An estimation of anurans species richness and abundance in Sebangau Peat-Swamp Forest, Indonesia, Borneo

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Abstract

This report presents the results of the effects of selective logging on anurans in the Sebangau forest in East Kalimantan, Borneo. We assessed the patterns of diversity, richness and abundance in anuran's communities for four sites in the Sebangau forest in East Kalimantan, an important region given the great number of fauna and flora species. The main objective was to assess anurans community factors relative to different degrees of disturbance for the habitats of the Sebangau Catchment. Additionally, the results were compared with the results obtained from other project conducted in the Bawan forest.

The data on anurans was obtained by Visual Encounter Surveys and Active Survey. Anurans diversity for each habitat was assessed by using Shannon-Wiener index and the relative abundance were standardized by capture rate (CR) for each species.

A total of 245 individuals and 8 species belonging to the family of Ranidae, Bufonidae, Dicroglossidae and Rhacophoridae were identified in the Sebangau forest in 27 days between September and October 2010. The highest species richness was in the least disturbed habitat, in the mixed peat swamp with 1.08 the Shannon- Wiener diversity index and the lower species diversity obtained in the higher disturbed habitats including a canal in the secondary peat swamp forest (0.28), a regenerating burnt area (0.6) and recently logged gaps (0.53).

Furthermore, anuran species richness between different habitats in the Sebangau forest and Bawan forest were compared using an independent samples t-test (2-tailed).

There was no significant difference in terms of species richness for the mixed peat swamp in the Sebangau forest and the mixed peat swamp in the Bawan forest ($p=0.1$).

There was no significant difference in terms of species richness for the mixed peat swamp in the Sebangau forest and kerangas in the Bawan forest (p=1).

There was no significant difference in terms of species richness for the mixed peat swamp in the Sebangau forest and the kerangas with stream in the Bawan forest (p=0.09).

There was significant difference in terms of species richness for canal in the secondary forest in the Sebangau and in the kerangas with stream in the Bawan forest (p=0.024).

There was significant difference in terms of species richness for the regenerating burnt area in the Sebangau and in the regenerating burnt area in the the Bawan forest (p=0.024).

There was significant difference in terms of species richness for the regenerating burnt area in the Sebangau and in the recently burnt area in the Bawan forest (p=0.003).

Contents page

Acknowledgements……………………………………………………….....2

Abstract……………………………………………………………………..3

Contents page……………………………………………………………………………..5

List of Tables……………………………………………………………………………7

List of Figures……………………………………………………………………………8

Introduction………………………………………………………………10

Biodiversity in Borneo……………………………………………………………………..10

Threats faced by Bornean forests…………………………………………………………11

Decline Amphibians………………………………………………………………………..12

Objectives and Hypotheses………………………………………………………………..15

Methods……………………………………………………………………16

The study site………………………………………………………………………………16

Environmental variables…………………………………………………………….......19

Conservation status of found anurans in the Sabangau forest.....................................20

Habitat description……………………………………………………………………....20

Survey design……………………………………………………………………………..22

Visual Encounter Survey………………………………………………………...22

Active survey……………………………………………………………………………...23

Other sampling methods…………………………………………………………24

Measurements of captured animals……………………………………………...24

Anurans calls……………………………………………………………………………...25

Relative abundance……………………………………………………………………25

Species richness………………………………………………………………………...26

Bawan catchment………………………………………………………………………27

Results…………………………………………………………………...29

Species composition of Sebangau forest...34

Environmental parameters………………………………………………………….37

Species accumulation curves……………………………………………………......38

Species diversity in Sebangau forest…………………………………………………40

Relative abundance……………………………………………………………………41

Anurans calls…………………………………………………………………………..45

Results of Anurans species richness in Bawan forest………………………………..46

Variation in anuran size and weight In the Sebangau forest and the Bawan forest and the Bawan forest……………………………………………………………………………..50

Discussion……………………………………………………………..51

Comparison in anurans species richness between the peat swamp lowland forests in Sebangau and Bawan catchment ……………………………………………......57

Conclusions…………………………………………………………...60

Evaluation of Project Success……………………………..................63

Appendix A…………………………………………………………...64

Appendix B…………………………………………………………....66

Appendix C……………………………………………………………69

List of references……………………………………………………...72

List of tables

Table 2.1 Conservation status of anurans from the Sebangau forest in according the IUCN Red List of Threatened Species.

Table 3.1 Number of individuals that were recorded in and out of transect during VES in four different habitats including the mixed peat swamp, canal, burnt area and gaps.

Table 3.2 The results for the active surveys in the Sebangau forest.

Table 3.3 The number of individuals and species found at each of the different survey sites using VES and active survey.

Table 3.4 Environmental parameters for the different habitat surveyed using VES

Table 3.5 Shannon- Wiener diversity and evenness index for anuran species in four different habitats including the mixed peat swamp, canal, burnt area and gaps.

Table 3.6 The relative abundance per habitat for the main surveyed species (VES date).

Table 3.7 The number of days of collection of anurans and person hours.

Table 3.8 The number of individuals and species found at each of the survey sites using VES and active survey in the Bawan forest (C = camp, K= kerangas, M-PS = mixed-peat swamp.

Table 3.9 Comparing species richness Sebangau vs. Bawan forest.

Table 3.10 Parametres for anurans found in the Sebangau forest (in black) and in the Bawan forest(in red).

Table 3.11 The list of calls anurans recorded in the Sebangau forest.

List of figures

Figure 2.1 Map of Borneo.

Figure 2.2. Map of Sebangau Forest in Borneo with Natural Laboratory of Peat Swamp Forest' (NLPSF).

Figure 2.3 Some habitats in the study site including mixed peat-swamp forest (upper), canal in peat-swamp forest (left) and forest sedge (right).

Figure 2.4 The location of transects including mixed peat-swamp forest (green), canal (blue), regenerating burnt area (red) and gaps (yellow) in the study site The grid system was designed for orangutans study in NLPSF, Sebangau.

Figure 2.5 Map of Bawan Forest in Borneo.

Figure 3.1 The percentage of species recorded on all VES and active surveys in 6 habitats including camp, the regenerating burnt area, canal in the secondary forest, recently logged gaps, the mixed peat swamp and forest sedge.

Figure 3.2 Species abundance of anurans at each of six habitats including camp, the mixed peat swamp forest.

Figure 3.3 Amphibian species found in the Sebangau forest. From left to right: *Ingerophrynus quadriporcatus* (top), *Pseudobufo subasper, Hylarana baramica, Occidozyga, laevis*, *Limnonectes paramacrodon* (bottom), *Polypedates leucomystax*, *Polypedates colletti, Polypedates macroti.*

Figure 3.4 Species accumulation curve of frogs observed in the mixed forest in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in- transect) and active survey.

Figure 3.5 Species accumulation curve of frogs observed in a canal in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

Figure 3.6 Species accumulation curve of frogs observed in a burnt area in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

Figure 3.7 Species accumulation curve of frogs observed in logged gaps in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

Figure 3.8 The Shannon- Wiener diversity index for anurans species in four different habitats including the mixed peat swamp, canal, burnt area and gaps.

Figure 3.9 The relative abundance of five different species in the mixed peat swamp.

Figure 3.10 The relative abundance of five different species in a canal in secondary peat swamp forest.

Figure 3.11 The relative abundance of five different species in a regenerating burnt area.

Figure 3.12 The relative abundance of species in recently logged gaps.

Introduction

Biodiversity in Borneo

The one of the major ecological issues, which is currently discussed among conservationists and researchers worldwide, is whether logging forest influences fauna and flora species diversity and ecological processes in the rain tropical forests. The description of biological diversity is crucial to protect and use suitably biological resources (Veith et al, 2004).

Borneo, which is the third largest island on the earth, is one the richest regions of biodiversity: the flora includes 15.000 species of flowering plants and 3000 species of tree; 222 species of mammal; 420 species of bird, about 145 amphibians (mostly frogs) and 250 reptiles are also found in Borneo (MacKinnon, 1996). This island is also inhabited by 13 non-human primate species, eight of which are endemic (Groves, 1993). Borneo is home to three primate species which are described by IUCN as “Endangered” including the Bornean orangutan (Pongo *Pygmaeus*), the Bornean southern gibbon (Hylobates *albibarbis*) and proboscis monkey (Nasalis *larvatus*) (Outroop, 2010).

About 140 species of frogs have been identified in Borneo and new species frogs are found every year. In this area six families of frogs occur including Bombinatoridae, Megophryidae, Bufonidae (the so-called ‘true toads’), Microhylidae, Ranidae (the so-called ‘true frogs’) and Rhacophoridae (Inger, 2005). Among amphibians, about 65% of the species are endemic to Borneo. The richness in diversity of amphibians is connected with the location Borneo on the equator in the humid tropics. Additionally, Borneo was connected and disconnected from the mainland and other islands many times in the past (Veith et al, 2004).

Peatlands cover 3 % of the world's surface. The Sebangau peat-swamp forest is located in the south of Borneo Island in the Indonesian province of Central Kalimantan. This ecosystem is the largest area of contiguous lowland rainforest remaining in Borneo (Cheyne, 2010). The tropical peat swamp forest, described as a dual ecosystem with a tropical forest and a peat layer, is the main habitat occurs in this area. A peat soil contents 65% or more organic matter. The peat deposits are usually at least 50cm thick, but they can be very deep up to 20 m (MacKinnon, 1996). The Sebangau forest has been illegally and legally logged and cleared partly as a result of 'mega rice project 'between 1997-98 (OuTrop, 2010). Additionally, the area has been affected by fires used in land clearance and drainage from building logging canals causing destruction of the hydrological systems (Cheyne, 2010).

Threats faced by Bornean forests

The percentage of the world's forest in Indonesia was estimated at between 3 and 4 percent in 2001. It was assessed that 2 million hectares of forest in Indonesia are cut down every year (Williams,2007).

The forest destruction in Borneo, is one of the main causes of the high degree of biodiversity loss in the world. According to FAO (2010), about 500.000 ha of forest are logged every year.

The degradation of the Borneo's forests is caused by agriculture, drainage, deforestation, fires and pollutions. Forest fires are the results of land clearing for agriculture. When forest is cut down, fires can easily spread out (Williams, 2007). For instance, the EL Niño/Southern Oscillation event, which happened between 1997 and 1998, was the largest fire disaster ever in a tropical rainforest and destroyed 5.2 million hectares of vegetation cover, including 2.6 million hectares of forest. Furthermore, peat swamp forests contain the high amount of carbon, which during a fire is released vast amounts into the atmosphere, making Indonesia one of the world's biggest CO_2 emitters (Veith et al, 2004).

Although the peatland is nutrionally poor, logging of these forests still continues (Williams, 2007).

The biodiversity in Indonesia is critically endangered because of an increase in the rate of tropical deforestation. The oil palm industry is one of the main cause that affecting Borneo's biodiversity. The expansion of oil palm plantations in Kalimantan, Indonesian Borneo, has causesd the degradation of native forests, with plantations of oil palm not able to provide suitable habitat for many species dependent on forests. This situation leads to the extinction of these species. Other factors which influence on deforestation are the timber and pulp industries, coal mining and extracting gold. Although international and national conservation organizations are trying to protect tropical forests, the clearance of the forests is still continuing (Venter, 2008).

Decline of Amphibians

There are about 6000 known species of Amphbians worldwide. Although, the discovery of new species is the most rapid among vertebrate group, the knowledge of the amphibian ecology is still only partial. The greatest amount of amphibians occurs in the tropical and moist tropical forest of Eastern and Southern Asia, Central America, South America and Equatorial Africa (Amphibian Web; Frost 2006).

Since the late 1980s, herpetologists have reported that the richness of amphibians declined worldwide and that some of them are being driven to extinction at an alarming rate (Stuart et al, 2004). For instance, 12% of bird species and 23% of mammal species are endangered in comparison to 32% of amphibian's species. Some conservation programs such as the Amphibian Conservation Action Plan are designed to conserve and protect them (Mendelson, 2006).

According to IUCN, about 33% of the amphibian species are described as vulnerable, endangered or critically endangered. In spite of the fact that habitat loss is the main reason for the decline amphibians, some evidence shows that these vertebrate suffer in apparently undisturbed ecosystem (Stuart et al, 2004).

