and adjust field activities accordingly.
5.	Unstable / wet ground	3	2	5	Wear appropriate footwear. Never enter forest alone. Seek local expertise on viability of access routes and research sites, and act accordingly.
6.	Malaria	2	3	7	Use of insect repellents, appropriate clothing and mosquito net and take anti-malarial medication.

KEY

<u>PROBABILITY</u>		<u>SEVERITY</u>		<u>RISK FACTOR</u>	
Probable	3	Critical	3	High Risk	5-9
Possible	2	Serious	2	Medium Risk	4
Unlikely	1	Minor	1	Low Risk	1-3

Calendar of Research

Date	Day	Task
28 th June	Mon	Edge effect on Artificial nest predation in a Tropical Peat Swamp forest Made and painted plastercine eggs for Site 1. Anna Lucas 222827
29 th June	Tues	Marked out transects at Site 1, moss collected.
30 th June	Wed	Purchased quails eggs for Site 1. Set out nests on transects at Site 1.
1 st July	Thurs	Check 1 (checked nests and removed those that had been predated) at Site 1.
4 th July	Sun	Check 2 at Site 1.
7 th July	Wed	Check 3 at Site 1.
10 th July	Sat	Check 4 at Site 1.
11 th July	Sun	Made plastercine eggs for Site 2.
12 th July	Mon	Painted plastercine eggs for Site 2.
13 th July	Tues	Check 5 at Site 1.
16 th July	Fri	Collected moss and prepared nests for site 2.
17 th July	Sat	Purchased quails eggs for Site 2.
18 th July	Sun	Transects cut and marked out and set out nests at Site 2.
19 th July	Mon	Check 1 at Site 2.
22 nd July	Thurs	Check 2 at Site 2.
25 th July	Sun	Check 3 at Site 2.
28 th July	Wed	Check 4 at Site 2.
30 th July	Fri	Canopy measurements of Transects AA - DD at Site 1
31 st July	Sat	Check 5 at Site 2, canopy measurements and GPS points taken.
1 st August	Sun	Canopy measurements and GPS of Transects EE-FF at Site 1.

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Index II

Site 1: Raw predation data

Transect	distance from edge (m)	Quail eggs		Plastercine eggs		
		Predated at check	No. of eggs predated	Predated at check	No. predated	species
AA	10	3	1	4	3	Primate
	25	5	1	2	1	Rodent
	35	U (unpredated)	0	2	2	Rodent
	60	U	0	U	0	Unpredated
	95	U	0	U	0	Unpredated
	155	3	3	3	3	Bird
	250	4	3	U	0	Unpredated
BB	10	U	0	U	0	Unpredated
	25	U	0	U	0	Unpredated
	35	U	0	U	0	Unpredated
	60	3	3	3	3	Bird
	95	U	0	4	2	Rodent and Reptile
	155	U	0	U	0	Unpredated
	250	U	0	U	0	Unpredated
CC	10	3	3	5	1	Bird
	25	3	1	1	2	Rodent
	35	1	1	4	3	Bird
	60	2	3	2	1	Rodent
	95	U	0	U	0	Unpredated
	155	U	0	4	2	Primate
	250	2	3	2	3	Bird
DD	10	2	1	2	1	Rodent
	25	2	1	2	1	Rodent
	35	3	3	5	1	Other
	60	U	0	U	0	Unpredated
	95	4	3	3	2	Other
	155	1	1	3	1	Other
	250	2	3	U	0	Unpredated
EE	10	4	2	U	0	Unpredated
	25	1	3	U	0	Unpredated
	35	3	2	5	1	Other
	60	2	2	U	0	Unpredated
	95	U	0	2	1	Primate
	155	3	3	3	3	Other
	250	4	3	3	2	Rodent
FF	10	3	3	2	2	Rodent
	25	U	0	U	0	Unpredated
	35	4	3	3	3	Bird
	60	4	3	5	3	Rodent and Reptile
	95	U	0	U	0	Unpredated
	155	4	3	4	3	Other
	250	U	0	2	3	Rodent

Site 2: Raw predation data

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Transect	distance from edge (m)	Quail eggs		Plastercine eggs		
		Predated at check	No. of eggs predated	Predated at check	No. of eggs predated	Predator
T1	10	5	1	1	1	Other
	25	2	2	2	2	Reptile
	35	1	2	2	2	Rodent
	60	2	3	2	2	Bird
	95	2	3	5	1	Reptile
	155	2	3	2	3	Bird and Rodent
	250	2	1	4	3	Rodent
T2	10	2	3	3	1	Reptile
	25	4	3	3	1	Reptile
	35	4	3	U	0	Unpredated
	60	1	1	4	1	Reptile
	95	U	0	3	3	Rodent
	155	U	0	1	3	Reptile
	250	1	1	1	3	Bird
T3	10	5	3	2	1	Other
	25	5	3	5	3	Primate and Rodent
	35	3	3	2	2	Other
	60	4	3	U	0	Unpredated
	95	2	2	2	1	Other
	155	U	0	U	0	Unpredated
	250	1	3	2	2	Reptile

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Site 1: canopy cover data

Transect	station	0-5m	5-15m	15m+
TAA	1	60	75	0
	2	0	80	60
	3	15	30	15
	4	85	40	25
	5	50	45	25
	6	80	40	30
	7	45	30	25
TBB	1	80	70	60
	2	0	90	45
	3	30	50	10
	4	15	40	45
	5	65	40	10
	6	95	50	60
	7	60	40	10
TCC	1	0	85	25
	2	40	65	20
	3	40	70	35
	4	50	70	15
	5	75	75	30
	6	25	55	65
	7	25	95	35
TDD	1	95	50	30
	2	40	95	0
	3	95	20	0
	4	40	90	0
	5	10	70	30
	6	80	80	60
	7	10	5	45
TEE	1	40	35	15
	2	70	5	10
	3	35	80	30
	4	25	60	50
	5	70	80	70
	6	75	40	35
	7	55	40	45
TFF	1	70	60	5
	2	60	90	70
	3	10	5	65
	4	15	60	40
	5	5	0	20
	6	30	50	75
	7	65	10	80

Site 2: canopy cover data

Transect	station	0-5m	5-15m	15m+
T1	1	95	10	10
	2	50	60	15
	3	85	50	20
	4	5	15	35
	5	80	10	30
	6	65	5	80
	7	25	10	30
T2	1	65	15	0
	2	40	50	70
	3	40	90	50
	4	10	65	30
	5	65	20	40
	6	40	45	70
	7	30	20	45
T3	1	80	90	0
	2	85	20	40
	3	10	60	60
	4	60	10	35
	5	0	40	35
	6	20	10	10
	7	5	60	30

Edge effect on artificial nest predation in a Tropical Peat swamp forest
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