BUTTERFLIES OF VERDE SUMACO, ECUADOR DURING LATE DECEMBER 2018

by

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ABSTRACT

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Key Words: Lepidoptera, Verde Sumaco, species richness, site types, Nymphalidae, Riodinidae, Uraniidae, Erebidae, Lycaenidae, Hesperiidae, Pieridae, Geometridae, Papilionidae.

This thesis explores the different Lepidopteran species that were found around the community of Verde Sumaco, Ecuador, in December of 2018. The objective of this thesis was to determine if there is a difference in Lepidoptera species richness within five different site types: chakra, river edge, trail, secondary forest, and open field. Species were photographed in 30-minute intervals and various sites within the site types over five days. The most significant result was that the chakra site type did not have any Lepidopteran species while the open field site type had the most. Another significant finding was that the area around the community had some Lepidopteran species that are usually only found within old-growth forests. More work should be done to obtain a more accurate representation of the Lepidopteran species found within the community over a longer time.

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1.0 INTRODUCTION

The Amazon rainforest is located in South America and covers most of the northern half of the continent. The Amazon basin is home to 10% of the world's known biodiversity (World Wildlife Fund 2019). The intricate levels of the forest structure account for the Amazon's high levels of biodiversity. The different abiotic and biotic factors create microhabitats which contain diverse assemblages of organisms adapted to each specific condition (Schulze et. al. 2001).

Several forms of natural disturbance occur within the rainforest, which includes fire, drought, and storms (Butler 2012). Of these disturbances, fire has changed from a natural disturbance to an anthropogenic disturbance, one that has been highlighted in the media recently (Gibbens 2019). Other significant human disturbances to the Amazon rainforest are deforestation, mining, and oil extraction. Ecuador is one of the countries located within the Amazon, and it depends on the extraction of oil to drive its economy.

Ecuador is believed to be the country with the highest biodiversity in the world (Dangles et. al. 2009). Two of the eight ecoregions in Ecuador are part of the Amazon rainforest, and they make up 40% of Ecuador's landmass (Dangles et. al. 2009). Ecuador has one of the highest deforestation rates in Latin America due to the increase in oil extraction and human expansion (Mosandl et. al. 2008). The oil industry began in the 1920s and now represents 40% of Ecuador's GDP and generates 80% of its exports (UN-REDD 2011). This rapid extraction of oil has left Ecuador susceptible to climate change.

It has been widely documented that insect populations have been declining due to climate change. Studies done in Germany have shown a decline of up to 76% of airborne insect biomass in 27 years (Hallmann et. al. 2017). Entomology has been neglected in Ecuador, with the main focus of any studies on economically important species (Dangles et. al. 2009). With Ecuador being a biodiversity hotspot, it is crucial to understand what insect species occur there as research is lacking. Lepidoptera are an easy insect order to recognize and are beloved by many. For example, Ecuador has approximately 4,000 species of butterflies (Checa et. al. 2009). Butterflies have been suggested as useful indicators for ecological changes within their environment as they are sensitive to such changes (Whitworth 2018).

Verde Sumaco is a small community of Kichwa people situated next to Sumaco Napo-Galera National Park, and is located within the Amazon rainforest in Ecuador. The people of this community use agroforestry as their primary source of food and conduct selective logging to harvest trees from the surrounding forest. Their concept of community includes the people, plants, animals, ecosystems, forces and spirits who live in the territory, and all of their interactions (Coq-Huelva et. al. 2017). The size of the community, their way of life, their proximity to a protected national park, and lack of documented insect species make Verde Sumaco an ideal location to study Lepidoptera species.

1.1 Objective

The objective of this thesis was to determine what species of Lepidoptera are found within the community of Verde Sumaco, Ecuador. By learning what species are found, it can be determined how the community's impact towards the environment has affected Lepidopteran species. The data collected could also assist in deciding which sites and times of day are more diverse regarding Lepidopteran species diversity.

1.2 Hypothesis

There are no significant differences in Lepidopteran species between the different sites in Verde Sumaco, Ecuador.

2.0 LITERATURE REVIEW

The Amazon rainforest is one of the most diverse areas on Earth for flora and fauna. It is continuously threatened by disturbance. Ecuador has had minimal research in entomology and other sciences due to lack of funding from the government. Ecuador is also one of the global biodiversity hotspots and has many different ecotypes, including the Amazon rainforest. Lepidoptera species are known to be the most diverse in equatorial regions. Lepidoptera are one of the most identifiable orders of insects and can be used as indicators for habitat health.

2.1 Amazon Rainforest

The Amazon rainforest is the largest area of continuous forest on Earth and its basin spans across the northern half of South America (Franca 2012). The Amazon basin covers 40% of South America and includes several countries such as Ecuador, Brazil, and Peru (World Wildlife Fund 2019). The Amazon, with half of the Earth's remaining tropical rainforests, has over 6,500 km of rivers and 566 million hectares of forest (World Wildlife Fund 2019). It stores about 90 billion to 120 billion metric tons of carbon, delivers 18% of the freshwater flowing into the oceans, and dissipates solar heat from Earth's surface to the atmosphere through evaporation and cloud condensation (Blaustein 2011). The dry season extends from late August to January, with December being the driest month of the year (Wesche et. al. 1999). The rainy season peaks during

June and July (Wesche et. al. 1999). The topography of the Amazon is continually changing from century to century, which results in higher levels of biodiversity (Colinvaux 1989). The Amazon is home to 30 million animal species (Colinvaux 1989), and there are around 2.5 million different insect species that can be located within the rainforest (National Geographic 2019).

2.1.1 Diversity

The Amazon rainforest has at least 10% of the world's known biodiversity, which includes endemic and endangered flora and fauna (World Wildlife Fund 2019). It was once believed that the diversity of the Amazon was a product of an ever-lasting stable climate of abundant rain and warmth (Laurance 2001). This theory has been disproven by evidence showing that the Amazon is subject to climate change on all time scales, which include glaciations (Colinvaux 1989). There are two hypotheses that suggest how the Amazon became as diverse as it is: The first is the refuge hypothesis which suggests that, during the glaciations, lowlands became drier than uplands, creating "islands" of upland regions that were more suitable habitats (Colinvaux 1989). The second is the intermediate-disturbance hypothesis which suggests that the highest species richness is found in areas where the environmental disturbance is frequent but not excessive (Colinvaux 1989).

The Amazon rainforest has a complex forest structure that can also account for the its high levels of biodiversity. The vertical structure of tropical rainforests can be described as having distinct vegetation layers (strata) which gradually modulate specific biotic and abiotic parameters (Schulze et. al. 2001). The biotic parameters that the forest structure affects are floristic composition, leaf area, biomass density, and species diversity. In contrast, the abiotic parameters are temperature, wind speed, and insolation, as well as many others (Schulze et. al. 2001). These parameters result in a high diversity of different microhabitats which contain diverse assemblages and communities of organisms adapted to those specific conditions (Schulze et. al. 2001).

2.1.2 Disturbance

Many natural forms of disturbance can affect the Amazon rainforest, including fire, drought, and storms (Nelson 2009). Volcanic eruptions may also level significant expanses of forest (Butler 2012). Volcanoes are found along the western range of the Amazon rainforest and are only a disturbance in those areas. A volcanic eruption can create a cloud of carbon dioxide that hangs low over the forest, killing many animal species (Butler 2012). Storms are the dominant type of disturbance in the Amazon and can create tree fall gaps (López et. al. 2018). These tree fall gaps are essential for the regeneration of the forest. Drought is another natural disturbance in the Amazon due to the cyclical effects of El Niño (Butler 2012). They are also a precursor to fire disturbance.

A forest is most susceptible to fire during periods of drought, and they are usually started by lightning or humans (Sanford et. al. 1985). During these fires, ground vegetation is often eradicated while the larger canopy species are spared (Butler 2012). Although fire is a natural disturbance, human impact has created fires that burn much larger areas. During 2019, Brazil's National Institute for Space Research reported an 80% increase in fires since 2018 with the summer of 2019, clearing more forest than the past three years combined (Gibbens 2019). The fires spreading across Brazil have become a hot topic in social media with a demand for change in deforestation policies in Brazil. Deforestation driven fires have also become an increasing concern for conservationists.

It has been estimated that 750,000 km^2 of the Amazon rainforest has been deforested since 1978 (Butler 2019). It has been on the rise due to an increase in government incentives towards industrial conversion, the scaling-up of private sector finance to make up for a growing interest in emerging markets, and the surging of commodities like beef, soy, sugar, and palm oil (Boucher at. al. 2011). Forest loss in Amazon countries varies but has been on the incline with all countries located in the Amazon basin (Butler 2019). Cattle ranching is the leading cause of human-made disturbance in the Amazon rainforest and contributes up to 80% of deforestation in countries like Brazil (Boucher et. al. 2011).

Another significant disturbance caused by human impact is mining and oil extraction. The main minerals that can be extracted from mining in the Amazon are copper, tin, nickel, bauxite, manganese, iron ore and gold (World Wildlife Fund 2019). Mining can have similar impacts on deforestation, but it creates higher levels of pollution and encroachment on indigenous lands (World Wildlife Fund 2019). For example, a pollutant used in gold extraction is mercury which is toxic and affects local communities (World Wildlife Fund 2019). Oil extraction can also lead to deforestation of the Amazon and result in the release of toxic by-products into rivers by broken pipelines (Southgate et. al. 2009). The Western Amazon, especially Ecuador, is where most oil extraction takes place (Southgate et. al. 2009).

2.2 Ecuador

Ecuador is one of nine countries within the Amazon basin. It is located between Brazil, Columbia, Peru, and borders the Pacific Ocean. Ecuador has an area of 283,560 km^2 (MacLeod et. al. 2020). Located down the centre of Ecuador are the Andes mountains. Recent studies have shown that the Andes uplift was separated by relatively long periods of stability (tens of millions of years) and rapid changes of 1.5 km or more in short periods (1 to 4 million years) (Dangles et. al. 2009). This rapid change allowed for the creation of new climatic and environmental niches in relatively short periods which is one of the reasons why Ecuador has the highest biodiversity in the world (Dangles et. al. 2009). Ecuador is home to 17.9% of bird species, 10% of vascular plants, 8% of mammals and 10% of amphibians worldwide (UN-REDD 2011). Many of these species are considered to be endemic and endangered (UN-REDD 2011).

There are eight ecoregions in Ecuador and consist of Ecuadorian western moist forests, Ecuadorian dry forests, South American Pacific mangroves, Guayaquil flooded grasslands, Northwestern Andean montane forests, Northern Andean paramo, Eastern Cordillera real montane forests and the Napo moist forests (Breure et. al. 2016). The last two ecoregions are part of the Amazon basin.

2.2.1 Amazon Rainforest in Ecuador

40% of Ecuador is a part of the Amazon rainforest (Dangles et. al. 2009). The Amazonia region of Ecuador gradually descends Eastward from the foothills of the Andes to an altitude of 100-600 metres above sea level (Jacobsen et. al. 1997). The mean precipitation amount is approximately 2820 mm a year with no month receiving less than 100 mm of rain (Dangles et. al. 2009). Temperatures in this region range from 22°C to 32°C (Dangles et. al. 2009). The biogeographic region of the Ecuadorian Amazon is evergreen lowland wet forest and has a canopy of 15-30 m tall trees with some emergent trees reaching 50 m in height (Dangles et. al. 2009).

2.2.2 Deforestation in Ecuador

Ecuador has approximately 10 million hectares of diverse forest types covering about 55% of the country (UN-REDD 2011). Data collected in 2000 estimated that 198,000 ha of forest are lost every year, but more recent research from the Ministry of Environment estimates that deforestation is around 61,764.50 ha/ year (UN-REDD 2011). Ecuador has the highest rates of deforestation in South America (Mosandl et. al. 2008). Human impacts from oil and gas companies created roads which allowed for the extensive colonialization and deforestation of the rainforest (Dangles et. al. 2009).

Ecuador's economy is based on raw material production and export from its natural resources (UN-REDD 2011). Extractive sectors, mostly the oil industry, agriculture, fisheries, aquaculture, and forestry, represent 40% of their GDP and generate 80% of its exports (UN-REDD 2011). The forestry industry has grown 48% between 1997 and 2006, with its contribution to the economy being stable every year (UN-REDD 2011). The forestry sector of Ecuador includes two main areas which are forestry and logging, and timber production and wood product manufacturing (Mosandl et. al. 2008). There are other contributions from the forestry industry which can be incorporated into other sectors (tourism, agriculture or industry) and into resources that cannot be quantified (water sources, biodiversity, and carbon sequestration) (UN-REDD 2011). With how vital forestry is to the economy, the objectives of forestry have been shifting from maximum production to a broader perspective that includes biodiversity preservation and ecosystem functioning (López et. al. 2018).

2.2.3 Mining in Ecuador

Oil extraction began in the early 1920s, with a significant increase in production since the 1970s after the discovery of a prosperous oil field beneath the Amazon rainforest (Widener 2007). Ecuador produces about 500,000 barrels of oil per day with the vast majority coming from the northern Amazon provinces of Napo, Sucumbios, and Orellana (Lessmann et. al. 2016). Oil production is the primary source of income for Ecuador and makes up 38.7% of government revenues, 58% of exports, and 11.3% of the GDP (Lessmann et. al. 2016). Contracts for the exploitation of oil fields are called blocks and can be up to 200,000 ha, and Ecuador currently has 35 blocks in just the Amazon (Lessmann et. al. 2016). These blocks overlap protected areas and ancestral or titled lands of indigenous groups (Lessmann et. al. 2016). Only 16% of the Ecuadorian Amazon is covered by portions of protected and free of oil extraction (Lessmann et. al. 2016).