Amphibians are generally considered suitable as indicator species in a variety of systems. Their biphasic life cycle and semi-permeable skin are two justifications often given for this use of amphibians. Amphibians as ecological indicators may enable to observe the dramatic changes in biological diversity. This class of vertebrate is really susceptible to any change in habitat in which they live. The great loss of amphibians is probably caused by a mix of different factors including infectious diseases, toxins, the introduction of exotic species, climate change and unsuitable land use (Stuart et al, 2004). Scientists and conservationists claim that understanding of the correlations between these factors and the amphibians loss is still unclear. Amphibians that occupy usually small areas are more susceptible to extinction because of habitat degradation than other vertebrate. They may be used as ecological indicators because of their complex life cycle and the diversity of species. These characteristics, in combination with their disappearances worldwide in twentieth century make them an important model for understanding global change; including climate change, earth warming, pollution or habitat loss and how they affect biodiversity (Stuart et al, 2004). For instance, global warming generates climatic events such as extreme droughts or heavy rainfall (Houghton, 2001). Additionally, climate change can cause the growth of disease transmission. In the past, organisms have reacted to climate change by changing their distribution. Currently, life forms are limited in their ability to move to different areas by agricultural development, urbanization or deforestation.

It is important to understand the causes of decline and extinction amphibians by monitoring amphibian diversity in long- term studies and developing conservation programmes. Overall, conducting flora and fauna biodiversity surveys in tropical rainforest, it is crucial to protect existing habitat, preventing habitat degradation and developing habitat restoration methods (Stuart et al, 2004).

My objectives during this study were to:

- Assess amphibian biodiversity in the peat-swamp forest of the Sebangau Catchment
- Compare the amphibians species richness and abundance between different habitats, related to degrees of disturbance of the Sebangau Catchment
- Compare the Anurans species richness between the peat-swamp forest of the Sebangau Catchment and on the kerangas (heath) forest of Kahayan Catchment, in Bawan District

Hypotheses

1) The abundance and richness of frogs will differ between different sites (with different degrees of forest disturbance) within peat-swamp forests of the Sebangau Catchment.

2) Species assemblage of frogs will differ between different sites (with different degrees of forest disturbance) within the Sebangau Forest.

3) Species richness will differ between the Sebangau Catchment and the kerangas (heath) forest of Kahayan Catchment

Methods

The study site

Figure 2.1 Map of Borneo (Googlemap)

Borneo, which is situated on the equator, has a moist and tropical climate (Figure 2.1). Temperatures are moderately steady during the year between 25C and 35 C in lowland areas. The amount of rainfall in equatorial lowland areas account is at least 60mm every month. Two main types of monsoons appear in Borneo including: a “dry” monsoon from May to October and a “wet “monsoon from November to April (MacKinnon, 1996).

Sebangau Catchment

The study took place at OuTrop's base camp Setia Alam [2*20'42"S, 114*2'11" E] within 500km² semi protected 'Natural Laboratory of Peat Swamp Forest' (NLPSF) in the Northern Sebangau catchment (Figure 2.2). NLPSF is located 20 km south-west of Palangkaraya, the provincial capital of Central Kalimantan (Hamard, 2010). The Sebangau National Park, which was established in 2004 is located between the Katingan River and the Kahayan River, Central Kalimantan. Although, NLPSF is not a part of the Sebangau National Park, this area was established as a research area and it is guarded by governmental decree (Morrogh-Bernard et al, 2003).

Setia Alam Field Station is within the edge of the forest that has been logged. NLPSF is directed by CIMTROP (the Centre for the International Cooperation in Management of Tropical Peatlands), an Indonesian research and conservation organization based at the University of Palangka Raya (UNPAR).

This area has been logged and drained by the building of logging canals. As result of this, the area comprises logged, recovering and primary forest. At the time when the study was conducted this forest was not logged. However, little amounts of non- timber forest products including bark, rattan, orchids or latex were being harvested (Hamard, 2010).

The lowland forest in NLPSF is classified as secondary closed –canopy evergreen. This area has a large amount of rainfall during the year and is seasonally flooded, approximately for 9 months. The Sebangau peat-swamp forest is divided into four classes of forest including the mixed swamp forest, transitional/ mixed-swamp, the low interior forest and tall interior forest (Cheyne, 2011).The mixed peat swamp forest occurs up to about 5-6 km between the edges of forest.

This type of forest has numerous types of different tree species up to 35 meters height with a closed layer of canopy from 15 to 25 m. The depth of peat is around 6m. This area is water logged during the wet season and most of the dry season. As result of logging, the forest is dense with *Pandanus* and *Freycinetia* spp.. There is, however, some illegal logging and the forest is susceptible to fires (Cheyne, 2011). The most common tree species of the upper canopy are *Gonystylus bancanus*, *Shorea spp*, *Cratoxylon glaucum* and *Dactylocladus stenostachys*.

The low interior forest is located between 6km and 11 km within the forest. The height of trees is from 10m to 15m. The tree species of the upper canopy include *Combretocarpus rotundat*us and *Calophyllum spp*.. Additionally, the large amount of light in the canopy and high water level in the forest causes the growth of the thick undergrowth of *Pandanus* and *Freycinetia spp*.. Furthermore, the tall interior forest, which is situated between 13 and 23 km within forest, has the largest number of different tree species, which are up to 45metres. Peat can be deep up to 13 meters in this forest. This type of forest comprises a large richness of tree species including species of the genera Agathis Dactylocladus, Gonystylus, Koompassia, Palaquium and Shorea (Husson, 2004, Morrogh-Bernard et al., 2003).

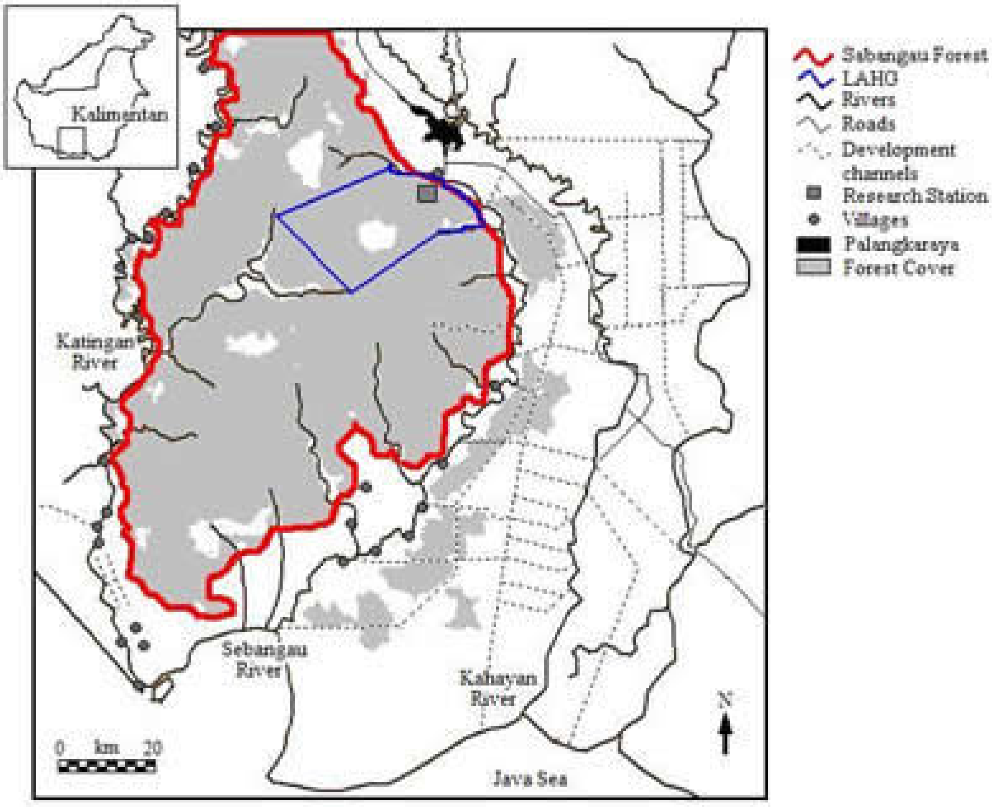


Figure 2.2. Map of Sebangau forest in Borneo with Natural Laboratory of Peat Swamp Forest' (NLPSF) (Outrop, 2010).

Environmental variables

Environmental variables were measured every night of the survey including temperature (^{0}C)

using a thermometer, humidity (%) using a thermo-hygrometer, cloud cover (%) visually as well as general information about the weather.

Furthermore, all habitats were described to investigate habitat preferences of anurans including canopy height, water depth, water temperature, canopy cover and scrub density. These were measured at 100 m intervals along each transect, apart from established transects in recently logged gaps which had 50 meters length.

Conservation status of found anurans in the Sebangau forest

There are 8 species of anurans known to be present in the Sebangau forest (IUCN, 2010) (Table 2.1).

Species	Family	IUCN Red List of Threaten Species
Ingerophrynus quadriporcatus	BUFONIDAE	Least Concern (LC)
*Pseudobufo subasper**	BUFONIDAE	Least Concern (LC)
Hylarana baramica	RANIDAE	Least Concern (LC)
Limnonectes paramacrodon	DICROGLOSSIDAE	Near Threatened (NT)
Occidozyga laevis	DICROGLOSSIDAE	Least Concern (LC)
Polypedates colletti	RHACOPHORIDAE	Least Concern (LC)
Polypedates leucomystax	RHACOPHORIDAE	Least Concern (LC)
Polypedates macrotis	RHACOPHORIDAE	Least Concern (LC)

Table 2.1 Conservation status of anurans from the Sebangau forest according the IUCN Red List of Threatened Species.

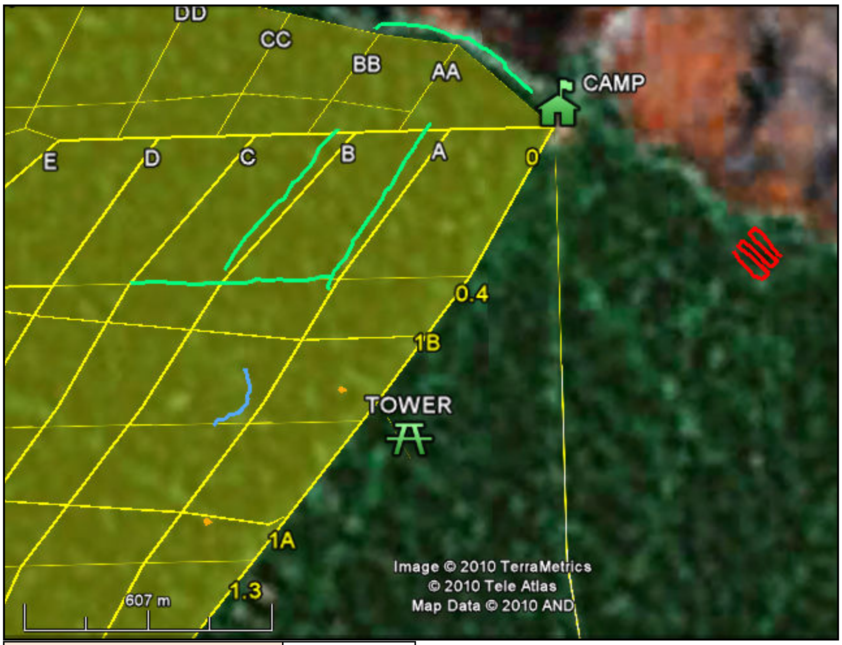
Habitat description

The study was conducted in four various habitats with differing levels of disturbance of the forest, including secondary mixed peat-swamp forest, canal in secondary peat-swamp forest, regenerating burnt forest and recently logged canopy gaps. Secondary mixed peat swamp and canals are less disturbed than regenerating burnt forest and logged canopy gaps. Canals were built to carry logged trunks to the river. As result of which, water was drained from the peat causing increased forest susceptibility to fires (Morrogh-Bernard, 2003).

The burnt areas developed during fires in the dry season of 2006 and 2007. Gaps were cut to enable hunting for bats (Harrison, M., 2009).

Additionally, different habitats were chosen to measure the anurans species richness including the camp area, the flooded sedge and a few other micro-habitats (Figure 2.3).

Figure 2.3 Some habitats in the study site, including mixed peat-swamp forest (top), canal in peat-swamp forest (left) and forest sedge (right) (pictured by Ivan Mohedano).



Legend	
transects	
Mixed peat swamp	
canal	
Burnt area	
gaps	

Figure 2.4 The location of transects including mixed peat-swamp forest (green), canal (blue), regenerating burnt area (red) and gaps (yellow) in the study site The grid system was designed for orangutans study in NLPSF, Sabangau (Harrison, M., 2009).

Survey design

The survey of Anurans was conducted in the downland rainforest in the Sebangau Catchment in East Kalimantan, Borneo between September and October 2010.

Two different sampling methods were used during the anuran study, including night transects Visual Encounter Survey (VES) and active surveys. In this site, eight transects were established in four main habitats.

Visual Encounter Survey (VES)

Transects were placed along pre-existing trails designed for orangutans study in the mixed –swamp forest, NLPSF, Sebangau (Husson, 2004). 8 straight-line transects were established, using a measuring tape, at length from 50m to 600m and were marked- out with raffia (following a compass bearing) (Table 3.1). For effective sampling, all transects were searched more than once during the study to find all the species occurred in the study site (Heyer *et al.* 1994) (Figure 2.4).