Oil mining can have devastating impacts on the environment. 630,000 ha of conservation agreements have been made in Ecuador, but these are continually being threatened by illegal mining activity or loopholes in the government system (UN-REDD 2011). Between 1994 and 2001, 29,000 crude oil barrels were spilt across the Ecuadorian Amazon and over 7,000 of those barrels were never recovered from the environment (Lessmann et. al. 2016). Wastes from oil mining companies are frequently dumped into open ponds which directly discharge into the environment (Widener 2007). Unfortunately, species diversity in Ecuador peaks in ecosystems that coincide with many of the oil blocks across Ecuador's Amazon (Lessmann et. al. 2016).

2.2.4 Legislation in Ecuador

The Ministry of Environment (MAE) is the main body of the government in Ecuador that handles environmental issues (UN-REDD 2011). MAE's National Directorate of Biodiversity contributes to the country's sustainable development through biodiversity conservation and the sustainable use of its components (UN-REDD 2011). The directorate has a responsibility to propose policies and strategies for biodiversity management and to manage the implementation of procedures related to biodiversity (UN-REDD 2011). The Socio Bosque Program was developed by the government to reverse forest loss in Ecuador by making deforestation rate a priority (UN-REDD 2011). This program seeks to complement many of the policies historically made in Ecuador's forestry sector in an effort to reconcile forest conservation with forest development (UN-REDD 2011).

2.3 Climate Change

The Amazon rainforest is vulnerable to climate change, especially with the exponential growth of human disturbance over the last fifty years. Much of the Amazon is at risk of dieback due to greenhouse gas emissions, land-use stresses, and climate change (Nobre et. al. 2016). Amazon dieback is described as the transmutation to savanna or other less biodiverse ecosystems from their original landscape (Blaustein 2011). The Amazon's tipping point has also come into consideration as it is the point reached when enough tropical biomass is lost, causing large areas of the Amazon to shift irreversibly to biologically impoverished biomes (Blaustein 2011). Due to this loss of forest, the Amazon's stored carbon could be released, causing declining stability of Earth's biosphere (Blaustein 2011). It has been shown that the Northwest parts of the

Amazon that are located in countries such as Ecuador have shown signs of resiliency towards dieback if conserved (Blaustein 2011). There are a few conservation efforts that can help reduce human disturbance in the Amazon and in turn reduce the risk of climate change.

2.3.1 Conservation

Climatologists have predicted that the atmospheric composition of the Amazon in the 21st century will result in temperature increases up to 3°C and a reduction in precipitation by 20% (Malhado et. al. 2010). This increase in temperature and decrease in precipitation will lead to Amazon dieback. With the increasing threat of climate change, conservationists have been challenged to design effective biodiversity conservation strategies in economically impoverished but biologically rich areas (Malhado et. al. 2010). Most conservation project areas are restricted to two types of groups: those who allow human presence and those who do not (Franca 2012). It is hard to manage project areas where humans are not allowed and by working with communities close to these areas, more land can be protected.

More and more projects are focusing on areas that can provide economic incentives designed to provide benefits for local communities and make them partners in saving species and wildlands (Bookbinder et al. 1998). Two conditions must be met; however, for the successful integration of biodiversity conservation. The first condition is the identification of economic incentives that provide immediate benefits to local people (Bookbinder et. al. 1998). The second incentive is the identification of financial incentives that are appropriate in space and time to the scale of threats to biodiversity (Bookbinder et. al. 1998). Two examples of projects that can have economic incentives are agroforestry and ecotourism.

2.3.1.1 Agroforestry

Agroforestry creates agriculturally productive systems while mimicking the biological structures of forest ecosystems (Schroeder 1993). These systems generate stability in degraded landscapes in many different ways which are deemed essential for ecosystems to repair themselves. They include enhancing an ecosystems ability to mitigate other areas of importance to ecological restoration and climate change, and necessary to design ecological restoration with the intent of managing the effects of climate change (Slobodian 2016). The integration of these productive systems within intact forested landscapes provides incentives to manage these ecosystems effectively and in a healthier manner (Slobodian 2016). The degree to which landscapes facilitate or impede movement among resource patches is fundamental for the conservation of isolated forest populations (Francesconi et. al. 2013). The biodiversity-friendly agroforestry practices have been suggested as a land-use alternative to keep the land under protection while maintaining many ecosystem services (Francesconi et. al. 2013).

In Ecuador, these agroforestry plots are called chakras. They can limit the territorial expansion of agriculture and have high levels of biodiversity (Schroeder 1993). Chakras are constructed in a way that can show how agricultural exploration and maintenance of high levels of biodiversity are compatible (Coq-Huelva et. al. 2017). In one study, the average percentage of primary or secondary forest within these chakras was always higher than 40% with an average farm being 16.7 hectares (Coq-Huelva et. al. 2017). Chakras allow for farmers to reduce the number of degraded soils and drought that usually come with farming and these agroforestry plots can create microclimates, increase soil fertility, and conserve water (Slobodian 2016).

Agroforestry still has its flaws. These sites cannot replace natural habitats as their role in species conservation depends on the presence of protected natural areas in the landscape (Francesconi et. al. 2013). If no protected areas are surrounding these agroforestry areas, they will not be able to reproduce the biodiversity found in protected habitats. Agroforestry sites must be near the primary forest to allow for optimal species conservation. If sites are not, it will lead to the overall decline of species in the landscape (Francesconi et. al. 2013).

2.3.1.2 Ecotourism

Ecotourism is another way of conservation that can create economic incentives for communities. It is defined as the responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education (International Ecotourism Society 2019). Community-based ecotourism is a new strategy for indigenous communities that moves towards a self-reliance source of income (Neth 2008). It can create more job opportunities within communities with a focus on conservation of the lands they already own. This form of ecotourism arose as a reaction to the encroachment of the mainstream ecotourism industry and hopes to capture a larger and more predictable share of the tourism dollar while limiting the negative social and cultural impacts of tourist visits (Wesche et. al. 1999). There are several advantages of community-based ecotourism and include being a viable commercial development option which is environmentally sustainable, helping advance indigenous land rights and environmental alliances, and help to contribute to strengthening indigenous culture and pride (Neth 2008). For ecotourism to succeed, a viable amount of revenue must return to the local communities to foster stewardship and to change local practices so that biologically valuable habitats, populations, and ecological processes are conserved (Bookbinder et. al. 1998).

Even though ecotourism can provide a stable source of income for communities while promoting biodiversity, there can still be negative impacts on all parties involved. Some studies have shown that the economic benefits for indigenous communities have been limited and unpredictable as entrepreneurs change priorities and destinations (Wesche et. al. 1999). It has also been found that in some communities, the employment potential of ecotourism is low and direct economic impact of ecotourism on household income is marginal (Bookbinder et. al. 1998). Some other side effects of ecotourism are damages to native flora and fauna, indigenous cultures, and various ecological assets (Isaacs 2000). Protection of wildlife resources using ecotourism requires informed choices regarding the impact and consequences of human activities on the environment (Isaacs 2000). If ecotourism is done right, making informed decisions on the effects it can have and the ways to mitigate them, it can be beneficial to communities.

2.4 Butterflies

Butterflies are one of the more easily identifiable insect orders. They are part of the order Lepidoptera which consists of both butterflies and moths. They are part of the second largest order in the class Insecta (Meyer 2016). The Lepidoptera order emerged during the Cretaceous period, developing parallel with flowering plants (New 2012). Fossil records are sparse with only 600-700 known specimens which are mostly in amber (New 2012). Coevolution with angiosperms helped found two of the significant ecological roles associated with modern Lepidoptera, which include being pollinators and an essential group of defoliators (Labandeira et. al. 1994). Lepidoptera larvae are called caterpillars and are mostly herbivorous (Academy of Natural Sciences 2018). Like most insects, adults have six legs, three body segments, wings, and antennae (Royal Entomological Society 2019). Adult Lepidoptera are different than other insects because they have large, scaled wings which create distinctive colour patterns that play an essential role in courtship and intraspecific recognition (Meyer 2016). Most adults have a proboscis that is used for feeding (Academy of Natural Sciences 2018).

The difference between moths and butterflies is mostly artificial, as they are very similar (Library of Congress 2020). Most butterflies are diurnal, brightly coloured, and have knobs or hooks at the end of the antennae (Library of Congress 2020). At rest, a butterfly's wings are held vertically over the body (Meyer 2016). Moths are mostly nocturnal, have a duller colouration of the wings, and have thread-like, spindle-like, or comb-like antennae (Meyer 2016). At rest, a moth's wings are held horizontally against the substrate, folded flat over the back, or curled around the body (Meyer 2016).

2.4.1 Tropical Rainforest Butterflies

The world's greatest diversity of butterflies and moths can be found in tropical rainforests; therefore, there are more butterflies closer to the equator (Matisoff et. al. 2008). Tropical rainforests are home to this high diversity of Lepidoptera for many reasons such as that over the past 100 million years lands near the equator remained undisturbed by sea-level change, climate change, or glaciations (Matisoff et. al. 2008). Contrasting rainfall and temperature during different seasons in tropical rainforests have led to butterfly species evolving seasonal dormancy, diapause, and seasonal reproduction (Grotan et. al. 2012). Seasonal fluctuations have also created significant differences in butterfly community compositions during the wet and dry seasons with the dry season having maximum species diversity (Grotan et. al. 2012). Tropical rainforests also have a wide range of microclimates through the different canopy layers of the forest and the diverse habitat types. Butterflies are highly selective species and are usually habitat-specific with their geographic range of distribution is relatively small (Spitzer et. al. 1997).

In a tropical rainforest, two types of forest canopies are usually studied regarding butterflies. The closed canopy forest, also called the climax or primary forest, is defined as a relatively stable and undisturbed plant community that has evolved through significant stages and adapted to its environment (Nix 2019). An open canopy forest, also called a canopy gap area or secondary forest, is an area that has gone through disturbance, whether it be natural or human. Several studies have shown that butterfly species that prefer an open canopy forest have larger, less restricted ranges than those that prefer a closed canopy forest (Willott et. al. 2000, Saikia et. al. 2009, Checa et. al. 2014). This pattern is due to open canopy forest being used by more opportunistic and cosmopolitan species of butterflies compared to closed canopy forests having more habitat specialist and endemic butterfly species (Saikia et. al. 2009).

2.4.1.1 Microclimates

Microclimates play an essential role in the high diversity and species richness found in tropical rainforests. Suitable microclimates are necessary for the survival and development of butterfly species by directly affecting diapause or larval growth, or indirectly affecting food availability (Checa et. al. 2014). At a butterfly community level, microclimate constraints may be critical in the evolution of life-history strategies and niche segregation, allowing diverse communities to persist (Checa et. al. 2014). Microclimate variables such as humidity, temperature and vegetation (canopy cover, vegetation density, and average tree diameter) are significant predictors of the structure and composition of butterfly communities (Checa et. al. 2014). A butterfly views the forest as a series of discontinuous patches of varying suitability which is relative to the butterfly's degree of specialization, acuity of perception, and speed of flight (Brown et. al. 1997). The patchiness of the specific microclimates that butterflies may prefer is due to the irregular distribution of essential resources such as light, heat, chemicals, food, mates, and shelter (Brown et. al. 1997). Species diversity and richness will be higher in microclimates where resources that are sought after are concentrated (Ribeiro et. al. 2008).

An open canopy forest creates an edge effect which is when light penetrates the understory, which promotes the growth of new plant tissue and increases microhabitat diversity and flower abundance (Brown et. al. 1997). A study conducted in 1997 has shown that the edge effect created by an open canopy forest may increase butterfly species recorded in a day by 50% (Brown et. al. 1997). Other studies have shown that neighbouring villages and large clearings on the forest edge, the diversity and species richness of butterfly communities is higher (Spitzer et. al. 1997). Selective logging, which promotes the edge effect, has 47% higher species richness than sites that are clear cut and can help in the conservation of tropical biodiversity (Whitworth et. al. 2016, Hamer et. al. 2003).

Food availability due to microclimates is something that also affects the diversity and species richness of butterflies in tropical rainforests. Fruit-feeding, flower-visiting, and carrion-feeding butterflies are the different types of butterflies that can be found in tropical rainforests. Flower-visiting butterfly species richness increases towards the top of the canopy, whereas fruit-feeding butterflies decrease in species richness towards the canopy (Schultze et. al. 2001). When using baited traps in tropical rainforests, traps baited with carrion have higher abundance and species richness (Whitworth 2018). The different microclimates can have a considerable impact on the diversity and species richness of butterflies found in tropical rainforests.

2.4.2 Monitoring and Sampling Methods

Monitoring biodiversity in tropical rainforests can be very difficult. It is not very easy because of tight budgets as well as short timeframes available for studies (Whitworth 2018). To study the biodiversity of an area, subset groups of taxa can be used as a biological indicator and are chosen due to their sensitivity to changes (Whitworth 2018). Butterflies are good indicators of biodiversity as they are quick to react to change, especially in temperate and tropical regions (Wood & Gillman 1998). One of the most difficult challenges in the analysis of species diversity of butterflies is that the number of species observed increases with sampling intensity (Grotan et. al. 2012). It is also important to note that long-term sampling of community dynamics can be used to test and predict ecological impacts of future climate change (Grotan et. al. 2012).