Specimens were collected by members of the field station and by foreign scientists. Observers walk along transects slowly at night using headlights, with a gap of approximately 2-4m between each observer. Specimens that could be seen within a (approximately) a 2m band, along both sides of a transect were counted and captured. Opportunistic contacts were recorded as well (out of transects). The number of observers varied between two and four people. Some of them were less or more experienced in searching anurans.

The location of each anuran individual was identified by sight or call and recorded using GPS.

Surveys were carried out between 6pm and 10 pm every night. The night transect was chosen because dusk and dawn are the times when most frogs are active and when most advertisement calling occurs (Inger,2005).

Walking within the study site was obstructed by a high density of vegetation, exposed tree roots and pneumatophores (mangrove roots). Additionally, the amount of the rainfall between September and October 2010 was greater than usually in the dry season in this area, causing water- logged transects.

Active survey

Additionally, an active survey was carried out during the anuran study, observers walked in different areas. This sampling method was carried out out- transects (-opportunistic) in prescribed time (30min, 1.30min and 2 hours), systematically searching for animals. Active searches were conducted at night (Table 3.2). The results were added to the estimation of species richness (Sutherland, 2006).

Other sampling methods

Other methods as such as day transect, trapping, or artificial refuge were not used in the Sebangau Forest. These methods have been used in the kerangas forest of the Kahayan Catchment and have been identified as not effective in a tropical environment (Waddell, 2011).

Measurements of captured animals

Each individual was put in a plastic bag and measured. The anurans weight was measured using a spring balance to the nearest 1g and their snout- vent length was assessed by dial caliper to the nearest 0.1mm. Animals were then identified based on taxonomic guides (Inger and Stuebing, 2005). In addition, unknown anurans were photographed and indentified (photographs from frogs-of-Borneo.com). All captured animals were released and relocated at the same location as they were found in. The survey wasn't conducted during storms because of health and safety procedure. The same transects were not surveyed on consecutive days in order to ensure independence of samples.

Anurans calls

There were identified five different anurans calls. Calls were recorder by a Dictaphone and identified by field staff.

Relative abundance

Anurans were detected ‘in–transect’ and ‘out-transect’ (opportunistic) during the performing of the sampling method VES. Only relative abundance could be measured because amphibians were not marked during their recapturing. VES is not effective method for accurately estimating population size unless it come together with a mark-recapture (Hill, 2005). The total number of individuals of one species was divided by the total number of individuals of all species to obtain relative abundance. The average of relative abundance for each species was determined by conducting repeated surveys for each transect. Survey was standardized by conducting sampling at the same time of day or by randomized observations (Hoyer, 1994). However, different amounts of time were spent on each transect and different sizes of groups people were involved in searching (Cook, 2010).

The total number of individuals recorded was divided by the person hours spent for each search. Person hours were obtained by multiplying the total amount of time spent searching by the number of people taking part in the search.

CR(capture rate)=the total number of individuals /total time*number of people for each species(person hours)

Species richness

Data obtained during VES (in- and out-transects) and active survey was used to measure the species richness. Active survey was employed to obtain a more comprehensive the species checklist.

The diversity indices used were heterogeneity measures that combine the species richness and evenness (Magurran, 2004). Shanonn -Wiener richness index was used to measure the diversity of species for each transects in every habitat.

Shannon-Wiener Index, $H' = - \sum (p_i \ln p_i)$

P_i = proportion of the total number of individuals represented by that species (i.e. n_i / N, where n_i = the number of individuals of that species, and N = total number of individuals).

Shannon evenness index: $E = H' / \ln S$

S = number of species observed.

The maximum value of E = 1, is obtained if all the species are equally abundant. (Seaby& Henderson, 2006)

The total number of individuals (N) for each habitat was modified by considering in the analysis only animals detected before the accumulating rate reached zero (Heyer, 1994).

Bawan catchment

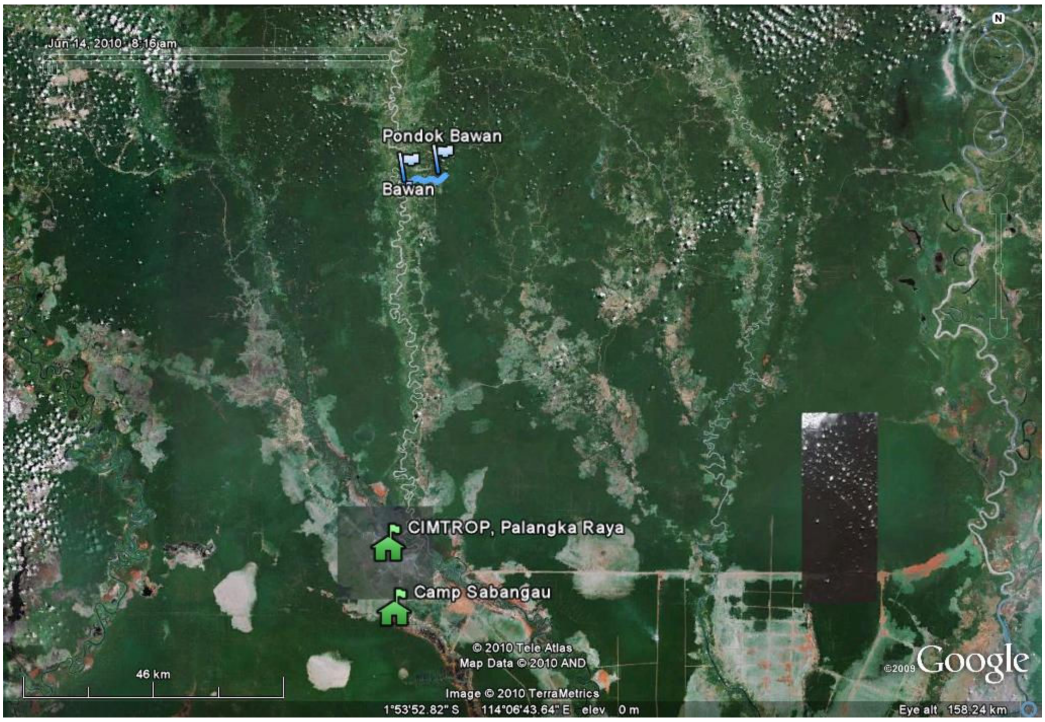


Figure 2.5 Map of Bawan Forest in Borneo (Map downloaded by Emily Waddell).

In addition to my own work I also used data from the other amphibian studies conducted in Bawan tropical rainforest 65km north of Palangkaraya in Central Kalimantan, Indonesian Borneo between July and August 2010 (Figure 2.5). This anuran survey was supervised by The Orangutan Tropical Peatland Project and the Centre for the International Cooperation in Management of Tropical Peatlands (CIMTROP) and was conducted as part of Emily Waddell's dissertation (OuTrop and CIMTROP, 2010).

The study area, which was logged and destroyed by fires area, is unprotected and was studied for the first time. There were studied different habitats including kerangas, kerangas with stream, peat swamp, newly burnt, regenerating burnt, low interior forest (low pole) and camp for 37 nights and nine days (OuTrop and CIMTROP, 2010).

Sampling methods which were used during this study included Visual Encounter Surveys, MacKinnon's List and stream quadrats. MacKinnon's List include every anuran found during VES, quadrat and opportunistically. These areas are considerably different from habitats in Sebangau forest, and include kerangas forest and kerangas with stream (heath) (MacKinnon et al., 1996) with tall dipterocarp trees (around 15-20 metres) with buttresses, a little amount of leaf litter and temporary pools. Furthermore, mixed peat swamp habitat was swampier and more flooded than kerangas habitat with canopy around 20 metres tall.

Additionally, the newly burnt area had mainly regenerating grasses, sedges, a few pools and the lack of a peat layer. The regenerating burnt area had a lack of a peat layer, the vegetation included grasses, sedges, few small trees (4 metres). The low interior forest had a deep peat layer and some pools. The terrain was swampy with large hummocks, aerial roots and canopy 15 metres high. Overall, the study site in the Sebangau forest was more flooded than in the Bawan forest.

421 individuals and 18 anurans species were found in 35 days during study in Bawan forest. Data analysis was based on anurans found during VES and opportunistically searching (Waddell, 2011).

The statistical *t*-test was used to assess differences in the number of amphibian species found between different sites in the Sebangau forest and the Bawan catchment.

Results

A total of 8 species in 4 families and 6 genera were identified in different habitats including secondary mixed peat-swamp forest, canal in secondary peat-swamp forest, regenerating burnt forest and canopy gaps recently logged, camp and forest sedge in the Sebangau forest.

The study was conducted between 9th of September and 12th of October 2010 during 14, non-consecutive, days using VES and 13 days using active survey, and a total of 245 individuals were found. Figure 3.1 shows the number of individuals that were recorded in and out of transects (- opportunistic).

Transect	**Date**	**Length of transect**	**Total number of individuals**	**Number of individuals In transect**	**Number of individuals Out transect opportunistic**	**Number of species**	**Species (number of individuals)**
Peat-swamp I	09-09-2010	500m	7	3	4	3	*Hylarana baramica(3)* *Occidozyga laevis (2)* *Polypedates colletti (2)*
Peat-swamp II	10-09-2010	500m	14	6	8	3	*Hylaranabaramica(7)* *Occidozyga laevis(4)* *Limnonectes*

							paramacrodon(3)
Peat-swamp III	11-09-2010	500m	10	3	7	3	*Hylarana baramica(8)* *Occidozyga laevis(1)* *Polypedates colletti*
Peat-swamp IV	13-09-2010	500m	15	9	6	3	*Hylarana baramica(1)* *Occidozyga laevis(11)* *Polypedates colletti (3)*
Peat-swamp V	15-09-2010	500m	12	9	3	4	*Hylarana baramica (6)* *Occidozyga laevis(1)* *Limnonectes paramacrodon (2)* *Polypedates colletti (3)*
Peat-swamp VI	17-09-2010	500m	16	8	8	2	*Hylarana baramica13)* *Limnonectes paramacrodon(3)*
Peat-swamp VII	20-09-2010	500m	10	4	6	3	*Hylarana baramica(6)* *Occidozyga laevis(2)* *Limnonectes paramacrodon(2)*
Peat-swamp VIII	01-10-2010	500m	12	5	7	3	*Hylarana baramica(10)* *Limnonectes*

							paramacrodon(1) *Polypedates colletti*
Canal I	30-09-2010	275m	8	5	3	2	*Hylarana baramica(6)* *Limnonectes paramacrodon(2)*
Canal II	11-10-2010	275m	6	3	3	3	*Pseudobufo subasper* *Hylarana baramica(3)* *Limnonectes paramacrodon(2)*
Burnt I	28-09-2010	580m	6	1	5	2	*Hylarana baramica (4)* *Occidozyga laevis(2)*
Burnt II	04-10-2010	580m	10	6	4	2	*Hylarana baramica (6)* *Occidozyga laevis(4)*
Gaps I	29-09-2010	50m	3	1	2	1	*Hylarana baramica(3)*
Gaps II	06-10-2010	50m	2	0	2	1	*Hylarana baramica(2)*

Table 3.1 Number of individuals that were recorded in and out of transect during VES in four different habitats including the mixed peat swamp, canal, burnt area and gaps

Another sampling method used in this study was active survey. Details of transects are in Table 3.2.

Transect	**Date**	**Length of transect**	**Duration of survey**	**Total number of individuals**	**Nuber species**	**Species (number of individuals)**
Peat-swamp I	19-09-2010	500m	30min	7	4	*Occidozyga laevis(4)* *Limnonectes paramacrodon(1)* *Polypedates colletti(1)* *Polypedatesmacrotis (1)*
Peat-swamp II	20-09-2010	500m	30min	4	3	*Limnonectes paramacrodon(1)* *Occidozyga laevis(2)* *Polypedates colletti(1)*
Peat-swamp III	01-10-2010	500m	30min	1	1	*Occidozyga laevis(1)*
Peat-swamp IV	02-10-2010	500m	1h 30min	21	4	*Hylarana baramica(1)* *Occidozyga laevis(9)* *Limnonectesparamacrodon(1)* *Polypedates colletti(10)*
Peat-swamp V	05-10-2010	500m	2h	7	3	*Hylarana baramica(2)* *Limnonectes paramacrodon(4)* *Polypedates colletti (1)*

Peat-swamp VI	13-10-2010	500m	1h 30min	5	3	*Hylarana baramica(2)* *Occidozyga laevis(1)* *Limnonectes paramacrodon(1)* *Polypedates colletti (1)*
Canal I	30-09-2010	275m	30min	0	0	-
Canal II	11-10-2010	275m	30min	2	1	*Limnonectes paramacrodon(2)*
Burnt I	14-09-2010	580m	30min	1	1	*Hylarana baramica(1)*
Burnt II	02-10-2010	580m	30min	1	1	*Occidozyga laevis(1)*
Gaps I	29-09-2010	50m	30min	0	0	-
Gaps II	12-10-2010	50m	30min	2	1	*Hylarana baramica(2)*
Gaps III	12-10-2010	50m	30min	1	1	*Hylarana baramica(1)*

Table 3.2 The results for the active surveys in the Sebangau forest

Table 3.1 and 3.2 demonstrate that the greatest number of species was encountered in the mixed peat swamp habitat during VES and active survey. Lesser number of species were found in canal in the secondary peat swamp forest, regenerating burnt areas and recently logged gaps.

Species composition of Sebangau forest

Species	Camp	mixed peat swamp	Canal	Burnt	Forest sedge	Gaps logged	Total number of individuals
Ingerophrynus quadriporcatus	**1**	**1**				**1**	**3**
Pseudobufo subasper			**1**				**1**
Hylarana baramica	**3**	**59**		**11**		**8**	**90**
Limnonectes paramacrodon	**1**	**19**	**6**				**26**
Occidozyga laevis	**2**	**38**		**3**	**2**		**45**
Polypedates colletti		**24**					**24**
Polypedates leucomystax	**1**						**1**
Polypedates macrotis		**1**					**1**
The number of species	**5**	**6**	**2**	**2**	**1**	**2**	**191**

Table 3.3 The number of individuals and species found at each of the different survey sites using VES and active survey.

The species abundance and composition differ between all the habitats. Table 3.3 demonstrates that the highest species richness with six species, was observed in the mixed peat swamp including *Ingerophrynus quadriporcatus, Hylarana baramica, Limnonectes paramacrodon, Occidozyga laevis, Polypedates colletti* and *Polypedates macrotis.*

Additionally, *Pseudobufo subasper, Hylarana baramica* and *Limnonectes paramacrodon* were found in a canal. Species *Hylarana baramica* and *Occidozyga laevis* were detected in burnt area. Only one species *Occidozyga laevis* was found in the forest sedge. *Ingerophrynus quadriporcatus and Hylarana baramica* were identified in logged gaps. Although, five different species were opportunistically encountered in camp during the active survey, including *Ingerophrynus quadriporcatus, Hylarana baramica, Limnonectes paramacrodon, Occidozyga laevis* and *Polypedates leucomystax,* the number of individuals for each species was low. However, dates obtained in a camp and forest sedge were excluded from an estimation of the richness and relative abundance of anurans

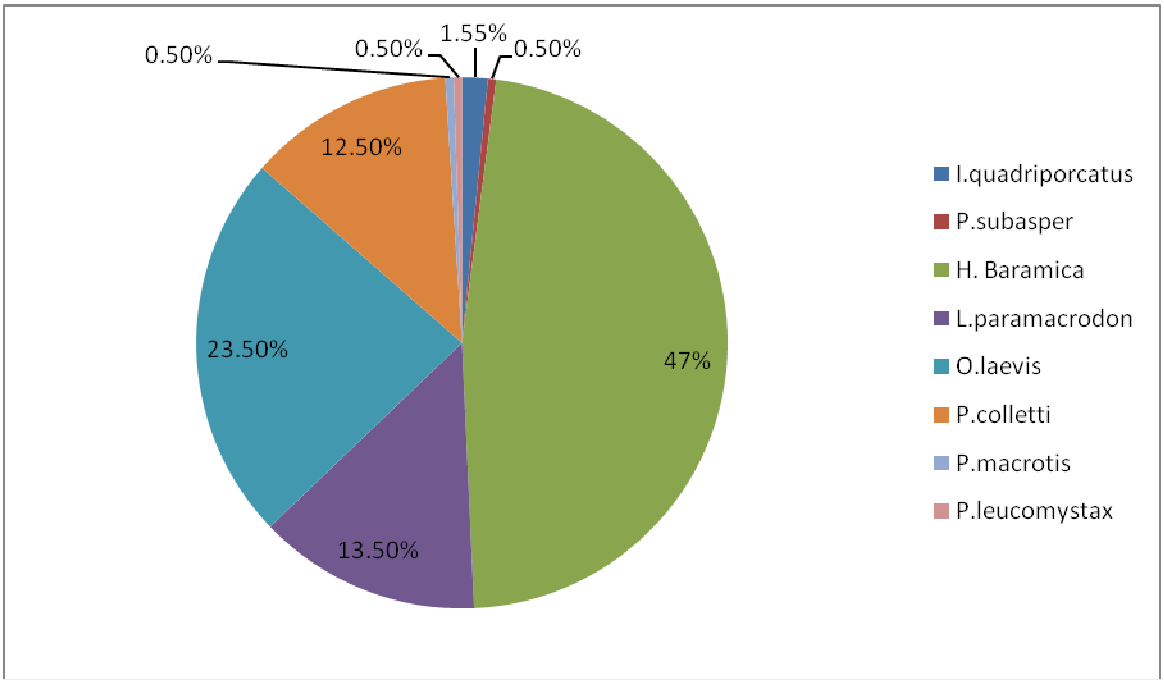


Figure 3.1 The percentage of species recorded on all VES and active surveys in 6 habitats including camp, the regenerating burnt area, canal in the secondary forest, recently logged gaps, the mixed peat swamp and forest sedge.

Figure 3.1 shows that *Hylarana Baramica* accounted for 47%of the individuals detected in all habitats, which is over two fold higher than any of the other species. In contrast, only one individual of *Polypedates leucomystax, Polypedates macrotis* and *Pseudobufo subasper* were found in different habitats and each accounted for 0.05% of the total individual found.

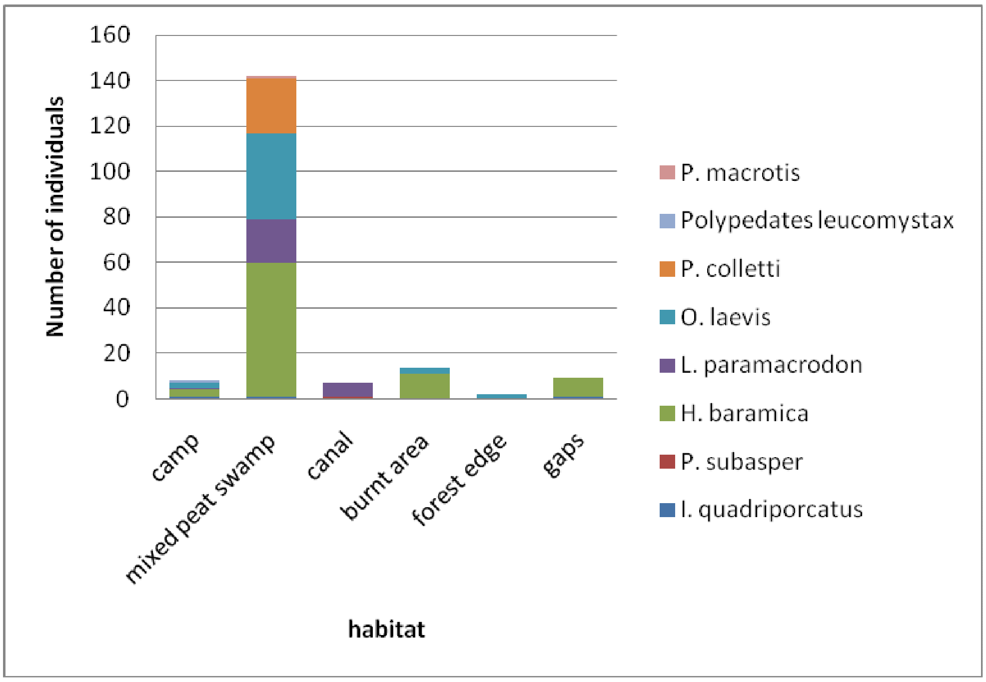


Figure 3.2 Species abundance of anurans at each of six habitats including camp, the mixed peat swamp, canal, burnt area, forest edge and gaps.

Figure 3.3 Amphibian species found in Sabangau forest. From left to right: *Ingerophrynus quadriporcatus* (top), *Pseudobufo subasper, Hylarana baramica, Occidozyga laevis*, *Limnonectes paramacrodon* (bottom), *Polypedates leucomystax*, *Polypedates colletti*, *Polypedates macroti* (Picture by Iván Mohedano).

Environmental parameters

Temperature (C^{o}) and humidity (%) was measured at the beginning survey at every transect. In according results, temperature had similar values in every habitat between 27 and 29 ˚C. Humidity was between 89 and 99%.

The intra-day humidity was not studied on this occasion, but its values probably oscillate considerably, especially in those areas where the canopy cover is not well developed.

HABITAT	SAMPLE (days)	TEMPERATURE VARIATION (˚C)	HUMIDITY RANGE (%)
Mixed peat-swamp forest	8	24,1-27,7	89-99
Canal in peat-swamp forest	2	28,8-29,6	97-99
Burnt regenerating	2	26,8-28,6	94-99
Gaps	2	27,8-28,7	99-99

Table 3.4 Environmental parameters for the different habitat surveyed using VES.

Species accumulation curves

Species accumulation curves for each habitat are shown below (Figure 3.4).

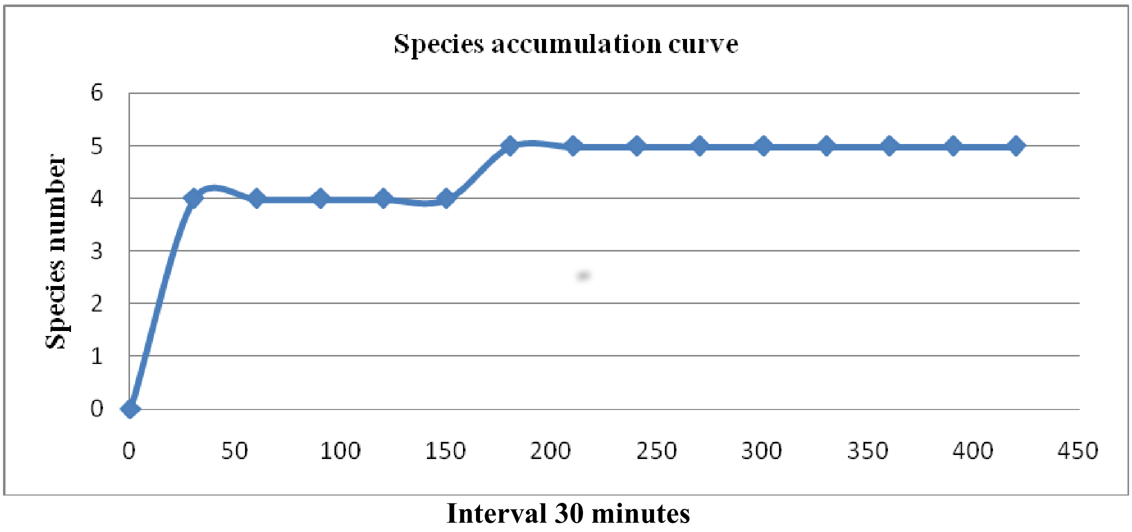


Figure 3.4 Species accumulation curve of frogs observed in the mixed forest in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

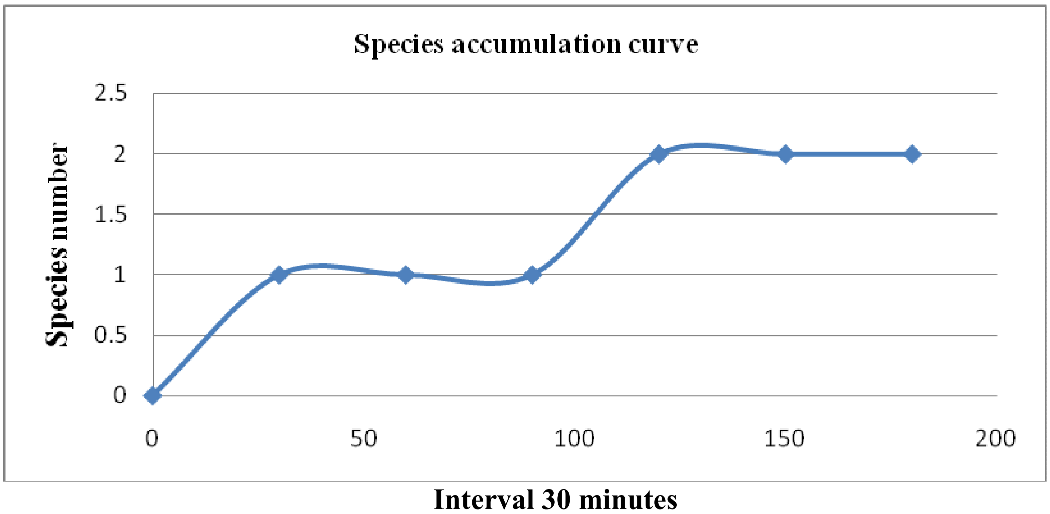


Figure 3.5 Species accumulation curve of frogs observed in a canal in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