The first step to sampling and monitoring species is to prepare and plan (USDA 2000). Before a survey is conducted, one must ask themselves a series of questions: What are your objectives? What is the right monitoring technique? How does your plan fit into other monitoring efforts? What are your resources in money and personnel? What habitats are your subjects of study? Are there any sites undergoing succession or disturbance? (USDA 2000). The second step in sampling and monitoring species is site selection. The study site chosen must identify the types of habitats or range of conditions that correspond to monitoring goals, the use of photographs or other methods to identify a set of sites, and the conduction of field studies to determine detailed characteristics for the site chosen (USDA 2000). Regarding butterfly monitoring, one study has suggested following these guidelines. For butterflies, the focus of the study should include both natural and disturbed habitat, identify a subset of Lepidoptera that are good to study, concentrate on common, habitat-specific species, have an excellent biological knowledge of select taxa, control for light-gap size, combine sampling techniques to maximize field efforts, base sampling frequency on monitoring needs, and concentrate monitoring effort to seasonal peak (Sparrow et. al. 1994).

2.4.2.1 Mark and Recapture

One of the most common methods used for monitoring butterfly populations is mark and recapture. It is when butterflies are captured, marked, released, and recaptured many times by repeated sampling (Pradel 1996). Mark and recapture are one of the most rigorous methods of studying butterflies as it allows for the estimation of daily and total population sizes, recruitment, survival, and detection probabilities (Henry et. al. 2015). This method can be resource-intensive and have the potential to harm fragile butterflies in the marking process (Henry et. al. 2015).

2.4.2.2 Point Sampling

Point sampling is another common sampling technique that is used to monitor butterflies. The observer records a butterfly's ongoing activity during a pre-selected moment in time and it is a method used to study butterfly behaviours (Altmann 1984). If the behaviour of each butterfly is sampled successively within a short period, the record approaches a simultaneous sample of all individuals, which can be referred to as scan sampling (Altmann 1984).

A smaller type of point sampling is timed spot surveys. The observer stands at a predetermined point selected by habitat type and during a standard period, commonly 10 minutes, records all target insects seen within a known radius (New 2012). It allows for more intensive investigations in small areas and can be replicated as required (New 2012).

2.4.2.3 Butterfly Netting

Two methods, entomological hand nets and bait traps, are found to work best to sample tropical butterflies. Hand netting butterflies can collect more species compared to bait traps, but it can injure the butterflies (Checa et. al. 2019). Bait netting is used to measure butterflies found in different canopy layers which can be inaccessible and poorly sampled (Checa et. al. 2019). Butterflies feed on a variety of different foods, and various traps should be set for fruit and nectar-feeding butterflies and carrion-feeding butterflies (Checa et. al. 2019). Another benefit of using the bait nets is to simultaneously sample multiple locations at the same time (Checa et. al. 2019).

2.4.3 Butterfly Conservation

With how sensitive insects are to climate change, they must be appropriately monitored and studied. Conservation plays an essential role in the protection of insects that are under threat of population decline. Climate change will have negative impacts on the habitat's butterflies call home. One study has even estimated that the microclimate herbaceous layer that some butterflies depend on will cool down to the point of negatively impacting population dynamics (Wallisdevries et. al. 2006).

It is essential to think about how heterogeneous forests increase biodiversity when looking at conservation methods. Local, fragmented landscapes efficiently maintain populations of many small arthropods, including butterflies (Ribeiro et. al. 2008). These areas of habitat disturbance on biodiversity are still poorly understood and is due to the poor understanding of how species respond to natural variation in environmental conditions within the primary forest and how these conditions alter following anthropogenic disturbance (Hamer et. al. 2003). Undisturbed habitats must also be conserved for butterflies. Certain butterfly species are endemic to closed canopy forest and cannot survive in open canopy forest (Wood & Gillman 1998). Although species diversity may be higher in disturbed forests, it is because wide-ranging and generalist butterfly species make up the majority and replace specialist butterflies (Saikia et. al. 2009). Agroforestry plots can contribute to butterfly conservation in fragmented agricultural landscapes (Francesconi et. al. 2013). They create less logging in primary forests but create the edge effects that generalist butterfly species find to be prime habitat. Selective logging in these sites can recreate natural disturbance which promotes biodiversity, but they must be managed in a way that maintains environmental heterogeneity (Hamer et. al. 2003).

2.5 Area of Interest

2.5.1 Declining Insect Populations

Insects have been declining at an alarming rate, and with the limited knowledge of most insect species, it predicts the impacts of climate change difficult to measure. A famous study done in Germany in 2017 has shown that, in the protected areas studied, there had been a decline of 76% of airborne insect biomass in just 27 years (Hallmann et. al. 2017). More studies have also been conducted concerning insect population trends. They show that 33% of insects studied by the International Union for the Conservation of Nature (ICUN) have been declining (Dirzo et. al. 2014). Population declines are a prelude to species extinction with many indications of population declines and potential for high extinction risk in many groups of invertebrates (Collen et. al. 2012).

Insects play a vital role in the environment. The variety of processes that they are involved in include pollination, herbivory and detrivory, nutrient cycling, and providing a food source for higher trophic levels (Hallmann et. al. 2017). 80% of wild plants are estimated to depend on insects for pollination, and 60% of birds rely on insects as a food source (Hallmann et. al. 2017). Insect pollination is needed for 75% of the world's food crops, and they are estimated to be worth greater than 10% of the economic value of the entire world's food supply (Dirzo et. al. 2014). It is believed that climate change, habitat loss and fragmentation, and deterioration of habitat quality are the main reasons for insect population declines (Hallmann et. al. 2017).

2.5.2 Entomology in Ecuador

Entomology in Ecuador has been driven by research related to agriculture and the insects that can affect it (Barragán et. al. 2009). The vast diversity of insects in Ecuador is also relatively unknown (Dangles et. al. 2009). Limited national funding is one of the significant obstacles to the development of entomology, as well as other life science disciplines in Ecuador (Barragán et. al. 2009). Functional diversity of insects is considered to be an essential component of diversity, but little has been researched in Ecuador (Dangles et. al. 2009). Understanding the relationships between insect diversity and ecosystem functioning is crucial to predicting the impact of the ongoing decline in insect populations in Ecuador (Dangles et. al. 2009).

Ecuador has approximately 4,000 species of butterflies (Checa et. al. 2009). There are about 2,700 species of Papilionidae, 50-55% of all Neotropical butterfly species, and 25% of the world's species, making it one of the world's three most diverse countries, along with Colombia and Peru (Dangles et. al. 2009). Any given site from 3 to 10 km^2 in Ecuador is expected to contain 600 to 1,600 species of Lepidoptera (Brown et. al. 1997).

2.5.3 Verde Sumaco

The community of Verde Sumaco is located along the Paushiyacu River in the province of Orellana along the borders of Sumaco Napo-Galera National Park. Sumaco National Park is home to Sumaco mountain, which is part of a lower mountain range of cloud forest parallel to the Andes (Wesche et. al. 1999). Sumaco mountain is a dormant volcano that reaches up to 3,900 metres in elevation (Wesche et. al. 1999). Most of the forest surrounding Sumaco national park are primary forests while the forests surrounding the community are secondary forest. The coordinates of Verde Sumaco are 0º22'24.14"S 77º15'17.00"W. Figure 1 shows the location of Verde Sumaco. The main form of transportation to Verde Sumaco is by outboard-powered dugout canoes which traditionally were carved whole out of large trees.

Figure 1. Location of Verde Sumaco, Ecuador.
(https://simple.wikipedia.org/wiki/Template:Location_map_Ecuador)

The Ecuadorian Amazon is home to at least nine indigenous nationalities (Lessmann et. al. 2016). Verde Sumaco is part of the Kichwa nationality. Kichwa occupies the Northeastern part of Ecuador in the rainforest (Wesche et. al. 1999). The villages are of varying sizes, and each has a central headman or shaman (Wesche et. al. 1999). Their concept of community includes not only the people but the plants, animals, ecosystems, forces and spirits who live in the territory and all of their interactions (Coq-Huelva et. al. 2017). Kichwa systems of knowledge and value play an essential role in the way of understanding the farming and the relationship between man and nature and the landscape (Coq-Huelva et. al. 2017).

Kichwa people use chakras as one of their primary sources of food. Each family has a chakra ranging in size from a couple to several hectares. Their knowledge contains the handling practices of the chakras which have been proven to be successful in sustaining high biodiversity levels, erosion control, preservation of soil fertility, maintenance of chakras, and pest control (Coq-Huelva et. al. 2017). The community of Verde Sumaco is in the process of developing their ecotourism for a stable source of income. Several cabins, a kitchen, showers, and toilets have been built to accommodate large groups for their growing business called Tambo Caspi Lodge. The cabins were made less than three years ago, and several groups have used them since construction was finished. The community promotes studies and exploration with their ecotourism.

2.5.4 Why Study Butterflies?

Lepidoptera are easily identifiable and beloved by many people across the globe. Butterflies and moths are suggested to be useful as indicators of ecological change due to their sensitivity to changes in vegetation structure and composition (Bonebrake et. al. 2010). Butterflies have a short generation time that allows for responses to change to be quickly monitored and detected (Whitworth 2018). Taxonomy of butterflies is well studied and provides easy identification of species (Whitworth 2018). Larvae of Lepidoptera are dependent on specific host plants and any change to their population due to changes in the environment would be seen within a couple of years (Sparrow et. al. 1994).

Warming in the tropical Amazon rainforest may have deleterious consequences as tropical insects are sensitive to temperature change (Dangles et. al. 2009). Lepidoptera population decline is less severe than for other insect taxa, but it is still vital (Dirzo et. al. 2014). Lepidoptera species have their highest species diversity around the equator. Ecuador is one of the biodiversity hotspots of the world, which makes it an ideal location to study biodiversity, ecology and evolution of Lepidoptera species (Dangles et. al. 2009). There has been little research in Ecuador in entomology as species of economic importance are the only ones that have been consistently monitored (Barragán et. al. 2009). The potential impact of climate change on Ecuadorian fauna also has been poorly explored and restricted to groups such as mammals and amphibians (Dangles et. al. 2009).

The community of Verde Sumaco has not had any research conducted into the different Lepidopteran species that are found there. In the region, there have been only a few studies on butterflies, but Verde Sumaco is unique because it borders Sumaco National Park. Verde Sumaco has a minimal impact on the forest surrounding it. Understanding how different types of butterflies are found in various areas will help to understand the impact the community is having on the forest. In terms of ecotourism, Lepidoptera is one of the most recognizable insect orders. With a look into the types of species that can be found in the community, it can help with expanding their eco-tourism industry.

3.0 MATERIALS AND METHODS

3.1 Subject of Study

The subject of the study consists of the Lepidopteran species found during the day in Verde Sumaco, Ecuador. The study was carried out over several days during late December of 2018 from midmorning to early afternoon. The area around Verde Sumaco has had little research regarding Lepidoptera species. The community's impact on the surrounding forest creates an ideal opportunity to study butterflies in many different eco sites. These sites include secondary forest, open fields, chakras, trails, and river edges. See Figure 3 for the area of study.

3.2 Sampling Methods

Entomological hand nets and bait traps are considered one of the best ways to sample tropical butterflies. Bait nets are used to measure butterflies found in different canopy layers (Checa et. al. 2019). Another benefit of bait netting is that multiple sites can be simultaneously measured (Checa et. al. 2019). Butterflies feed on a variety of different foods, and bait nets should be baited with a variety of different foods. Some examples of baits used in this study are chicken faeces and fermented bananas. Four nets were purchased from Bioquip.com.

Timed spot surveys are another method of sampling butterflies because it is less invasive than bait netting. The observer stands at a predetermined point selected by habitat type and records all target insects within a known radius (New 2012). This type of sampling allows for intensive investigations of small areas that can be easily replicated (New 2012). A camera is an excellent way to capture a photo of the butterfly for later identification. This method was used if bait nets did not work.

3.3 Site Types

The secondary forest was chosen as a sampling site because it is a forest that has grown back after a disturbance. These sites are good indicators for a forest's biodiversity and how the forest is responding to change. Trails are the sites with the most human disturbance. These sites have frequent foot traffic from humans and other animals. Trails have more waste product and create an edge effect which is proven to benefit butterfly populations. Chakras were chosen as a site because they are a unique mix of natural forest and agriculture. These sites are said to increase the biodiversity of many different species, including butterflies. Some chakras, however, were clear-cut and may reduce the biodiversity of that area. Open fields were chosen as a site because they represent an extreme form of human disturbance within the Amazon rainforest. These sites were created around many of the main buildings. The last site to be chosen were the river edges. After staying in Verde Sumaco for a few days, many butterflies were observed using the river's edge to obtain nutrients from the sand; therefore, sites were added to see if unique species were found along the river's edge. Old growth forest was not selected as a site because there was not enough time spent there. The time that was available to study butterfly species was not during the same peak hours used in the other sites and would have created an inaccurate representation of what species could be found there. See Figure 2 for pictures of the five site types.

Figure 2. The five different site types in this study. A. open field site type. B. secondary forest site type. C. River edge site type. D. trail site type. E. chakra site type. (E. photo courtesy of Rebecca Sitar).

3.4 Data Collection

Four bait nets were placed in the secondary forest sites for over 24 hours with no luck, so timed spot surveys were used instead. The bait used was attracting many different wasp and ant species and was not safe to collect butterflies.

Starting with the secondary forest, three different areas were selected for this forest site (see Figure 3). The location, habitat description, time of day, date, and weather were recorded for each of the three areas. Thirty-minute segments were used for each area within the secondary forest site type. The thirty-minute portion for the three areas studied in the secondary forest site was further broken down into ten-minute intervals using a timer. Between each interval, a distance of twenty metres was walked in a line West to avoid sampling the same butterfly. After the timer was started, each butterfly seen within the visible radius (about nine metres) was recorded, and a photo was taken using a Canon Rebel T5 (see Figure's 3 and 4 for example pictures). The photo identification number was recorded next to butterfly description in notes. As it is hard to identify butterfly species without a computer, all data was uploaded to an Excel spreadsheet every night. These steps were repeated for each of the three areas located with the secondary forest site. All steps are the same for each of the five sites selected. Once back in Canada, all photos were analyzed, and butterflies identified. The methods used to determine the butterfly species were insect identification guides and websites such as learnaboutbutterflies.com and flickr.com (see Appendix for a complete list of identification guides). If a species was identified, it was cross-referenced against a database of butterflies identified by professors from the University of Florida and the Smithsonian Institute (Hall & Willmott 2019).

Figure 3: *Methona confuse* spotted in secondary forest site.

Figure 4: *Urania leilus* spotted in river edge site.

3.5 Data Processing

Data was analyzed using Microsoft Excel. Data was summarized into smaller sections which were easier to analyze. The website “scribblemaps” was used to make Figure 5

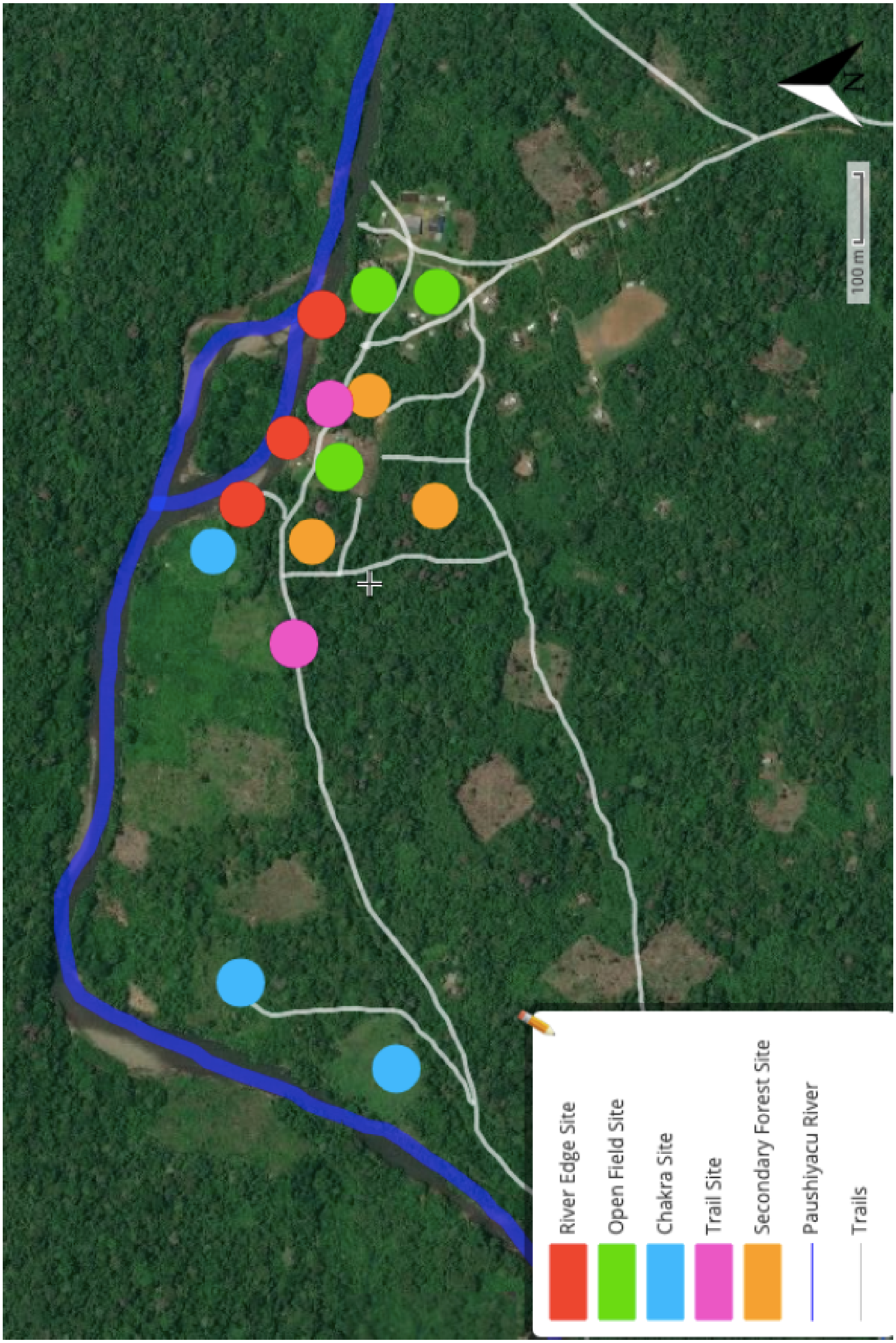


Figure 5. Map of Verde Sumaco with five site types.

4.0 RESULTS

Table 1 displays a summary of the number of Lepidopteran species found within each family. Overall, nine families were identified between the study sites. They include Nymphalidae, Riodinidae, Pieridae, Papilionidae, Hesperiidae, Geometridae, Lycaenidae, Uraniidae, and Erebidae. Table 1 also shows the number of different species within a genus. The genus *Euptychoides* within the family Nymphalidae has two species which are *Euptychoides griphe* and *Euptychoides albofasciata*. In the genus *Heliconius* within the family Nymphalidae, there are several species, and they include *Heliconius erato emma*, *Heliconius wallacei*, *Heliconius doris*, *Heliconius charithonia*, *Heliconius numata bicoloratus*, *Heliconius numata*, and *Heliconius xanthocles*. Within Nymphalidae, five specimens could not be identified down to genus or species. Within the family Riodinidae, two specimens could not be identified down to genus or species. Within the family Pieridae, there was only one genus that had more than one species. This genus is *Melete*, and the species were *Melete lycimnia lycimnia* and *Melete leucanthe*. In the family Papilionidae, there were only four specimens that could not be identified down to genus or species. In the family Hesperiidae, there is only one genus with more than one species within it. The genus is *Staphylus*, and the species are *Staphylus oeta* and *Staphylus minor minor*. There are also 6 unidentified specimens within the family Hesperiidae.

Table 1. Summary of the number of species found in each family.

Family	Genus	Species	Count
Nymphalidae	*Adelpha*	*cytherea*	6
	Anartia	*jatrophae*	7
	Archaeoprepona	*amphimachus*	1
	Cissia	*terrestris*	1
	Cithaerias	*phantoma*	1
	Dryas	sp.	4
	Dynamine	sp.	1
	Eresia	*eunice*	1
	Euptychoides	*griphe*	1
		albofasciata	2
	Haetera	*piera*	1
	Heliconius	*erato emma*	4
		wallacei	1
		doris	1
		charithonia	1
		numata bicoloratus	1
		numata	3
		xanthocles	1
	Hermeuptychia	*cucullina*	28
	Historis	*odius*	1
	Hypanartia	*lethe*	1
	Junonia	*genoveva*	3
	Megeuptychia	*antonoe*	3
	Metamorpha	*elissa elissa*	3
	Methona	*confusa*	1
	Morpho	*helenor*	6
	Philaethria	*dido*	5
	Pierella	spp.	5
	Pseudoscada	*florula aureola*	1
	Pteronymia	*sao*	2
	Taygetis	*cleopatra*	1
	Temenis	*laothoe*	2
	Tithorea	*harmonia*	1
	Unknown		5
Riodinidae	*Amarynthis*	*meneria*	2
	Calospila	*emylius*	1
	Caria	*mantinea*	1
	Eurybia	*caerulescens*	1
	Lasaia	*arsis*	1
	Rhetus	*dysonii*	1
	Unknown		2
Pieridae	*Anteos*	*menippe*	2
	Heliopetes	*alana*	4
	Leucidia	*brephos*	3
	Melete	*lycimnia lycimnia*	1
		leucanthe	7
	Phoebis	*philea*	4
Papilionidae	*Heraclides*	*torquatus*	2
	Mimoides	*xynias*	3
	Neographium	*agesilaus*	1
	Unknown		4
Hesperiidae	*Callimormus*	*corades*	3
	Ebrietas	*anacreon*	2
	Heliopetes	*alana*	1
	Milanion	spp.	2
	Nisoniades	*evansi*	1
	Pompeius	*pompeius*	2
	Pyrgus	*orcus*	1
	Staphylus	*oeta*	3
		minor minor	1
	Urbanus	*teleus*	4
	Vehilius	*stictomenes*	1
	Unknown		6
Geometridae	*Erateina*	*staudingeri*	1

Lycaenidae	*Theritas*	*hemon*	1
Uraniidae	*Urania*	*leilus*	1
Erebidae	*Hypocritia*	spp.	1

Source: Thesis research 2020.

Table 2 displays the number of genera found within each of the nine different families. The family Nymphalidae has the highest number of species at 107 with Geometridae, Lycaenidae, Uraniidae, and Erebidae only having 1 genus and 1 species.

Table 2. Number of each genus within family and count of butterflies.

Family	Number of Genera	Count
Nymphalidae	27	107
Riodinidae	6	9
Pieridae	5	21
Papilionidae	3	10
Hesperiidae	10	27
Geometridae	1	1
Lycaenidae	1	1
Uraniidae	1	1
Erebidae	1	1

Source: Thesis research 2020.

Table 3 compares the Lepidopteran species found in the morning between 10 am and 1 pm and the species found in the afternoon from 1 pm to 5 pm. Several unique species were found in either the morning or afternoon but not both and are indicated by a checkmark in Table 3. The species that were found in both the morning and afternoon are *Adelpha Cytherea*, *Anartia jatrophe*, *Callimormus corades*, *Dryas* spp., *Heliconius charithonia*, *Helioptes alana*, *Hermeuptchya cucullina*, *Junonia genoveva*, *Leucidia brephos*, *Megauptychia antonoe*, *Melete leucanthe*, *Metamorpha elissa elissa*, *Milanion* spp., *Mimoides* xynias, *Philaethria dido*, *Pierella* spp., and *Urbanus teleus*.

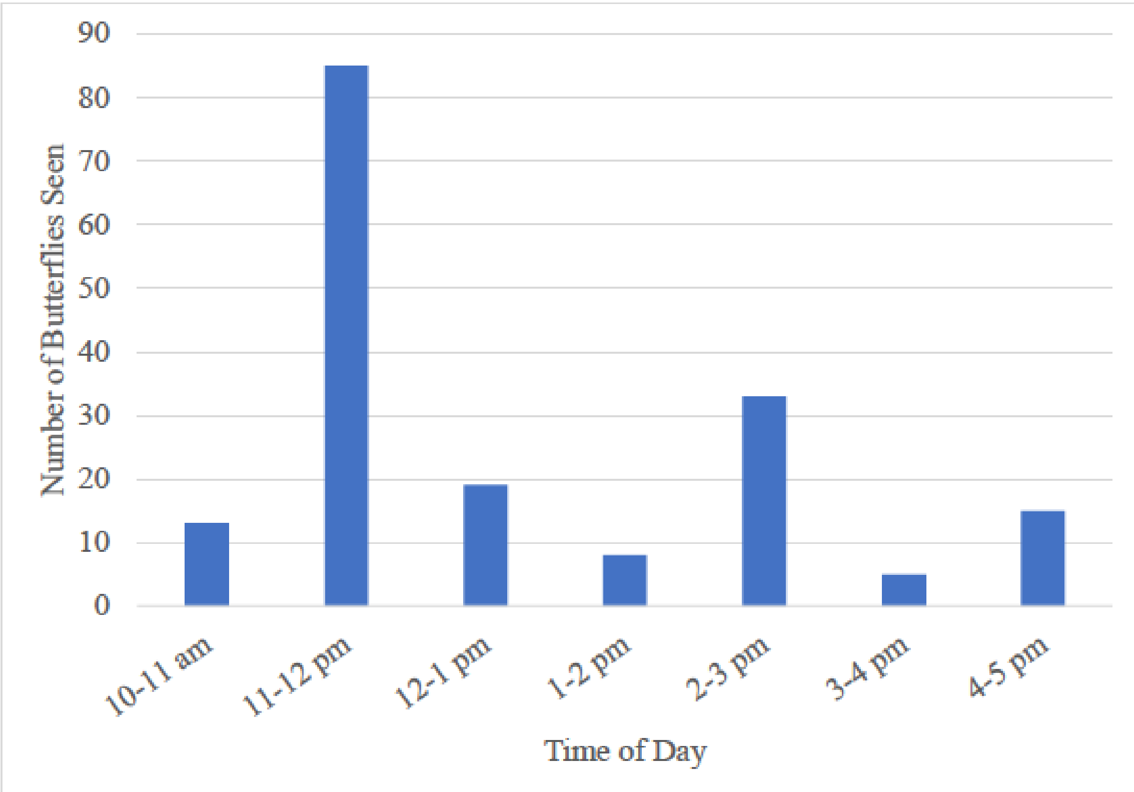
Table 3. Species found in the morning (10 am – 1 pm) compared to the species found in the afternoon (1 pm – 5 pm). A check indicates that a species is unique to the morning or afternoon.