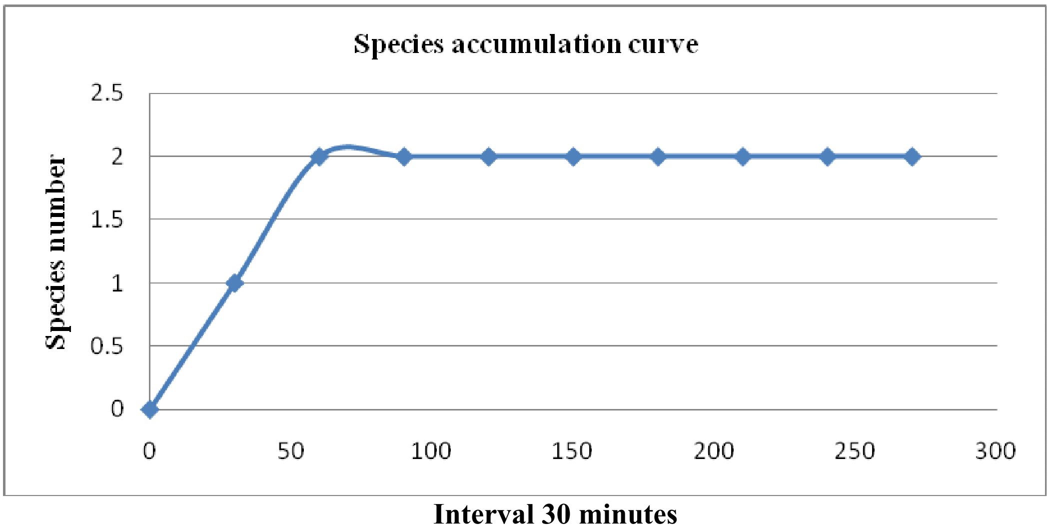


Figure 3.6 Species accumulation curve of frogs observed in a burnt area in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey

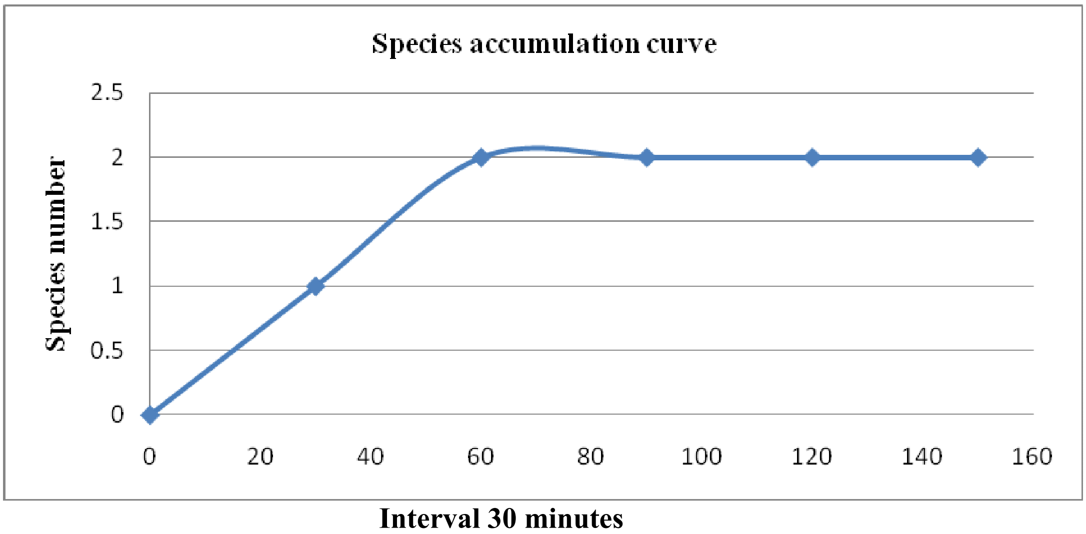


Figure 3.7 Species accumulation curve of frogs observed in logged gaps in the Sebangau forest during 18 days (interval 30 minutes). Results include data from VES (in transect) and active survey.

The species accumulation curve (Figure 3.4, 3.5, 3.6 and 3.7) for the mixed swamp, canal, burnt area and logged gaps has reached an asymptote. It suggests that additional species of anurans are expected to be detected if more surveys are done.

Species diversity in Sebangau forest

The Shannon- Wiener diversity index for anurans species was the highest for the mixed peat swamp (1.08), compared to either canal (0.28), burnt area (0.68) or logged gaps (0.53).In terms of species evenness, the distribution of individuals among species was uneven in the peat swamp (E=0.58) compared to canal (E=0.66), burnt area (E=0.98) and gaps logged (E=0.23) (Table 3.5).

Habitat	Shannon-Wiener index	Species Evenness
Secondary mixed peat swamp	1.08	0.58
Canal in secondary forest	0.28	0.66
Regenerating burnt area	0.68	0.98
Gaps recently logged	0.53	0.23

Table 3.5 Shannon-Wiener diversity and evenness index for anuran species in four different habitats including the mixed peat swamp, canal, burnt area and gaps.

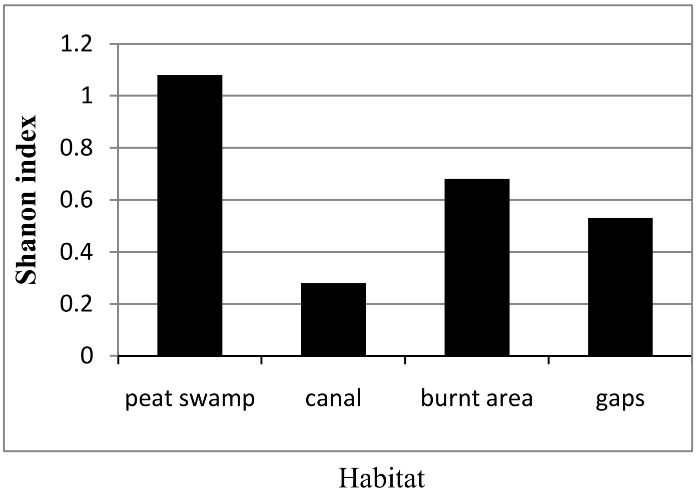


Figure 3.8 The Shannon- Wiener diversity index for anurans species in four different habitats including the mixed peat swamp, canal, burnt area and gaps.

Relative abundance

Habitat	HYLBAR	OCCLAE	LIMPAR	POLCOL	PSESUB
Peat-swamp	6.11	5.45	1.73	2.29	0
Canal	0	0	4.72	0	0.75
Burnt	1.38	3.13	0	0	0
Gaps	0.38	0	0	0	0

Table 3.6 The relative abundance per habitat for the main surveyed species (VES date).

Table 3.6 shows VES (in –transects contacts) that were standardized by capture rate (CR) for each species (Cook, 2010).

CR(capture rate)=the total number of individuals /total time*number of people for each species(person hours)

	Visual Encounter Survey	
Habitat type	Days of collection	Person hours
Mixed-peat swamp	8	25.033
Canals in peat-swamp forest	2	2.88
Burnt areas	2	4.05
Gaps	2	3.57
Total	12	

Table 3.7 The number of days of collection of anurans and person hours

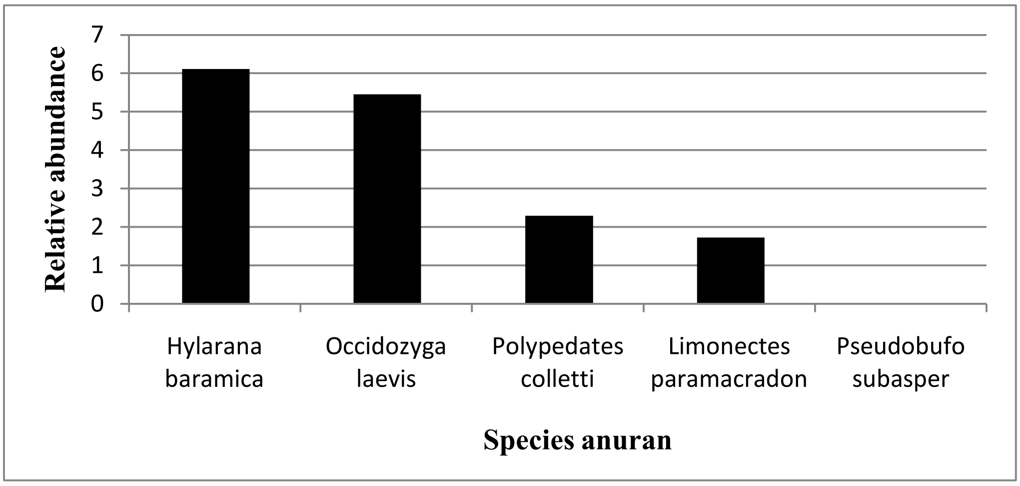


Figure 3.9 The relative abundance of five different species in the mixed peat swamp

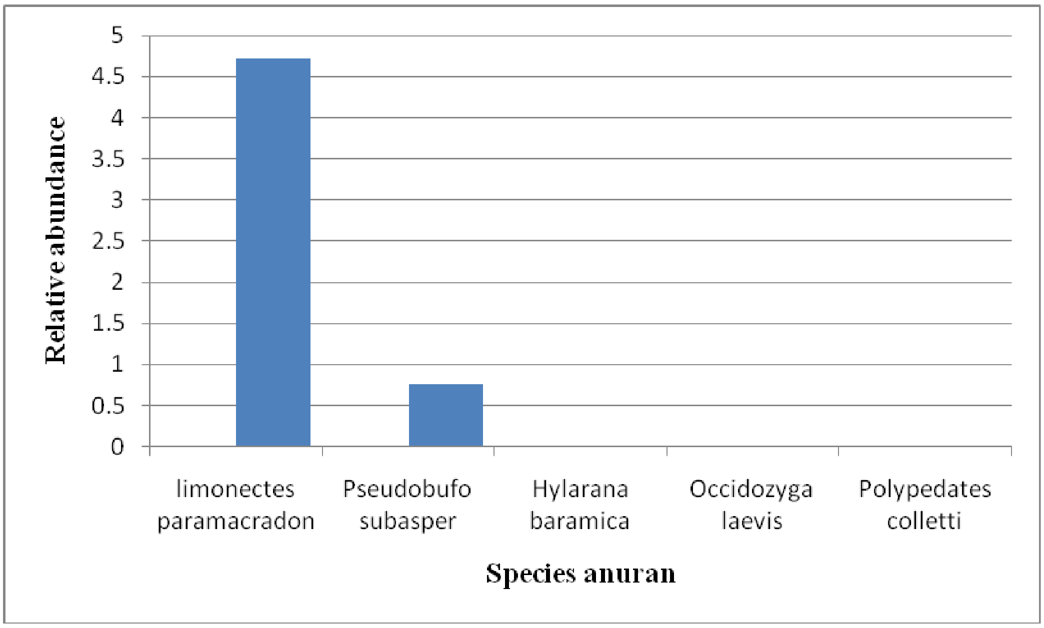


Figure 3.10 The relative abundance of five different species in a canal in secondary peat swamp forest

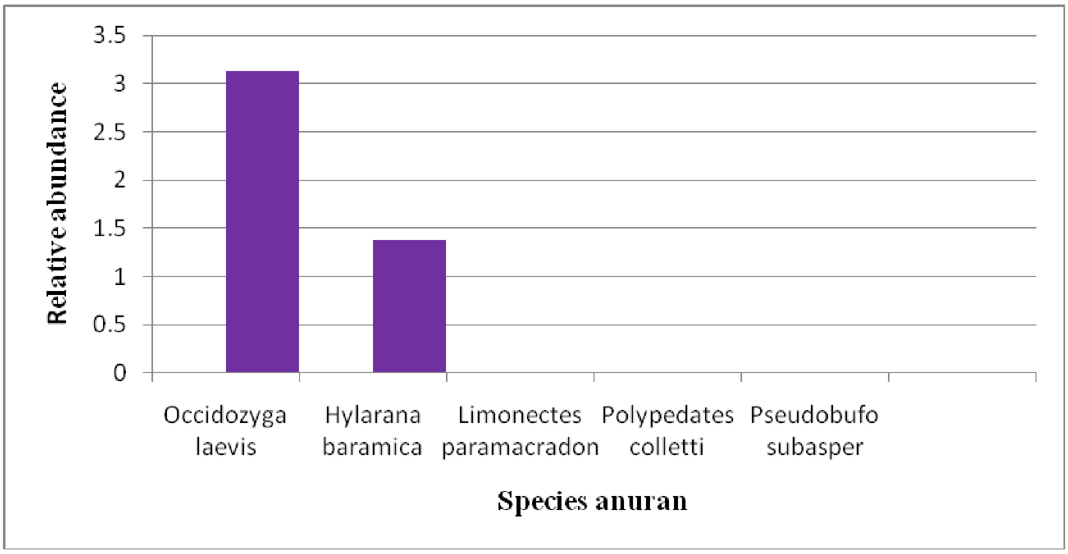


Figure 3.11 The relative abundance of five different species in a regenerating burnt area

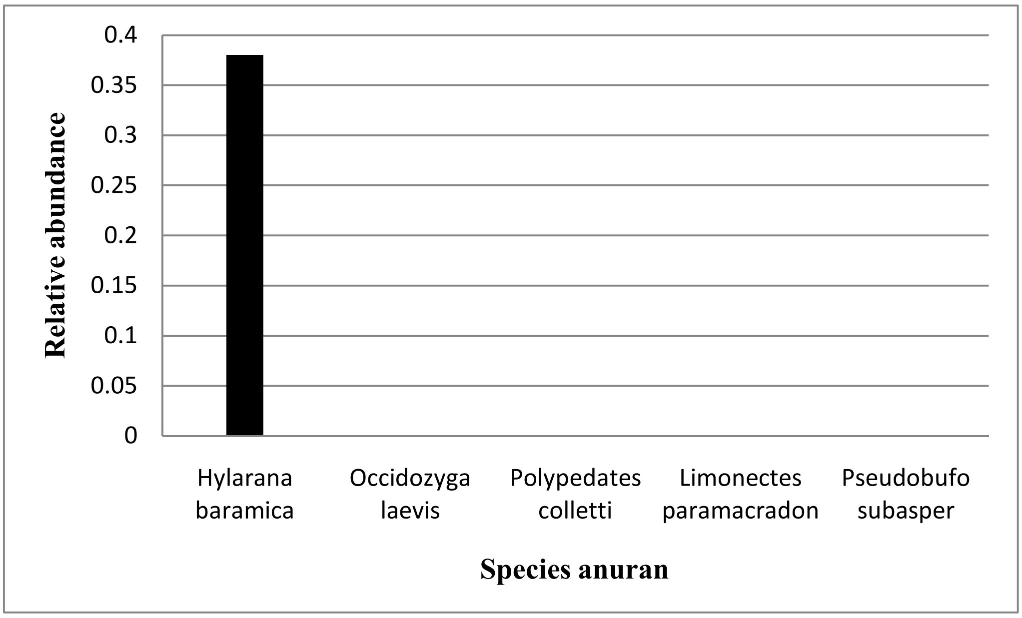


Figure 3.12 The relative abundance of species in recently logged gaps

Anurans calls

There were recognized and recorded calls of different species.

Species	**Type of call**	**Description**
Ingerophrynus quadriporcatus	Territorial day call	Heard throughout the year
Hylarana baramica	Territorial night call	Heard throughout the year
Limnonectes paramacrodon	Alarm call	Observed some alarm calls during captures
Occidozyga laevis	Breeding call Alarm call	Breeding call heard during one month only
Polypedates colletti	Breeding call	Heard just for a couple of weeks
Polypedates macrotis	Breeding call	Heard for just one week, coinciding with the full moon

Table 3.11 The list of calls anurans recorded in the Sebangau forest

Results of Anurans species richness in Bawan forest.

Table 3.8 presents the number of anuran species that were recorded at each of the survey habitat using VES and active survey in the Bawan forest.

Species	C	K	M-PS	K+S	BN	BR	LP
Bufonidae			X				
Fejervarya cancrivora						X	
Hylarana baramica	X	X	X	X	X	X	X
Hylarana glandulosa	X						
Hylarana raniceps		X	X	X			
Ignerophrynus quadriporcatus	X	X	X	X			
Kalophrynus sp.			X				
Kalophrynus pleurostigma		X	X			X	
Leptobrachium spp.	X	X	X		X	X	
Limnonectes malesianus				X			
Limnonectes paramacrodon	X		X	X			
Microhyla borneensis				X			
Nyctixalus pictus				X			
Occidozyga laevis			X	X	X	X	
Polypedates colletti		X	X	X	X		X
Polypedates leucomystax	X						
Polypedates macrotis		X	X	X	X	X	
Rhacophorus appendiculatus					X		
Total	6	7	11	10	6	6	2

Table 3.8 The number of individuals and species found at each of the survey sites using VES and active survey in the Bawan forest (C = camp, K= kerangas, M-PS = mixed-peat swamp, K+S = kerangas plus stream, BN = burnt new, BR = burnt regenerating and LP = low interior forest). *Bufonidae, Kalophrynus sp* and *Leptobrachium spp* were not qualified to species level (Data provided by Emilly Waddell).

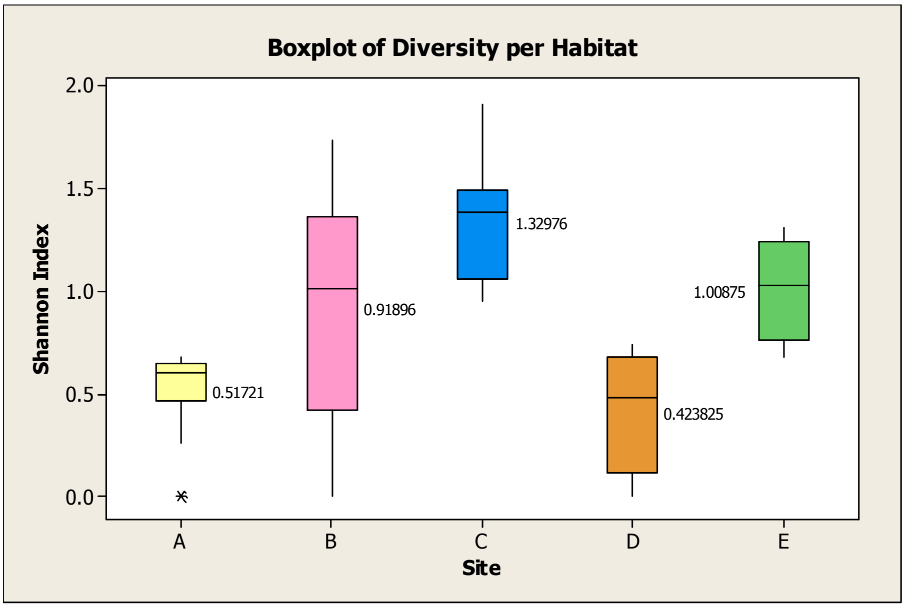


Figure 3.13 Shannon- Wiener diversity index for anuran species in five different habitats including A-kerangas, B-mixed-peat, C-kerangas+stream, D-burnt new and E-burnt regenerating. The Shannon index was calculated for each individual night at each site (Waddell, 2011).

The Shannon- Wiener diversity index for anurans species was the highest for the kerangas with stream (1.32976) and the lowest in the burnt new area (Figure 3.13).

The null hypothesis (H_0) that there was no difference between the species richness in the habitats in the Sabangau and mixed peat swamp the Bawan forest, was tested using an independent samples t-test (2-tailed). Table 3.9 summarises these results.

Habitats	**Sebangau forest mean**	**Bawan forest mean**	**t-test**
mixed peat swamp forest Sebangau vs. mixed peat swamp in the Bawan forest	3; SD=0.53	4; SD= 1.51	(t (14)=1.76, p=0.1
mixed peat swamp forest in the Sebangau vs. kerangas in the Bawan forest	3; SD=0.53	3; SD= 0.75	(t (14)=0, p= 1)
mixed peat swamp forest in the Sebangau vs. kerangas with stream the Bawan forest	3; SD=0.53	4.14; SD=1.67	(t (13)=1.83, p=0.09),
canal in the secondary peat swamp forest in the Sebangau vs. kerangas with stream the Bawan forest	1.5; SD=1.29	4.14; SD=1.67	(t (9)=2.706, p=0.024)
regenerating burnt area in the Sebangau vs. regenerating burnt area in the Bawan	1.5; SD=0.57	3; SD=0.81	(t (9)=3, p=0.024)
regenerating burnt area in the Sebangau vs. recently burnt area in the Bawan forest	1.5; SD=0.57	3.5; SD=0.57	(t (6)=4.89, p=0.003)

Table 3.9 Comparing species richness Sebangau vs. Bawan forest.

H_0 was accepted p>0.05 (t (14)=1.76, p=0.1), there was no difference between the richness species in the mixed peat swamp forest in the Sebangau (mean=3; SD=0.53) and in mixed peat swamp the Bawan forest (mean=4; SD= 1.51).

H_0 was accepted $p>0.05$ (t (14)=0, p= 1), there was no difference between the richness species in the mixed peat swamp forest in the Sebangau (mean=3; SD=0.53) and kerangas the Bawan forest (mean=3; SD= 0.75).

H_0 was accepted $p>0.05$ (t (13)=1.83, p=0.09), there was no difference between the richness species in the mixed peat swamp forest in the Sebangau (mean=3; SD=0.53) and the kerangas with stream the Bawan forest (mean=4.14; SD= 1.67).

H_0 was rejected $p<0.05$ (t (9)=2.706, p=0.024), there was significant difference between the richness species in canal in the secondary forest in the Sebangau (mean=1.5; SD=1.29) and in the kerangas with stream the Bawan forest (mean=4.14; SD= 1.67).

H_0 was rejected $p<0.05$ (t (9)=3, p=0.024), there was significant difference between the richness species the regenerating burnt area in the Sebangau (mean= 1.5; SD= 0.57) and in the regenerating burnt area in the the Bawan forest (mean=3; SD= 0.81).

H_0 was rejected $p<0.05$ (t (6)=4.89, p=0.003), there was significant difference between the richness species in richness for the regenerating burnt area in the Sebangau (mean= 1.5; SD= 0.57) and in the recently burnt area in the Bawan forest (mean=3.5; SD= 0.57).

Variations among anurans size and weight in the Sebangau forest and the Bawan forest

Table 3.10 presents body size range (mm) and weight range (gr) of anurans found in the Sebangau forest and the Bawan forest during the study.

SPECIES	SAMPLE	SIZE RANGE (mm)	WEIGHT RANGE (gr)
Ingerophrynus quadriporcatus	0	-	-
Hylarana baramica	30 8	18 - 48 30 - 48	<1 - 8,0 2,0 - 7,0
Limnonectes paramacrodon	46 24	9 - 61 9 - 72	<1 - 24,5 <1 - 40,0
Occidozyga laevis	23 33	13 - 25 12 - 28	<1 - 3,0 <1 - 3,5
Polypedates colletti	35 25	45 - 77 34 - 66	4,5 - 26,5 3,0 - 20,0
Polypedates leucomystax	0	-	-
Polypedates macrotis	23 1	45 - 87 82	4,0 - 45,0 31,0

Table 3.10 Parametres for anurans found in the Sebangau forest (in black) and in the Bawan forest (in red).

Discussion

The highest number of species and individuals was found in the secondary mixed peat swamp in the Sebangau forest with the value, on The Shanon–Wiener index, of 1.08 including *Hylarana baramica, Limnonectes paramacrodon, Occidozyga laevis, Polypedates colletti* and *Polypedates macrotis*. This could be due to the mixed peat swamp being less disturbed than other sites. Although air temperatures and humidity during the night transects had similar ranges in all sites, there could be great differences in light intensity between sites during daytime.

The regenerating burnt area, the canal in secondary forest and gaps recently logged included less abundance of species and individuals of anurans than the mixed peat swamp. The Shannon–Wiener index (0.68) was second in species diversity in the regenerating burnt area followed by recently logged gaps (0.53) and the canal in the secondary forest (0.28). The relative abundance of species of anurans found in the regenerating burnt area was 1.38 for *Hylarana baramica* and 3.13 for *Occidozyga laevis.* Furthermore, *Pseudobufo subasper* (0.75) and *Limnonectes paramacrodon* (4.72) were detected in the canal and *Hylarana baramica* (0.38) was found in recently logged gaps.

Hylarana baramica was the most common frog in three habitats but not from the canal in the secondary forest. This species prefers the forest floor and low vegetation where it climbs, usually peat swamp forest and swampy flatland in primary forest at low elevations. It known that it breeds in water but its breeding habitats are unclear (Inger& Stuebing, 2005). Most of the individuals that were recorded during this study were calling males. This frog is not qualified as fast declining species due to its wide distribution and large population (IUCN, 2010).

Limnonectes paramacrodon favours clay and the gravel banks of small streams in primary forest as well as selectively logged rain forest at low elevations. It lives in heath and peat swamp forests, and preys on moderate to larger sized invertebrates. It breeds in streams and can adapt to live in selective logging forests but they are not able to live in strongly disturbed habitats. It is suggested that this species may be endangered by clear-cutting of forest, agriculture or fire (Inger& Stuebing, 2005; IUCN 2010).