Species in Morning (10am - 1pm)			Species in Afternoon (1 pm - 5 pm)		
Genus	Species	Unique	Genus	Species	Unique
Adelpha	*cytherea*		*Adelpha*	*cytherea*	
Amarynthis	*meneria*	✓	*Anartia*	*jatrophae*	
Anartia	*jatrophae*		*Anteos*	*menippe*	✓
Archaeoprepona	*amphimachus*	✓	*Callimormus*	*corades*	
Callimormus	*corades*		*Calospila*	*emylius*	✓
Caria	*mantinea*	✓	*Dryas*	spp.	
Cissia	*terrestris*	✓	*Dynamine*	spp.	✓
Cithaerias	*phantoma*	✓	*Euptychoides*	*griphe*	✓
Dryas	spp.		*Haetera*	*piera*	✓
Ebrietas	*anacreon*	✓	*Heliconius*	*charithonia*	
Erateina	*staudingeri*	✓	*Heliopetes*	*alana*	
Eresia	*eunice*	✓	*Hermeuptychia*	*cucullina*	
Euptychoides	*albofasciata*	✓	*Historis*	*odius*	✓
Eurybia	*caerulescens*	✓	*Junonia*	*genoveva*	
Heliconius	*erato emma*	✓	*Leucidia*	*brephos*	
Heliconius	*wallacei*	✓	*Megeuptychia*	*antonoe*	
Heliconius	*doris*	✓	*Melete*	*leucanthe*	
Heliconius	*numata bicoloratus*	✓	*Metamorpha*	*elissa elissa*	
Heliconius	*numata*	✓	*Milanion*	spp.	
Heliconius	*charithonia*		*Mimoides*	*xynias*	
Heliconius	*xanthocles*	✓	*Nisoniades*	*evansi*	✓
Heliopetes	*alana*		Nymphalidae spp.		
Heraclides	*torquatus*	✓	Papilionidae spp.		
Hermeuptychia	*cucullina*		*Philaethria*	*dido*	
Hesperiidae spp.		✓	*Pierella*	spp.	
Hypanartia	*lethe*	✓	*Pyrgus*	*orcus*	✓
Hypocritia	*spp.*	✓	Riodinidae spp.		
Junonia	*genoveva*		*Taygetis*	*cleopatra*	✓
Lasaia	*arsis*	✓	*Tithorea*	*harmonia*	✓
Leucidia	*brephos*		*Urbanus*	*teleus*	
Megeuptychia	*antonoe*				
Melete	*lycimnia lycimnia*	✓			
Melete	*leucanthe*				
Metamorpha	*elissa elissa*				
Methona	*confusa*	✓			
Milanion	*spp.*				
Mimoides	*xynias*				

Morpho	*helenor*	✓
Neographium	*agesilaus*	✓
Philaethria	*dido*	
Phoebis	*philea*	✓
Pierella spp.		
Pompeius	*pompeius*	✓
Pseudoscada	*florula aureola*	✓
Pteronymia	*sao*	✓
Rhetus	*dysonii*	✓
Staphylus	*oeta*	✓
Staphylus	*minor minor*	✓
Temenis	*laothoe*	✓
Theritas	*hemon*	✓
Urania	*leilus*	✓
Urbanus	*teleus*	
Vehilius	*stictomenes*	✓

Source: Thesis research 2020.

Figure 6 displays the number of individual butterflies seen at each time during the average day. 13 butterflies were observed between 10 am, and 11 am. Eighty-five butterflies were observed between 11 am and 12 pm. Nineteen butterflies were seen between 12 pm and 1 pm. Eight butterflies were observed between 1 pm and 2 pm. Thirty-three butterflies were seen between 2 pm and 3 pm. Five butterflies were seen between 3 and 4 pm. Fifteen butterflies were observed between 4 pm and 5 pm.



Source: Thesis research 2020.

Figure 6. Number of butterflies seen at a given time of day.

Table 4 compares the number of Lepidopteran species found at the three different site types (Site #1, #2, and #3) within each site type. In the secondary forest site type, there were eight butterflies observed in Site #1, five butterflies observed in Site #2, and ten butterflies observed in Site #3. In the open field site type, there were twenty-eight butterflies observed in Site #1, ten butterflies observed at Site #2, and twenty-nine butterflies observed at Site #3. For the river edge site type, fifteen butterflies were observed at Site #1, fourteen butterflies were observed at Site #2, and thirteen butterflies were observed in Site #3. For the trail site type, twenty-two butterflies were observed at Site #1, twenty-four butterflies were observed at Site #2, and there was no Site #3.

Table 4. Butterflies seen at each study site in each site type.

Site Type	Site #1	Site #2	Site #3
Secondary Forest	*Archaeoprepona amphimachus*	*Adelpha cytherea*	*Haetera piera*
	Cissia terrestris	*Eurybia caerulescens*	*Hermeuptychia cucullina*
	Hermeuptychia cucullina	*Morpho helenor*	*Leucidia brephos*
	Lasaia arsis	*Phoebis philea*	*Mimoides xynias*
	Methona confusa	*Pteronymia sao*	*Pierella* spp.
	Morpho helenor		*Pierella* spp.
	Pierella spp.		*Pierella* spp.
	Unknown (Nymphalidae) #2		*Rhetus dysonii*
			Taygetis cleopatra
			Unknown (Riodinidae) #19
Open Field	*Adelpha cytherea*	*Adelpha cytherea*	*Adelpha cytherea*
	Anartia jatrophae	*Erateina staudingeri*	*Adelpha cytherea*
	Anartia jatrophae	*Hermeuptychia cucullina*	*Amarynthis meneria*
	Callimormus corades	*Hermeuptychia cucullina*	*Anartia jatrophae*
	Callimormus corades	*Hermeuptychia cucullina*	*Anartia jatrophae*
	Calospila emylius	Unknown (Hesperiidae) #55	*Euptychoides albofasciata*
	Dryas spp.	Unknown (Hesperiidae) #61	*Euptychoides albofasciata*
	Dynamine spp.	Unknown (Riodinidae) #54	*Heliconius erato emma*
	Euptychoides griphe	*Urbanus teleus*	*Heliconius erato emma*
	Heliopetes alana	*Urbanus teleus*	*Heliconius wallacei*
	Heliopetes alana		*Heliopetes alana*
	Heliopetes alana		*Hermeuptychia cucullina*
	Hermeuptychia cucullina		*Hermeuptychia cucullina*
	Hermeuptychia cucullina		*Hermeuptychia cucullina*
	Hermeuptychia cucullina		*Hermeuptychia cucullina*
	Hermeuptychia cucullina		*Hermeuptychia cucullina*
	Historis odius		*Junonia genoveva*
	Junonia genoveva		*Megeuptychia antonoe*
	Junonia genoveva		*Philaethria dido*
	Megeuptychia antonoe		*Phoebis philea*

	Megeuptychia antonoe		*Pompeius pompeius*
	Nisoniades evansi		*Pompeius pompeius*
	Philaethria dido		*Staphylus oeta*
	Pyrgus orcus		*Theritas hemon*
	Tithorea harmonia		Unknown (Hesperiidae) #70
	Unknown (Nymphalidae) #39		Unknown (Hesperiidae) #79
	Urbanus teleus		Unknown (Hesperiidae) #82
	Urbanus teleus		*Urania leilus*
			Vehilius stictomenes
River Edge	*Anartia jatrophae*	*Adelpha cytherea*	*Caria mantinea*
	Anartia jatrophae	*Anartia jatrophae*	*Dryas* spp.
	Ebrietas anacreon	*Anteos menippe*	*Ebrietas anacreon*
	Heliconius doris	*Heliconius charithonia*	*Hermeuptychia cucullina*
	Heliconius erato emma	*Hermeuptychia cucullina*	*Hermeuptychia cucullina*
	Heliconius erato emma	*Hermeuptychia cucullina*	*Leucidia brephos*
	Heraclides torquatus	*Melete leucanthe*	*Melete leucanthe*
	Hermeuptychia cucullina	*Melete leucanthe*	*Melete lycimnia lycimnia*
	Melete lycimnia lycimnia	*Melete leucanthe*	*Morpho helenor*
	Mimoides xynias	*Melete leucanthe*	*Neographium agesilaus*
	Morpho helenor	*Metamorpha elissa elissa*	*Phoebis philea*
	Phoebis philea	*Metamorpha elissa elissa*	*Temenis laothoe*
	Pteronymia sao	*Milanion* spp.	Unknown (Papilionidae) #125
	Unknown (Nymphalidae) #105	Unknown (Papilionidae) #114	
	Unknown (Papilionidae) #100		
Trail	*Cithaerias phantoma*	*Amarynthis meneria*	N/A
	Dryas spp.	*Callimormus corades*	
	Eresia eunice	*Dryas* spp.	
	Heliconius charithonia	*Heliconius numata*	
	Heliconius numata	*Heliconius numata*	
	Heliconius numata bicoloratus	*Heliconius xanthocles*	
	Heraclides torquatus	*Hermeuptychia cucullina*	
	Hermeuptychia cucullina	*Hermeuptychia cucullina*	
	Hermeuptychia cucullina	*Hermeuptychia cucullina*	
	Hermeuptychia cucullina	*Hermeuptychia cucullina*	
	Hermeuptychia cucullina	*Hypocritia* spp.	
	Hermeuptychia cucullina	*Leucidia brephos*	
	Hypanartia lethe	*Melete leucanthe*	
	Metamorpha elissa elissa	*Melete leucanthe*	

Milanion spp.	*Mimoides xynias*
Philaethria dido	*Morpho helenor*
Pseudoscada florula aureola	*Morpho helenor*
Staphylus minor minor	*Philaethria dido*
Staphylus oeta	*Philaethria dido*
Temenis laothoe	*Pierella* spp.
Unknown (Hesperiidae) #148	*Staphylus oeta*
	Unknown (Nymphalidae) #173
	Unknown (Nymphalidae) #178
	Unknown (Papilionidae) #155

Source: Thesis research 2020.

Table 5 shows the different butterflies seen in different weather conditions. The days that were cloudy in the morning with sunshine in the afternoon, overcast and humid, as well as very hot and sunny all had the same number of butterflies seen which was thirty-five. The day that was overcast and rainy only had seven butterflies seen.

Table 5. Butterflies seen in different weather.

Cloudy in Morning with Sunshine in Afternoon	Overcast and Rainy	Overcast and Humid	Very Hot and Sunny
Adelpha cytherea	*Adelpha cytherea*	*Adelpha cytherea*	*Amarynthis meneria*
Anartia jatrophae	*Erateina staudingeri*	*Amarynthis meneria*	*Callimormus corades*
Archaeoprepona amphimachus	*Hermeuptychia cucullina*	*Anartia jatrophae*	*Caria mantinea*
Callimormus corades	*Urbanus teleus*	*Anteos menippe*	*Cithaerias phantoma*
Calospila emylius	Unknown (Hesperiidae) #55	*Ebrietas anacreon*	*Dryas* spp.
Cissia terrestris	Unknown (Hesperiidae) #61	*Euptychoides albofasciata*	*Ebrietas anacreon*
Dryas spp.	Unknown (Riodinidae) #54	*Heliconius charithonia*	*Eresia eunice*
Dynamine spp.		*Heliconius doris*	*Heliconius charithonia*
Euptychoides griphe		*Heliconius erato emma*	*Heliconius numata*
Eurybia caerulescens		*Heliconius wallacei*	*Heliconius numata bicoloratus*
Haetera piera		*Heliopetes alana*	*Heliconius xanthocles*
Heliopetes alana		*Heraclides torquatus*	*Heraclides torquatus*
Heliopetes alana		*Hermeuptychia cucullina*	*Hermeuptychia cucullina*
Hermeuptychia cucullina		*Junonia genoveva*	*Hypanartia lethe*
Historis odius		*Megeuptychia antonoe*	*Hypocritia* spp.
Junonia genoveva		*Melete leucanthe*	*Leucidia brephos*
Lasaia arsis		*Melete lycimnia lycimnia*	*Melete leucanthe*

Leucidia brephos	*Metamorpha elissa elissa*	*Melete lycimnia lycimnia*
Megeuptychia antonoe	*Milanion* spp.	*Metamorpha elissa elissa*
Methona confusa	*Mimoides xynias*	*Milanion* spp.
Mimoides xynias	*Morpho helenor*	*Mimoides xynias*
Morpho helenor	*Philaethria dido*	*Morpho helenor*
Nisoniades evansi	*Phoebis philea*	*Neographium agesilaus*
Philaethria dido	*Pompeius pompeius*	*Philaethria dido*
Phoebis philea	*Pteronymia sao*	*Phoebis philea*
Pierella spp.	*Staphylus oeta*	*Pierella* spp.
Pteronymia sao	*Theritas hemon*	*Pseudoscada florula aureola*
Pyrgus orcus	*Urania leilus*	*Staphylus minor minor*
Rhetus dysonii	*Vehilius stictomenes*	*Staphylus oeta*
Taygetis cleopatra	Unknown (Hesperiidae) #70	*Temenis laothoe*
Tithorea harmonia	Unknown (Hesperiidae) #79	Unknown (Hesperiidae) #148
Urbanus teleus	Unknown (Hesperiidae) #82	Unknown (Papilionidae) #125
Unknown (Nymphalidae) #2	Unknown (Nymphalidae) #105	Unknown (Papilionidae) #155
Unknown (Nymphalidae) #39	Unknown (Papilionidae) #114	Unknown (Nymphalidae) #173
Unknown (Riodinidae) #19	Unknown #100	Unknown (Nymphalidae) #178

Source: Thesis research 2020.

Table 6 displays the Lepidopteran species found at each site type. A check mark indicates if a species is present at the site. The symbol (*) indicates that a species is unique to that site type. For the secondary forest site type, sixteen Lepidopteran species were found with eight of those species being unique to the secondary forest. For the trail site type, twenty-seven different Lepidopteran species were identified with nine of those species being unique to trails. For the open field site type, twenty-eight Lepidopteran species were identified with eighteen of the species being unique to the site type. Lastly, the river edge site type had twenty-two different Lepidopteran species with five species being unique to the river edge.

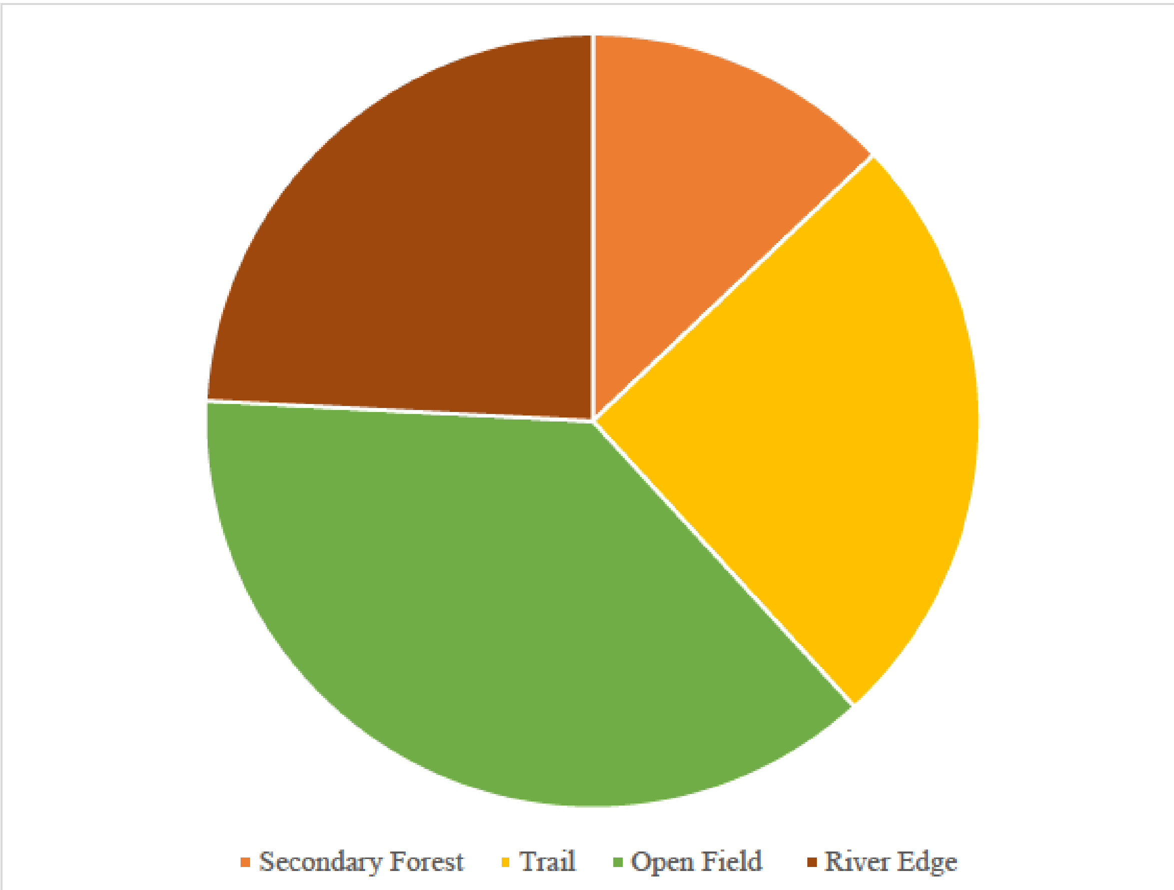
Table 6. Species found at each site type. A checkmark indicates presence at site. (*) before genus name indicates species is unique to site type.

Genus	Species	Secondary Forest	Trail	Open Field	River Edge
Adelpha	*cytherea*	✓	✓		✓
Amarynthis	*meneria*		✓	✓	
Anartia	*jatrophae*			✓	✓
**Anteos*	*menippe*				✓
**Archaeoprepona*	*amphimachus*	✓			
Callimormus	*corades*		✓	✓	
**Calospila*	*emylius*			✓	
**Caria*	*mantinea*				✓
**Cissia*	*terrestris*	✓			
**Cithaerias*	*phantoma*		✓		
Dryas	spp.		✓	✓	✓
**Dynamine*	spp.			✓	
**Ebrietas*	*anacreon*				✓
**Erateina*	*staudingeri*			✓	
**Eresia*	*eunice*		✓		
**Euptychoides*	*griphe*			✓	
**Euptychoides*	*albofasciata*			✓	
**Eurybia*	*caerulescens*	✓			
**Haetera*	*piera*	✓			
Heliconius	*erato emma*			✓	✓
**Heliconius*	*wallacei*			✓	
**Heliconius*	*doris*				✓
Heliconius	*charithonia*		✓		✓
**Heliconius*	*numata bicoloratus*		✓		
**Heliconius*	*numata*		✓		
**Heliconius*	*xanthocles*		✓		
**Heliopetes*	*alana*			✓	
Heraclides	*torquatus*		✓		✓
Hermeuptychia	*cucullina*	✓	✓	✓	✓
**Historis*	*odius*			✓	
**Hypanartia*	*lethe*		✓		
**Hypocritia*	spp.		✓		
**Junonia*	*genoveva*			✓	
**Lasaia*	*arsis*	✓			
Leucidia	*brephos*	✓	✓		✓

***Megeuptychia**	**antonoe**			✓	
***Melete**	**lycimnia**				✓
Melete	**lycimnia leucanthe**		✓		✓
Metamorpha	**elissa elissa**		✓		✓
***Methona**	**confusa**	✓			
Milanion	spp.		✓		✓
Mimoides	**xynias**	✓	✓		✓
Morpho	**helenor**	✓	✓		✓
***Neographium**	**agesilaus**				✓
***Nisoniades**	**evansi**			✓	
Philaethria	**dido**		✓	✓	
Philaethria	**dido**		✓	✓	
Phoebis	**philea**	✓		✓	✓
Pierella	spp.	✓	✓		
***Pompeius**	**pompeius**			✓	
***Pseudoscada**	**florula aureola**		✓		
Pteronymia	**sao**	✓			✓
***Pyrgus**	**orcus**			✓	
***Rhetus**	**dysonii**	✓			
Staphylus	**oeta**		✓	✓	
***Staphylus**	**minor minor**		✓		
***Taygetis**	**cleopatra**	✓			
Temenis	**laothoe**		✓		✓
***Theritas**	**hemon**			✓	
***Tithorea**	**harmonia**			✓	
***Urania**	**leilus**			✓	
***Urbanus**	**teleus**			✓	
***Vehilius**	**stictomenes**			✓	

Source: Thesis research 2020.

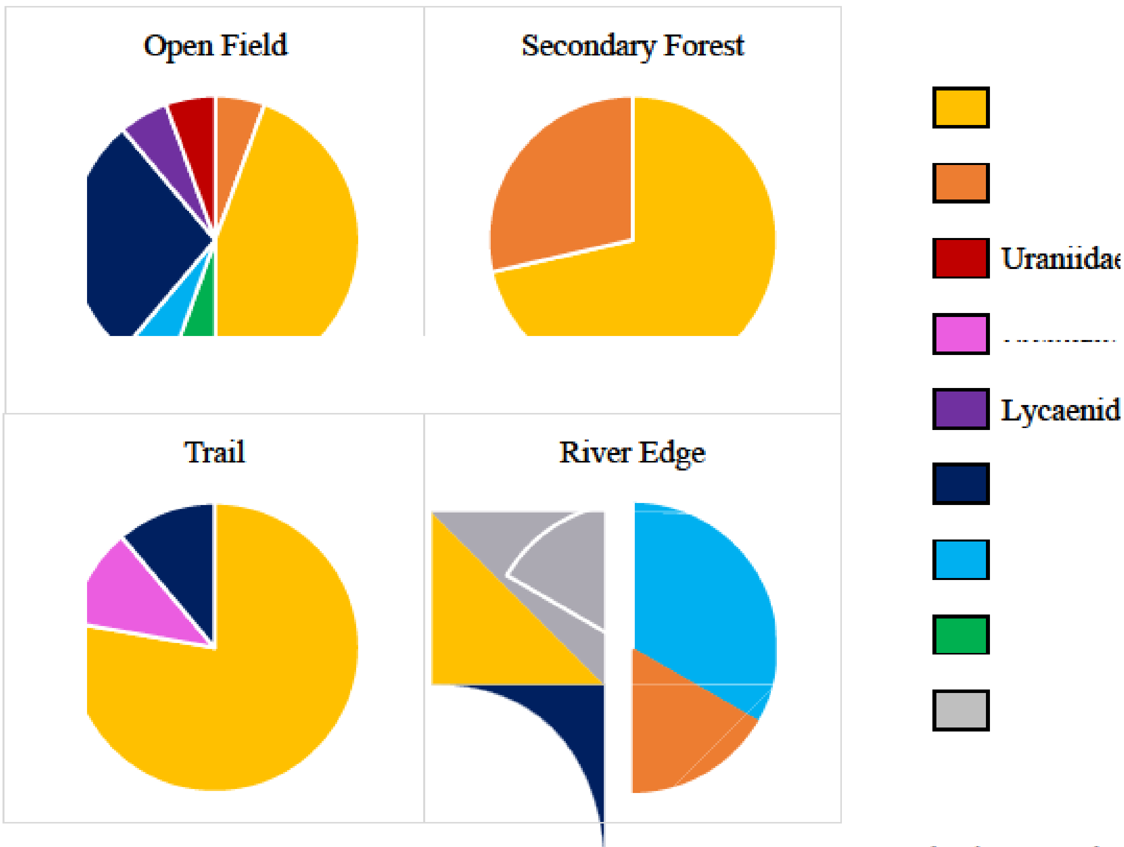
Figure 7 displays the amount of Lepidopteran species at each site as a percentage. 38% of species were found in the open field site type, 25% were found in the trail site type, 24% were found in the river edge site type, and 13% were found within the secondary forest site type.



Source: Thesis research 2020.

Figure 7. The amount of butterflies at each site type.

Figure 8 displays the percent of each unique species at each site type. A unique species is one that is only found at that site type. The charts shows each species by how many are in each family.



Source: Thesis research 2020.

Figure 8. Unique species in each family found at each site type.

5.0 DISCUSSION

The results of this study show that there are many different families of Lepidoptera that can be found around the community of Verde Sumaco. The families found were Nymphalidae, Riodinidae, Pieridae, Papilionidae, Hesperiidae, Geometridae, Lycaenidae, Uraniidae, and Erebidae. Each of these families had varying amounts of genera and species and will be talked about more in detail later. There were also differences in the number and types of Lepidopteran species found at each of the five site types.

There was a difference between the number of species within each family. Nymphalidae had the highest number of genera at 27, and 107 individual butterflies were observed throughout the study (Table 2). This is because Nymphalidae has the highest number of species of any Lepidopteran family at over 6000 species in 542 genera (NSG 2015). Within the family Nymphalidae, the most common genus was *Heliconius* (Table 1). *Heliconius* is one of the main genera across South America with more than 40 recognized species and more than 400 colour patterns (Arias et. al. 2017). The family with the second highest number of genera is Hesperiidae with 10 genera identified over the study period. 27 individual butterflies were observed in Hesperiidae. The family Hesperiidae has over 3,500 described species (Lotts et. al. 2017). Only one genus within Hesperiidae had more than one species, and it is *Staphylus*. There are 55 species within the genus *Staphylus,* and they are located all across South America (Hoskins 2020). Riodinidae was the family with the next highest number of genera at 6. There were also 9 butterflies seen during the study period from this family. There are about 1,300 species with the family Riodinidae and are found throughout tropical latitudes, especially in South America (Lotts et. al. 2017). There were no genera with more than one species identified within the study period for the family Riodinidae. The family with the next highest number of genera is Pieridae at 5. There were 21 butterflies seen within this family. There are about 1,200 species of Pieridae with most of them living in the tropics (Layberry et. al. 2013). Only one genus has more than one species, and it is *Melete*. The genus *Melete* contains only 6 species and occur all across the Southern United States to South America (Hoskins 2020). The family with the next highest number of genera is Papilionidae, and there are 3. There were 10 butterflies seen over the study period that belong to the family. Papilionidae has around 560 species worldwide, with most occurring in the tropics (Lotts et. al. 2017). There were no genera that had more than one species. The last four families all had one genus, and only one butterfly was observed over the study period. Geometridae is a family of moths and has over 21,000 described species with 6,450 occurring in South America (Bodner et. al. 2010). Ecuador's montane rainforest in the Andes is considered a hot spot for Geometridae species, but where this study occurs, it is at a much lower altitude; therefore only 1 species was identified (Bodner et. al. 2010). The family Lycaenidae had only one genus identified over the study period with it only being spotted once. This family has over 4,700 species that are evenly distributed around the world (Lotts et. al. 2017). The one genus seen describes a hairstreak which is common to the New World tropics (Lotts et. al. 2017). Uraniidae is a family of moths, and only one genus was observed. The Uraniidae family is common only to the tropical regions (Lotts et. al. 2017). The last family identified during the study period was Erebidae.

Each site type had varying results to the number of genera and species found. The chakra site type did not have any results and was not used in the tables and figures in the results section. Compared to the other site types, chakras had no Lepidopteran species richness. This may be because of a reduction in canopy cover compared to the other site types. One study done in Cameroon found that sites with the highest species richness were secondary forest, but the lowest species richness was found in agroforestry sites (Bobo et. al. 2006). This study also found that agroforestry sites with higher levels of canopy cover had higher species richness levels compared to agroforestry sites with lower canopy cover levels (Bobo et. al. 2006). The chakra sites studied in Verde Sumaco had little to no canopy cover, thus the lack of species richness.