During these studies *Limnonectes paramacrodon* was found in the mixed secondary peat swamp forest and a canal in secondary peat swamp forest. The highest abundance of Limnonectes *paramacrodon* occured in a canal where the water depth was approximately 60cm, which was probably full of predator fish species. This site was dominated by large individuals of *Limnonectes paramacrodon*. Smaller *Occidozyga laevis*, which prefer shallow aquatic habitats, was not found in a canal. This may be linked to competition between these two water frogs. Larger *Limnonectes paramacrodon*, which favours deeper water bodies, may be less endangered by predator fish species (Inger& Stuebing, 2005; IUCN, 2010).

Occidozyga laevis lives in marshy habitats, small puddles and streams in lowland rainforest. Fragmentation of the habitat may be the main threat for this frog which doesn't live in groups.. The species was reported in the mixed secondary peat swamp and in the regenerating burnt area. The greatest abundance of Occidozyga *laevis* was detected in a regenerating burnt area which was flooded to water depth of approximately 10 cm. (Inger & Stuebing, 2005; IUCN, 2010).

Another aquatic anuran *Pseudobufo subasper* was detected in the bank of a canal, eating termites.

This toad lives and breeds in swamps and peat swamps forests, it is not usually found in disturbed habitats. Wetland drainage, air pollution or logging are the major threats for this species (IUCN, 2010).

Polypedates colletti lives in primary and secondary lowland peat swamp forests at different elevations up to 650 meters. Secondary forest cannot be heavily disturbed. Adults occupy trees and breed around temporary rain pools. Although, this species is not considered as threatened, further deforestation may influence their decline. During this study, *Polypedates colletti* occurred only in the mixed secondary peat swamp forest. This habitat seems to provide optional conditions for this species with the high abundance of trees and small pools with standing water (Inger & Stuebing, 2005; IUCN, 2010).

Another tree species *Polypedates macrotis* is known to live in primary and secondary lowlands forests, in vegetation over standing water at forest edges. It can breed in rain puddles, ditches or build foam nests (Inger& Stuebing, 2005; IUCN, 2010). Although, it is is not considered as endangered, one individual of *Polypedates macrotis* was found in the mixed secondary peat swamp forest only.

Additionally, other microhabitats were surveyed opportunistically including flooded forest sedge or a base camp. And one individual of *Polypedates leucomystax*, for instance, was found in a base camp during opportunistic searching. This species has learnt adapt to living in modified human areas including towns, villages, agricultural areas, artificial ponds and logged forests. It is often found in or under grass around shallow standing water and builds foam nests on the ground at water's edge. *Polypedates leucomystax* is resilient and though, and can tolerate more extreme temperature and dryness (Inger& Stuebing, 2005, IUCN, 2010).

Apart from *Polypedates leucomystax*, other anurans were found in low abundance at the camp site including *Ingerophrynus quadriporcatus, Hylarana baramica, Limnonectes paramacrodon and Occidozyga laevis*.

Another anuran, which has been recorded in only a few habitats was *Ingerophrynus quadriporcatus.* This toad has not been seen but its calls has been heard in Sabangau forest. Swamps forests are favourable for this species, where they breed in standing water. *Ingerophrynus quadriporcatus* can be threatened by logging or oil palm plantation (Inger, 2005; IUCN, 2010).

Canopy gaps that were more common in study sites including a canal in the secondary peat swamp, regenerating burnt areas and recently logged gaps, could be correlated with a lower diversity of anurans there. Canopy openings, may influence changes in the level of light, conductivity and pH of stream, temperature of air, humidity or distribution of leaf litter (Meijaard et al 2005).

Additionally, the abundance of amphibians may be linked to the amount of understory vegetation at each site. Anurans use this part of vegetation as shelter and calling sites (Parris & McCarthy, 1999). Those that are dependent on different environmental factors, they can be sensitive to any changes in their habitat. Particular anurans orders tend to rely on particular type of resources (Porter, 2010). Logging may cause some changes in the structure of the forest leaf litter in riparian habitats, ponds and streams, and these changes can cause disturbances in anuran population structures. As a result of logging, primary tropical rainforest is replaced by secondary forest, where the species richness of trees is lower than in primary ones.

Secondary forest is ruled by pioneer tree species that have more open- branched crowns. This characteristic causes the forest floor to be influenced by a larger amount of light. Furthermore, wind speed, air temperature and soil temperature increase and humidity decrease during the day in secondary tropical rainforest (Whitmore, 1998). Results that were obtained during a study conducted in North Sumatra, suggested that changes in the quantity of forest leaf litter may cause a decrease in the diversity of anurans in secondary forest (Iskandar, 1999a, b). Logging, which causes disturbances in floor litter and lower vegetation, leads to a large rise in sedimentation levels in streams and, consequently, to negative effects on the stream breeding anurans reproduction, affecting survival of tadpoles (Meijaard et al 2005).

Another factor, which may lead to amphibians decline, is an increase in the intensity of light in secondary forest (Porter, 2010; Lannoo, 2005). Larvae or juvenile amphibians may be hurt by too much intensive light (Blaustein& Bancroft, 2007). Also an abundance of amphibians is an influence on UVB rays on the forest floor. These rays could destroy nitrogen consumers, including phytoplankton, causing an increase of the accessibility of active nitrogen to anurans. Or could limit food resources for anurans tadpoles (Hader *et al*. 1998; Macias *et al*, 2007).

Anurans have various reproductive systems associated with complicated life cycles including a larvae (tadpoles) and adults. The reproductive life of anurans is linked to aquatic environments including streams or ponds (Inger, 2001). Some frog species even use plant and tree holes filled with water for either egg deposition or tadpole growth. Logging may affect the development of these anurans. Moreover, changes in water chemistry may influence larval anurans (Meijaard et al 2005).

Previous studies in different study sites have shown that logging may affect anurans through impact upon ponds, streams and watersheds, and on forest leaf litter in no riparian habitats. Studies conducted in Sumatra showed that approximately 20% individuals non-riparian anurans were detected in logged forest compared to unlogged forest in the same area Iskandar (1999a, b). The decrease in anurans abundance was associated with the change in the amount of forest leaf litter.

However, some studies showed that selective logging did not significantly affect anurans abundance (Iskandar, 2004, Wong, 2003). And according to Iskandar (2004), the relative abundance of amphibians in the Malinau rainforest in the North Sumatra was higher in logged forest than in unlogged forest. It was not possible to explain this phenomena. There were suggestions that logged forests still had quite close canopy or some differences in habitat that were not identified.

Another study conducted in Sabah rainforest showed that logging had a low impact on frog richness and abundance (Wong, 2003). Some anurans species including *Rhacophorus pardalis, Polypedates colletti, P. macrotis, Leptobrachium montanum, and Rananicobariensis and R. signata* had a high abundance in selectively logged forest. There is a suggestion that logging created some microhabitats such as ponds, which are suitable for pond breeders and for those that prefer secondary forest. Anurans species were found in selectively logged forests that tolerated disturbed habitats as well as in primary forest (Wong, 2003).

Amphibians have not been well studied in peat swamp forests in Indonesia because it has been thought that biodiversity in peat swamps is less rich than in different lowland rainforests (Page, 1997). The limited number of amphibian surveys has perhaps influenced the low number of species found in this habitat. For instance, 19 species only were found at the

Pekan Forest Reserve in Malaysia (Yule, 2010).

The richness of species of amphibians in the peat swamp downland forests is probably less diverse than in other types of forest in Borneo because of the acidic and flooded environment. For instance, in the lowland mixed dipterocarp rainforest at Ulu Temburong National Park in Brunei 54 anuran species were found (Ulmar , 2009) and 65 frogs species were detected in the hilly and mountainous ever-wet tropical rainforest in the Kayan Mentarang National Park East Kalimantan in Indonesia (Veith, 2004). However, these studies were conducted for long-term periods, of at least one year.

Comparison in anurans species richness between the peat swamp lowland forests in Sebangau and Bawan catchment

421 anuran were found during studies in Bawan forest. Waddell (2011) showed that kerangas with stream was the most species diverse habitat and burnt new habitat was the least. Burnt regenerating was the second, followed closely by mixed-peat swamp and then by kerangas.

Additionally, although the greatest number of anurans species was found in the mixed-peat swamp, this diversity richness of this habitat was assessed as third among all studied habitats (Figure 3.13) . In according statistical test as a General Linear Model there was a significant difference between kerangas, mixed-peat swamp, kerangas with stream, burnt new and burnt regenerating habitats (Waddell, 2011).

In this study temperature, humidity and rate of rainfall was not included. Overall, average values for each parameter are similar for the Sebangau forest and the Bawan forest.

An independent- samples *t-test* was used to test differences in the richness of amphibian species found between different habitats in the Sebangau forest and the Bawan catchment. The results showed that there was no difference between the species richness in the mixed peat swamp forest in the Sebangau and mixed peat swamp the Bawan forest, the mixed peat swamp forest in the Sebangau and in kerangas in the Bawan forest, the mixed peat swamp forest in the Sebangau and in kerangas with stream the Bawan forest. Furthermore, the there was a significant difference between the richness species in a canal in the secondary peat swamp forest in the Sebangau and in kerangas with stream the Bawan forest, regenerating burnt area in the Sebangau and in regenerating burnt area in the Bawan forest regenerating burnt area in the Sebangau and in recently burnt area in the Bawan forest.

Overall, the species number of anurans found in Bawan forest was 18 species (Waddell, 2011) and was greater than in the Sebangau forest, with 8 species. There are some suggestions that may explain these differences in the richness of anurans species.

First of all, the Sebangau forest is more flooded and swampy over a year than the Bawan forest. This characteristic may limit the occurrence some types of anurans such as the ground anurans. The ground anurans including *Leptobrachium abbotti*, *Kalophrynus pleurostigma*, *Microhyla borneensis* and *Ansonia minuta* were found in the kerangas forest in Bawan catchment. This area is drier and suitable for anurans species that spend most of time on forest floor. In the Sebangau forest, the limited amount of the forest floor may be not suitable for the development of ground anurans.

Furthermore, the number of tree frogs species was lower in the Sebangau forest than in the Bawan catchment. In the first site only two trees anurans *Polypedates colletti and*

Polypedates macrotis were detected and six tree species in the Bawan forest.

These differences in the diversity of tree frogs between two forests may be linked to types of disturbance in the forests, types of predators, an access to breeding locations or food.

One of the most probable explanations may be problems connected with searching some tree frogs in the canopy. Some tree frogs may possible be detected only during their breeding periods around water bodies such as ponds. The species of frogs found in the Sabangau forest breed in the lower parts of the vegetation.

Moreover, the most suitable habitat for aquatic anurans could be a canal in the peat swamp forest. Only two species were found there, however, *Limnonectes paramacrodon* and *Pseudobufo subasper* .These species live in peat swamp forests and probably, this disturbed site is not suitable for common water frogs.

In both study sites, the species richness was greater in less disturbed habitat, including the mixed peat swamp forest, kerangas and kerangas with stream, in the Bawan forest and the mixed peat swamp in the Sabangau forest. More disturbed areas including regenerating burnt areas in both sites, recently burnt areas in the Bawan forest and a canal in secondary peat swamp forest in the Sebangau catchment significantly were significantly less diverse in anuran species. These results suggest that intensive logging and fires may affect the density and disturbance of anurans.

Overall, the body size and weight of anurans were similar in the Sebangau forest and the Bawan forest. However, *Occidozyga laevis* and *Limnonectes paramacrodon* were a little larger in the Sebangau forest than in the Bawan forest, and *Polypedates colletti* and *Polypedates macrotis* were larger in the Bawan forest. These differences in body size between anurans may be caused by various ecological differences between kerangas habitat in the

Bawan forest and peat swamp in the Sebangau forest and a degree of the disturbance in each site.

Conclusions

Although that this study was conducted for only a short period, the number of species and individuals found in the Sebangau forest showed clear differences in each site. However, it is difficult to assess how the disturbance of primary forest can affect species diversity because Bornean frogs have complex ecological adaptations (Meijaard *et al.* 2005). Generally, the results showed that more intensively disturbed habitats, including a canal, logged gaps or regenerating burnt areas, compared to mixed peat swamp forest area, had a lower the anuran species richness and abundance. It may be concluded that logging, fires and wetlands drainage in tropical forests may negatively affect anurans distribution and cause their decline (Porter, 2010).

A study of amphibians should be conducted in different seasons throughout the year. It is known that the behavior of amphibians is depended on rainfall and temperature (Inger 2003). Anurans can call and breed at the beginning of a rainy period or over a whole season. It is suggested that surveys of amphibians that are conducted to assess their richness and abundance in any tropical area, should be carried out at differing times in order to cover the variation in their activity (Inger, 2003).