The site type that had the highest species richness was the open field (Table 6). 35 different Lepidopteran species were identified within 26 genera. 38% of all Lepidopteran species found were in the open field site type (Figure 7). 18 of the species from the 26 genera were unique to the open field site type (Figure 8). For the open field site type, it had the highest number of unique species divided into seven families. This site type also had unique families like Geometridae and Lycaenidae. The two families with the most unique species are Nymphalidae and Hesperiidae. The family Nymphalidae has the highest number of species around the world and is adapted to many different environments. In contrast, Hesperiidae species prefer to live in meadows or grassy areas near edges of the forest (University of Michigan 2020). Therefore, most Hesperiidae species should be found in the open field site type and are. The open field site type has also been divided further into three study sites: #1, #2, and #3 (Table 4). Eighteen species were found in site #1, 7 species were found in site #2, and 20 species were found in site #3. *Helioptes alana*, *Hermeuptychia* cucullina, *Urbanus teleus*, *Megauptychia antone*, and *Junonia genoveva* were the most common species found in each of the site types. *Hermeuptychia cucullina* is commonly found around roadsides and disturbed forest and prefer to rest on grasses (Hoskins 2020). The open field site type has the highest species diversity compared to the other sites because of the edge effect. The edge effect in the open fields promotes flower abundance (Brown et. al. 1997). It has also been shown that large clearings near communities have higher butterfly diversity and species richness (Spitzer et. al. 1997). This is because large clearings near people provide more food opportunities for flower, fruit, and carrion feeding butterflies.

Within the secondary forest site type, 18 different species were identified within 16 genera. 13% of all species found were found within the secondary forest site type (Figure 7). 7 species from the 16 genera were found to be unique to the secondary forest site type (Figure 8). The unique species of the secondary forest were only found in two families, Nymphalidae and Riodinidae. Nymphalidae has the highest number of species in the world, but Riodinidae focuses on areas with young leaves or flowers which are found in secondary forests (Atlas of Living Australia 2020). The secondary forest site type is divided further into three study sites: #1, #2, and #3 (Table 4). Seven species were found in site #1, 5 species were found in site #2, and seven species were found in site #3. Three species were common in this site: *Morpho helenor*, *Hermeuptychia cuculina*, and *Pierella* spp. *Morpho helenor* prefer forested habitats and can range from arid forests to wet rainforests (Hoskins 2020). *Hermeuptychia cuculina* are indicators of a disturbed forest, as mentioned in the open site type. *Pierella* spp. Prefer to live in the undergrowth of rainforests and will not be found out in open fields (Hoskins 2020). The secondary forest site type has fewer food opportunities than the open field site type; thus, there is less species richness.

The trail site type has 31 individual Lepidopteran species divided into 22 genera. 25% of all species found were in the trail site type (Figure 7). 9 of the 31 species found were unique to the trail site type. Most are from the family Nymphalidae, but some species are from Erebidae and Hesperiidae (Figure 8). With many kinds of grass growing along the trail edges, it is not uncommon to see Hesperiidae there. Erebidae, on the other hand, is one of the largest family of moths that prefer open wooded areas (Iowa State University 2020). They are usually nocturnal, but the dark understory of the trails in the secondary forest and disruption from doing the study may have disturbed it. The trail study site is further divided into two study sites, #1 and #2. There are 13 species identified in both study site #1 and #2. The *Heliconius* genus was most common in the trail site type. They are pollen-feeders and due to an edge effect with the trails creating more growth opportunities for flowers, are more common (Beltrán et. al. 2004). *Hermutychia cuclina* is another common species found within the trail site type, but this is because they are well adapted to disturbance as mentioned above. The trail site type has the second highest species richness and this also because of the edge effect. Unlike the open field though, the trail provides a minimal disturbance within the secondary forest. The trail site type is also frequently used by people and animals, which creates food opportunities for Lepidoptera who partake in puddling. Puddling is when adult Lepidoptera feed from mud, dung, carrion, or sweat to feed on sodium and proteins (Boggs et. al. 2004). The trail study site provides many opportunities for these species to feed and creates a more species-rich habitat.

The last site type discussed in this study is the river edge. The river edge site type has 26 individual species divided into 17 genera. 24% of all Lepidopteran species identified were found in the river edge site type (Figure 7). 6 species found were unique to the river edge site type and were from the Pieridae, Papilionidae, Riodinidae, Hesperiidae, and Nymphalidae families (Figure 8). Species within the Pieridae and

Papilionidae family prefer to live in open areas where their food is available (University of Michigan 2020). The river edge site type also provides puddling sites for Lepidoptera species. More unique and "flashy" butterflies were observed partaking in this along the river edge by mud. Hesperiidae are found at this site type because of their preference for grasses which grow along the river's edge. Riodinidae and Nymphalidae are more generalist families that occur at many different site types. The river edge site type is divided further into study site #1, #2, and #3. There are 11 individual Lepidopteran species in study site #1, 8 in study site #2, and 11 in study site #3. The most common species at this site type were *Hermeuptychia cuculina*, *Anartia jatrophe*, *Melete leucanthe*, and *Heliconius* spp. As discussed above, *Hermeuptychia cuculina* is a species that is found in disturbed areas. *Anartia jatrophe* is commonly found within open spaces that are near water (University of Michigan: Museum of Zoology 2020). *Melete leucanthe* are located at a wide range of habitats in lowland rainforests (Hoskins 2020). *Heliconius* spp. are similar to the trail site type where they prefer areas with an edge effect. The river edge site type provides another edge effect which promotes the growth of flowers and fruits. Mud along the riverbank also encourages puddling behaviour seen in many species of butterflies.

With the forest around Verde Sumaco being all secondary forest, it is interesting to see how this forest shift has modified Lepidopteran species diversity. 62 species of Lepidoptera were identified over the study period. These do not include the species that could not be identified. Of the 62 species, 41 species of butterfly that were only seen at one of the four site types (Table 6). 35 of the 41 species were only spotted once (Table 1). With Ecuador having approximately 4,000 species of butterflies, it is no surprise that there are so many unique species found within the community (Checa et. al. 2009). Any site ranging in size from 3 to 10 km^2 is expected to contain 600 to 1,600 species of Lepidoptera species alone (Brown et. al. 1997). 5 species of the 41 are unique to just Around Ecuador. They are *Cithaerias* phantoma, *Heliconius numata bicoloratus*, *Heliconius xanthocles*, *Lasaia arsis*, and *Staphylus minor minor*. *Cithaerias phantoma* is a species that is usually found in the primary forest. However, *Cithaerias phantoma* prefers deeply shaded areas under dense forest cover, which was provided in some parts of the secondary forest around Verde Sumaco (Hoskins 2020). *Heliconius numata bicoloratus* and *Heliconius xanthocles* are a part of the genus *Heliconius*. The genus *Heliconius* as mentioned above, is found mostly in the tropics. There are only 40 species but many different colour morphs which makes certain morphs unique to certain areas (Joron et. al. 2006). *Lasaia arsis* is unique to Northwestern South America (Savela 2020). *Staphylus minor minor* is the last unique species found at the different site types. It occurs on the eastern side of the Andes mountains within an altitude of 400-1500 metres (Hoskins 2020). These 5 species show that there are opportunities for species with unique habitat types to live and thrive around Verde Sumaco. 21 of the remaining species were seen in more than one of the different site types (Table 6). Some species are observed at 3 or more sites. *Adelpha cytherea*, *Dryas* spp., *Hermeuptychia cucullina*, *Leucidia brephos*, *Mimoides xynias*, *Morpho helenor*, and *Phoebis philea*. As discussed earlier, *Hermeuptychia cucullina* is a generalist species who live in disturbed forest habitats. *Adelpha cytherea* is also a species that prefers to live in secondary forest and disturbed areas (Hoskins 2020). The *Dryas* genus is present in disturbed forests where there are many flowers (Hoskins 2020). *Phoebis philea* is also another species that prefer open areas along forest edges (Lotts et. al. 2017). Open canopy forests have more butterflies with less restricted ranges than those found in primary forest (Willott et.

al. 2000, Saikia et. al. 2009, Checa et. al. 2014). An open canopy forest is used by more opportunistic and cosmopolitan species like *Hermeuptychia cucullina*, *Adelpha cytherea*, *Phoebis philea*. Therefore, it makes sense that these four species would be present at three or more of the site types studied. The other three species that are present at three site types or more are considered specific to South America and tropical rainforests and would be more common in these places.

The time of day showed that more Lepidopteran species were present from 10 am to 1 pm compared to 1 pm to 5 pm (Table 3). There are two peaks during the day for butterfly sightings and are 11 am to 12 pm and 2 pm to 3 pm (Figure 6). Most species are seen during the 11 am to 12 pm due to clouds forming in the afternoon from water vapour released from trees through a process called transpiration (NASA 2020). From data collected in Table 5, days that did not rain had more Lepidopteran species than days that did rain. Lepidopteran species are sensitive to temperature and rain cools them down, making them less mobile (Heath et. al. 1971). 53 different species were seen in the morning with 36 of these species only being seen in the morning. 30 different species were observed in the afternoon with 10 species only being observed in the afternoon. More unique species are found in the morning because of the weather change in the late afternoon.

6.0 CONCLUSION

Overall, there are significant differences in butterfly species richness between the five different site types within Verde Sumaco, Ecuador. Species richness for each of the sites was contrary to expectations that each site type would be equal. The site type with the highest species diversity was the open field with 35 different species in 26 genera. The site type with the second highest species richness is trail with 31 different species found in 22 genera. The river edge site type is third with 26 species divided into17 genera. The secondary forest site type is fourth with 18 different species divided into 16 genera. The chakra site type did not have any Lepidopteran species. This disagrees with many studies discussed in the literature review which state that agroforestry sites should increase species richness and diversity. Only some forms of disturbance promote species richness such as open fields and trails while others like chakras do not. The edge effect played an important role in the number of Lepidopteran species found at each site type. The more edges to the forest, the more likely it would be for a higher species diversity.

For the ecotourism industry in Verde Sumaco, their use of the forest increases Lepidopteran species richness and diversity. There were even species found in the secondary forest that are supposedly unique to old growth forests. The community provides many different ecosystem types which promote Lepidoptera.

To create better results for the future, a few things would need to be changed. Although the bait nets did not work, more research could be done into nets tailored for rainforests. Lepidoptera within the site types should be sampled multiple times throughout the year. December is when the rainforest starts to move into the rainy season which is when Lepidoptera usually reproduce. A new site type, old growth forest, could be included. Comparing data found near Verde Sumaco to old growth forest would create a better understanding of the community's impact on the Lepidoptera found around their community. Ultimately the goal of this study was met and provides a brief overview of the Lepidopteran species that can be found around Verde Sumaco.

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APPENDICES

APPENDIX I: INSECT IDENTIFICATION GUIDES

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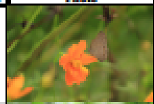
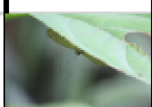
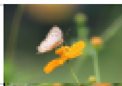
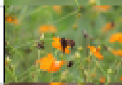
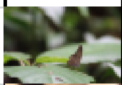
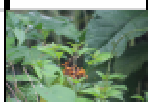
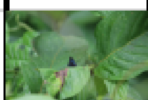
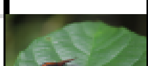
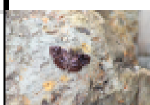
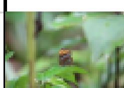
APPENDIX II: RAW DATA

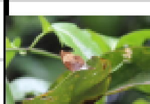
Butterfly Number	Description	Photo Number	Photo	Family	Genus	Specie	Frequency	Habitat Location	Habitat Description	Sample	Time	Date	Weather
1	Small brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	11:00 AM	December 20	Cloudy with sunshine in afternoon
2	Dark with black and white	401 (16 gb)		Nymphalidae						10 minutes	11:00 AM	December 20	Cloudy with sunshine in afternoon
3	Blue morpho	One from last year		Nymphalidae	Morpho	helenor	Frequent			10 minutes	11:00 AM	December 20	Cloudy with sunshine in afternoon
4	Smallish blue with same wings as blue morpho but underside of wing is light blue	IMG_1362		Riodinidae	Lasaia	arsis		Secondary Forest : behind lodge (#1)	Open forest with tall trees and grasses. No shrubs. Pretty open mid forest	20 minutes	11:12 AM	December 20	Cloudy with sunshine in afternoon
5	Brown with stripes	402 (16 gb)		Nymphalidae	Cissia	terrestris	Frequent			20 minutes	11:12 AM	December 20	Cloudy with sunshine in afternoon
6	Black and yellow with yellow tipped antenae with polka dot body	410 (16 gb)		Nymphalidae	Methona	confusa				30 minutes	11:30 AM	December 20	Cloudy with sunshine in afternoon
7	Brown and large	472 (16 gb)		Nymphalidae	Pierella	?	Frequent			30 minutes	11:30 AM	December 20	Cloudy with sunshine in afternoon
8	Brown and large with bottom of wing blue		?	Nymphalidae	Archaeoprepona	amphimachus				30 minutes	11:30 AM	December 20	Cloudy with sunshine in afternoon
9	Blue_morpho	Blue_morpho		Nymphalidae	Morpho	helenor	Frequent			20 minutes	11:58 AM	December 20	Cloudy with sunshine in afternoon
10	Small brown with eye spots	426 (16 gb)		Riodinidae	Eurybia	caerulescens	Frequent			20 minutes	11:58 AM	December 20	Cloudy with sunshine in afternoon
11	Orange and brown with elongated wings and yellow tiped antenae	521 (16 gb)		Nymphalidae	Adelpha	cytherea		Secondary forest: towards community (#2)	Dense forest but light reaches forest floor	30 minutes	12:25 PM	December 20	Cloudy with sunshine in afternoon
12	large yellow sulfur	899 (16 gb)		Pieridae	Phoebis	philea				30 minutes	12:25 PM	December 20	Cloudy with sunshine in afternoon
13	Glasswing with yellow spot on top wing and orange stripe		?	Nymphalidae	Pteronymia	sao				30 minutes	12:25 PM	December 20	Cloudy with sunshine in afternoon
14	Black with red on lower wing and blue patches		?	Riodinidae	Rhetus	dysonii				10 minutes	12:49 PM	December 20	Cloudy with sunshine in afternoon
15	Large brown	472 (16 gb)		Nymphalidae	Pierella	?	Frequent			10 minutes	12:49 PM	December 20	Cloudy with sunshine in afternoon
16	large brown	472 (16 gb)		Nymphalidae	Pierella	?	Frequent			20 minutes	1:01 PM	December 20	Cloudy with sunshine in afternoon
17	Small brown	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	1:01 PM	December 20	Cloudy with sunshine in afternoon
18	Small pure white		?	Pieridae	Leucidia	brephos	Frequent			20 minutes	1:01 PM	December 20	Cloudy with sunshine in afternoon
19	Small with orange on wings	209 (16 gb)		Riodinidae				Secondary forest: towards sumaco (#3)	Dense forest but no light reaches the forest floor	20 minutes	1:01 PM	December 20	Cloudy with sunshine in afternoon
20	Dark brown with jagged wings with light stripe	480 (16 gb)		Nymphalidae	Taygetis	cleopatra				30 minutes	1:14 PM	December 20	Cloudy with sunshine in afternoon
21	Black and big with elongated wings with yellow spot on top wing and red lower wing		?	Papilionidae	Mimoides	xynias				30 minutes	1:14 PM	December 20	Cloudy with sunshine in afternoon
22	Large brown	472 (16 gb)		Nymphalidae	Pierella	?	Frequent			30 minutes	1:14 PM	December 20	Cloudy with sunshine in afternoon
23	Glasswing with completely clear upper wing and orange lower wing		?	Nymphalidae	Hastra	plava				30 minutes	1:14 PM	December 20	Cloudy with sunshine in afternoon