An estimation of accurate anurans abundance is difficult to achieve because of their life patterns. Many species live underground for the greater part of their lives. Besides this, they do not have high food requirements and can be visible when weather conditions are optimal (Sutherland, 2006). This study was carried out only for a few weeks during the same season and this factor may have influenced the results. It is necessary to continue amphibian studies over many weeks and months.

Long term studies would be able to assess anuran decline or an increase in species diversity and abundance. Additionally, such a study would show the beginning of anurans decline in disturbed primary forests or the beginning of recovery of secondary forests (Porter, 2010).

The methods of a Visual Encounter Survey and an Active Survey used during this study, are simple and not expensive but may be labour intensive (Rodel & Ernst, 2004). It is considered that transect sampling, combined with other methods, including trapping, drift fencing or mark- recapture, could be the best solution to amphibian studies (Sutherland, 2006). Another study showed that the combination of Visual Encounter Survey (VES) and quadrates can be the most suitable in rainforest environments (Doan, 2003). However, these methods are not efficient in a peat swamp download rainforest which is flooded most of the time. The transect method, moreover, seems to be the least invasive for anurans. Despite of the fact that the transect method, supported by mark –recapturing, is considered the optimal sampling method (Sutherland, 2006), for ethical reasons, toe clipping of anurans was not included during studies. It is claimed that toe-clipping methods can reduce frog survival rates (May, 2004). In terms of amphibian decline, the trapping method could be useful to assess reasons for a decrease in the population of amphibians in different habitats, including the infectious diseases or abnormalities of the limbs of anurans (Porter, 2010). Furthermore, Visual and Acoustic Encounter Surveys combined with opportunistic trapping and transect surveys, for long term studies, were recommended in tropical habitats (Rodel & Ernst, 2004).

It is recommended to conduct further long term studies for amphibians, and may be desirable to study relationships between leaf litter arthropods and life patterns of leaf anurans, in the increased abundance of some anurans species in selective logged forests, or changes in abundance of species of insects, caused by habitat (Meijaard et al 2005).

Amphibians can be potentially good ecological indicators in biological ecosystems. They have thin, semi-permeable skin and complex life cycles making them sensitive to any changes in habitat and environmental stress. Herpetological monitoring may assess the quality of the environment or assess the effects of restoration of ecosystems (Hardin, 2006). Amphibians are abundant locally and their survey may be low cost (Heyer et al. 1994). These vertebrate probably may be good indicators of the aquatic (reproduction) and terrestrial (feeding, dispersal) habitats (Hardin, 2006).

Furthermore, more studies are needed to investigate relationships between the particular stress and its effects on the amphibians (Pechmann & Wilbur, 1994). While the IUCN Red List of Threatened Animals in 2000 did not listed any Indonesian amphibian species, the 2006 Red List of Threatened Species listed 39 threatened amphibians (IUCN 2006). It is necessary to understand more about habitat destruction or El Niño Southern Oscillation (ENSO) events influence population size in amphibians. For instance Iskandar (1999) have pointed out that fires in 1998 in Kalimantan have caused the disturbances in amphibian reproductive cycles. Indonesia has been logging intensively for the last few decades and it is still not known in what degree amphibians can adopt to changes in their natural habitats. In Kalimantan, amphibians that are endemic and occur in limited geographical ranges may become extinct.

The species richness of amphibians in Indonesia is probably one of the highest worldwide, however, studies of these vertebrates are really limited. It is important to take action to protect the herpetofauna in the face of degradation of the rainforests (Iskandar, 2006).

Evaluation of Project Success

- Weather conditions, such as rainfall or wind, obstructed searching in the study site.
- Sampling methods used in peat swamp forest need to be more studied and developed.
- Studying of abundance and richness of animals requires longer-time periods of survey. More intensive study of the relationships between environmental factors and diversity of anurans is needed.
- Amphibians were not surveyed in the higher part of vegetation including the canopy. Some microhabitats in the study site may be more studied, including interior pole, forest sedge and others.
- Unidentified calls of anurans probably underestimated the richness of anurans frogs.

Appendix A

Results include data from VES (in transect) and active survey in Sabangau forest

Interval (30min)	Number of individuals	New species
1	7	OCCLAE/LIMPAR/POLCOL/POLMAC
2	4	-
3	1	-
4	7	-
5	7	-
6	7	HYLBAR
7	3	-
8	2	-
9	1	-
10	1	-
11	1	-
12	3	-
13	1	-
14	2	-
15	1	-
Total	48	

Table1. Results include data from VES (in transect) and active survey in the peat swamp forest in Sabangau forest (HYLBAR- *Hylarana baramica*, LIMPAR- *Limnonectes paramacrodon*, POLCOL- *Polypedates colletti*, OCCLAE- *Occidozyga laevis*).

Interval (30min)	Number of individuals	New species
1	5	LIMPAR
2	1	-
3	1	-
4	3	PSESUB
5	1	-
6	1	-
Total	12	

Table 2.Results include data from VES (in transect) and active survey in a canal in Sabangau

forest (LIMPAR- *Limnonectes paramacrodon*, PSESUB- *Pseudobufo subasper*).

Interval (30min)	Number of individuals	New species
1	2	HYLBAR
2	3	OCCLAE
3	1	-
4	5	-
5	1	-
6	1	-
7	5	-
8	4	-
Total	22	

Table 3. Results include data from VES (in transect) and active survey in recently logged gaps in Sabangau forest (HYLBAR- *Hylarana baramica* , OCCLAE- *Occidozyga laevis*).

Interval (30min)	Number of individuals	New species
1	1	INGQUA
2	2	HYLBAR
3	2	-
4	1	-
5	1	-
Total	7	

Table 4. Results include data from VES (in transect) and active survey in recently logged gaps in Sabangau forest (HYLBAR- *Hylarana baramica*, INGQUA- *Ingerophrynus quadriporcatus*).

Appendix B

Relative abundance of anurans in Sabangau forest

Transect	Distance	Time	Person number	Person hours	Number of individuals HYLBAR	Relative abundance HYLBAR
9-9-10	500	1.1166	3	3.35	0	0
10-9-10	500	1.1833	3	3.55	1	0.28
11-9-10	500	1.2666	2	2.53	1	0.39
13-09-10	500	0.8333	3	2.65	0	0
15-09-10	500	0.85	4	3.4	3	0.88
17-09-10	500	0.8333	3	2.5	8	3.2
20-09-10	500	1.6166	3	4.85	0	0
1-10-10	500	0.7333	3	2.2	3	1.36
Total					16	6.11

Number of individuals LIMPAR	Relative abundance LIMPAR	Number of individuals POLCOL	Relative abundance POLCOL	Number of individuals OCCLAE	Relative abundance OCCLAE
0	0	1	0.27	2	0.59
1	0.28	0	0	4	1.13
0	0	1	0.39	1	0.39
0	0	2	0.75	7	2.64
2	0.59	3	0.88	1	0.29
0	0	0	0	0	0
2	0.41	0	0	2	0.41
1	0.45	1	0	0	0
6	1.73	8	2.29	17	5.45

Table 5. Relative abundance of anurans in the peat swamp forest in Sabangau forest

(HYLBAR- *Hylarana baramica* ,LIMPAR- *Limnonectes paramacrodon*, POLCOL- *Polypedates colletti*, OCCLAE- *Occidozyga laevis*).

Transect	Distance	Time	Person number	Person hours	Number of individuals HYLBAR	Relative abundance HYLBAR	Number of individuals OCCLAE	Relative abundance OCCLAE
30-9-10	275	1.1166	3	3.35	0	0	0	0
11-9-10	275	1.1833	2	3.55	0	0	0	0
Total					0	0	0	0

Number of individuals LIMPAR	Relative abundance LIMOAR	Number of individuals POLCOL	Relative abundance POLCOL	Number of individuals PSESUB	Relative abundance PSESUB
5	3.22	0	0	0	0
2	1.5	0	0	1	0.75
7	4.72	0	0	1	0.75

Table 6. Relative abundance of anurans in a canal in Sabangau forest (HYLBAR- *Hylarana baramica* ,LIMPAR- *Limnonectes paramacrodon*, POLCOL- *Polypedates colletti*, OCCLAE- *Occidozyga laevis*, PSESUB- *Pseudobufo subasper*).

Transect	Distance	Time	Person number	Person hours	Number of individuals HYLBAR	Relative abundance HYLBAR
28-9-10	580	0.8666	3	2.6	0	0
04-10-10	580	0.48333	3	1.45	2	1.38
Total					2	1.38

Number of individuals LIMPAR	Relative abundance LIMOAR	Number of individuals POLCOL	Relative abundance POLCOL	Number of individuals OCCLAE	Relative abundance OCCLAE
0	0	1	0.27	1	0.38
1	0.28	0	0	4	2.75
1	0.28	1	0.27	5	3.13

Table 7. Relative abundance of anurans in regenerating burnt area habitat in Sabangau forest (HYLBAR- *Hylarana baramica* ,LIMPAR- *Limnonectes paramacrodon*, POLCOL- *Polypedates colletti*, OCCLAE- *Occidozyga laevis*).

Transect	Distance	Time	Person number	Person hours	Number of individual s HYLBAR	Relative abundance HYLBAR
29-9-10	100	0.8666	3	2.6	1	0.38
6-9-10	100	0.4833	2	0.966	0	0
Total					1	0.38

Number of individuals LIMPAR	Relative abundance LIMOAR	Number of individuals POLCOL	Relative abundance POLCOL	Number of individuals OCCLAE	Relative abundance OCCLAE
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Table 8. Relative abundance of anurans in recently logged gaps in Sabangau forest (HYLBAR- *Hylarana baramica* ,LIMPAR- *Limnonectes paramacrodon*, POLCOL- *Polypedates colletti*, OCCLAE- *Occidozyga laevis*).

Appendix C

Shannon- Wiener diversity and evenness index for anuran species in Sebangau forest

Shannon- Wiener diversity and evenness index for anuran species in the mixed peat swamp in Sabangau forest.

species	hylbar	limpar	occidozyg	polcolleti	polmar	
npop.size	1	3	16	12	1	
pi	0.03	0.09	0.48	0.36	0.007	
lnpi	-3.50656	-2.40795	-0.73397	-1.02165	-4.96185	
pixlnpi	-0.1052	-0.21672	-0.35231	-0.36779	-0.03473	-1.07674
						D=1.07674

Shannon-Weaver Information Function –

$D = -\Sigma p_i \ln p_i$

Species

Diversity(S) = 5

N=33

D = -Σ pi ln pi= 1.08

Species Evenness

$E = e^D/s$

e = 2.7 (= constant), D = the value of the Shannon-Weaver

b. and s = number of species in sample (= simple species diversity).

E=2.7*1.08/5=0.584

Shannon- Wiener diversity and evenness index for anuran species in a canal in the secondary peat swamp forest in Sabangau forest.

species	LIMPAR	PSESUB	TOTAL
npop.size	11	1	12
pi	0.92	0.08	
lnpi	-0.08338	-2.52572864	
pixlnpi	-0.07671	-0.20205829	-0.27877
			D= 0.28

$D = -\Sigma\, p_i \ln p_i$ *Shannon-Weaver Information Function –*
Species Diversity
(S=2
N=12

Species Evenness

$E = e^D/s$
: e = 2.7 (= constant), D = the value of the Shannon-Weaver
b. and s = number of species in sample (= simple species diversity).

E=2.7*0.28/2=0.66

Shannon- Wiener diversity and evenness index for anuran species in a regenerating burnt area in Sabangau forest.

species	hylbar	occlaevis	total
npop.size	13	9	22
pi	0.59	0.41	
lnpi	-0.52763	-0.8916	
pixlnpi	-0.3113	-0.36556	-0.67686
			D=0.68

$D = -\Sigma\ p_i \ln p_i$ *Shannon-Weaver Information Function –*
Species Diversity (S) =2
N=22

Species Evenness

$E = e^D/s$
: e = 2.7 (= constant), D = the value of the Shannon-Weaver
b. and s = number of species in sample (= simple species diversity).

E=2.7*0.68/2=0.98

Shannon- Wiener diversity and evenness index for anuran species in recently logged gaps in Sabangau forest.

species	hylbar	ingqua	total
npop.size	6	1	7
pi	0.86	0.14	
lnpi	-0.15082	-1.96611	
pixlnpi	-0.25942	-0.27526	-0.53467
			D= 0.53

$D = -\Sigma\ p_i \ln p_i$ *Shannon-Weaver Information Function –*
Species Diversity (S)
N=2

Species Evenness

$E = e^D/s$
: e = 2.7 (= constant), D = the value of the Shannon-Weaver
b. and s = number of species in sample (= simple species diversity).

E=2.7*0.53/2=0.234

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