24	White with orange and black markings with 3 black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
25	Black skipper with elongated lower wings	502 (16 gb)		Hesperiidae	Urbanus	teleus	Frequent			10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
26	Small black and white	497 (16 gb)		Pieridae	Heliopetes	alana	Frequent			10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
27	Small brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
28	Small brown with blue inside	487 (16 gb)		Nymphalidae	Magneuptychia	antonoe				10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
29	Large leafy one with orange inside	392 (16 gb)		Nymphalidae	Historis	odius				10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
30	Medium-dark brown with dark markings	370 (16 gb)		Hesperiidae	Mnasicles	[illegible]				10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
31	Brown with 2 orange stripes ad 3 eye spots	182 (16 gb)		Nymphalidae	Junonia	genoveva	Frequent			10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
32	Small with orange stripe and white spots	499 (16 gb)		Riodinidae	Calospila	emylius				10 minutes	2:28 PM	December 20	Cloudy with sunshine in afternoon
33	Small brown with 2 orange stripes and 3 eye spots	182 (16 gb)		Nymphalidae	Junonia	genoveva	Frequent			20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
34	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
35	Small brown	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
36	Large body and elongated wings with yellow stripe on top wing		?	Nymphalidae	Tithorea	harmonia				20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
37	Skipper with elongated tail	502 (16 gb)		Hesperiidae	Urbanus	teleus	Frequent	Open Area: by lodge (#1)	Pretty open with bright orange flowers. Open right down to the water. Low grasses and shrubs	20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
38	Small brown skipper with yellow on antenae	504 (16 gb)		Hesperiidae	Callimormus	corades	Frequent			20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
39	Small orange with tiger stripes	509 (16 gb)		Nymphalidae						20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
40	Small black and white	497 (16 gb)		Hesperiidae	Heliopetes	alana				20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
41	Light brown with white spots	514 (16 gb)		Hesperiidae	Pyrgus	oileus				20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
42	Small with brown and orange with large white spots	517 (16 gb)		Nymphalidae	Dynamine	?				20 minutes	2:40 PM	December 20	Cloudy with sunshine in afternoon
43	Small brown	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
44	Small brown skipper	504 (16 gb)		Hesperiidae	Callimormus	corades	Frequent			30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
45	Elongated orange wings	328 (16 gb)		Nymphalidae	Dryas	?				30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
46	Small brown	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina				30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
47	Elongated wings striped with lime green and black	800		Nymphalidae	Philaethria	dido				30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
48	Small white and black	497 (16 gb)		Pieridae	Heliopetes	alana	Frequent			30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
49	Sharp black wings striped with orange and white	521 (16 gb)		Nymphalidae	Adelpha	cytherea				30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
50	Brown with stripes	487 (16 gb)		Nymphalidae	Magneuptychia	antonoe	Frequent			30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon
51	Brown with eye spots on bottom wings	522 (16 gb)		Nymphalidae	Euptychoides	[illegible]				30 minutes	2:51 PM	December 20	Cloudy with sunshine in afternoon

52	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	2:53 PM	December 21	very overcast and rainy
53	Skipper with elongated tail	502 (16 gb)		Hesperiidae	Urbanus	teleus	Frequent			10 minutes	2:53 PM	December 21	very overcast and rainy
54	Little orange	209 (16 gb)		Riodinidae						10 minutes	2:53 PM	December 21	very overcast and rainy
55	Little brown skipper	619 (16 gb)		Hesperiidae			Frequent			10 minutes	2:53 PM	December 21	very overcast and rainy
56	Brown with orange and white and pointy wings	521 (16 gb)		Nymphalidae	Adelpha	cytherea		Open Area: community centre (#2)	Open with short grasses and shrubs. Trees within 5 metres	10 minutes	2:53 PM	December 21	very overcast and rainy
57	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	3:05 PM	December 21	very overcast and rainy
58	Skipper with elongated tail	502 (16 gb)		Hesperiidae	Urbanus	teleus	Frequent			20 minutes	3:05 PM	December 21	very overcast and rainy
59	large moth like thing with stripes			Geometridae	Eratelna	staudingeri				20 minutes	3:05 PM	December 21	very overcast and rainy
60	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina				30 minutes	3:17 PM	December 21	very overcast and rainy
61	Small brown skipper	619 (16 gb)		Hesperiidae			Frequent			30 minutes	3:17 PM	December 21	very overcast and rainy
62	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	11:02 AM	December 22	overcast but humid
63	Elongated wings with brown, orange, and yellow	685 (16 gb)		Nymphalidae	Heliconius	erato emma				10 minutes	11:02 AM	December 22	overcast but humid
64	Little brown with blue	487 (16 gb)		Nymphalidae	Magneuptychia	antonoe	Frequent			10 minutes	11:02 AM	December 22	overcast but humid
65	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	11:02 AM	December 22	overcast but humid
66	Brown with orange and white and pointy wings	521 (16 gb)		Nymphalidae	Adelpha	cytherea	Frequent			10 minutes	11:02 AM	December 22	overcast but humid
67	Small white and black	497 (16 gb)		Pieridae	Melete		Frequent			10 minutes	11:02 AM	December 22	overcast but humid
68	Dark blue with blue inside and blue streak on outside and small tail things	687 (16 gb)		Lycaenidae	Theritas	hemon				10 minutes	11:02 AM	December 22	overcast but humid
69	Brown with 2 dark stripes	691 (16 gb)		Nymphalidae	Euptychoides	albofasciata				10 minutes	11:02 AM	December 22	overcast but humid
70	Little brown skipper	619 (16 gb)		Hesperiidae			Frequent			10 minutes	11:02 AM	December 22	overcast but humid
71	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	11:14 AM	December 22	overcast but humid
72	Black with red stripes on wings	455 (16 gb)		Riodinidae	Amarynthis	meneria				20 minutes	11:14 AM	December 22	overcast but humid
73	Brown with 2 stripes and eye spots	691 (16 gb)		Nymphalidae	Euptychoides	albofasciata				20 minutes	11:14 AM	December 22	overcast but humid
74	Elongated wings with small yellow patches		?	Nymphalidae	Heliconius	wallacei				20 minutes	11:14 AM	December 22	overcast but humid
75	Yellow sulphur	899 (16 gb)		Pieridae	Phoebis	philea		Open area: by store (#3)	Open area right by forest edge at the head of trail to tambo caspi with many flowers	20 minutes	11:14 AM	December 22	overcast but humid
76	Brown skipper with dark patches on inside	695 (16 gb)		Hesperiidae	Pompeius	pompeius				20 minutes	11:14 AM	December 22	overcast but humid
77	Elongated wings with brown, orange, and yellow	685 (16 gb)		Nymphalidae	Heliconius	erato emma	Frequent			20 minutes	11:14 AM	December 22	overcast but humid
78	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			20 minutes	11:14 AM	December 22	overcast but humid
79	Small brown skipper	619 (16 gb)		Hesperiidae			Frequent			20 minutes	11:14 AM	December 22	overcast but humid
80	Black swallowtail with white tail and blue stripes	202 (16 gb)		Uraniidae	Urania	leilus				20 minutes	11:14 AM	December 22	overcast but humid
81	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
82	Small brown skipper	619 (16 gb)		Hesperiidae			Frequent			30 minutes	11:26 AM	December 22	overcast but humid
83	Brown skipper with dark patches on inside	695 (16 gb)		Hesperiidae	Pompeius	pompeius	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
84	Brown with 2 orange stripes ad 3 eye spots	162 (16 gb)		Nymphalidae	Junonia	genoveva	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
85	Small brown skipper with veiny wings	702 (16 gb)		Hesperiidae	Vehilius	stictomenes				30 minutes	11:26 AM	December 22	overcast but humid
86	Brown with orange and white and pointy wings	521 (16 gb)		Nymphalidae	Adelpha	cytherea	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
87	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
88	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			30 minutes	11:26 AM	December 22	overcast but humid
89	Small brown with tiny white dots	703 (16 gb)		Hesperiidae	Staphylus	ceos				30 minutes	11:26 AM	December 22	overcast but humid
90	Elongated wings striped with lime green and black	900 (16 gb)		Nymphalidae	Philaethria	dido				30 minutes	11:26 AM	December 22	overcast but humid

91	Elongated streaky wings	685 (16 gb)		Nymphalidae	Heliconius	erato emma		By River: towards village (#1)	Open rocks with some mud and trees hanging over the water	10 minutes	11:40 AM	December 22	overcast but humid
92	Black and big with elongated wings with yellow spot on top wing and red power wing			Papilionidae	Mimoides	zynlax				10 minutes	11:40 AM	December 22	overcast but humid
93	Glasswing with yellow spot on top wing and orange stripe			Nymphalidae	Pteronymia	zeo				10 minutes	11:40 AM	December 22	overcast but humid
94	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			10 minutes	11:40 AM	December 22	overcast but humid
95	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	11:53 AM	December 22	overcast but humid
96	Yellow with lime green and orange	361 (16 gb)		Pieridae	Melete	lycimnia lycimnia				20 minutes	11:53 AM	December 22	overcast but humid
97	Yellow swallowtail	443 (16 gb)		Papilionidae	Heraclides	torquatus				20 minutes	11:53 AM	December 22	overcast but humid
98	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			20 minutes	11:53 AM	December 22	overcast but humid
99	Big elongated with yellow small patch at top of wing and orange at bottom		?	Nymphalidae	Heliconius	doris				20 minutes	11:53 AM	December 22	overcast but humid
100	Black swallowtail with white tail and blue stripes	201 (16 gb)		Papilionidae			Frequent			30 minutes	12:05 PM	December 22	overcast but humid
101	Yellow sulphur	899 (16 gb)		Pieridae	Phoebis	philea				30 minutes	12:05 PM	December 22	overcast but humid
102	Brown crinkle wings with purple	712 (16 gb)		Hesperiidae	Ebrietas	anacreon				30 minutes	12:05 PM	December 22	overcast but humid
103	Elongated streaky wings	685 (16 gb)		Nymphalidae	Heliconius	erato emma				30 minutes	12:05 PM	December 22	overcast but humid
104	Blue morpho	Blue_morpho		Nymphalidae	Morpho	helenor				30 minutes	12:05 PM	December 22	overcast but humid
105	White and black	401 (16 gb)		Nymphalidae						30 minutes	12:05 PM	December 22	overcast but humid
106	Black an white spotted	715 (16 gb)		Hesperiidae	Milanion			By River: across from lodge (#2)	lots of clay and mud with creek flowing into main river	10 minutes	4:20 PM	December 22	overcast but humid
107	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	4:20 PM	December 22	overcast but humid
108	White with orange and black markings and three black spots	494 (16 gb)		Nymphalidae	Anartia	jatrophae	Frequent			10 minutes	4:20 PM	December 22	overcast but humid
109	Large dark wings with yellow stripes		?	Nymphalidae	Heliconius	charithonia				10 minutes	4:20 PM	December 22	overcast but humid
110	Brown with orange and white and pointy wings	521 (16 gb)		Nymphalidae	Adelpha	cytherea	Frequent			10 minutes	4:20 PM	December 22	overcast but humid
111	Green leafy with inside wings yellow and white	742 (16 gb)		Pieridae	Anteos	menippe				10 minutes	4:20 PM	December 22	overcast but humid
112	White with orange patch near body	734 (16 gb)		Pieridae	Melete	leucanthe				10 minutes	4:20 PM	December 22	overcast but humid
113	Green leafy with inside wings yellow and white	742 (16 gb)		Pieridae	Anteos	menippe				20 minutes	4:30 PM	December 22	overcast but humid
114	Black swallowtail with white tail and blue stripes	201 (16 gb)		Papilionidae			Frequent			20 minutes	4:30 PM	December 22	overcast but humid
115	Cream white with single black spot on wing	734 (16 gb)		Pieridae	Melete	leucanthe				20 minutes	4:30 PM	December 22	overcast but humid
116	White with orange patch near body	734 (16 gb)		Pieridae	Melete	leucanthe				20 minutes	4:30 PM	December 22	overcast but humid
117	Yellow and orange outer wing with orange and yellow inner striped	735 (16 gb)		Nymphalidae	Metamorpha	elissa elissa				20 minutes	4:30 PM	December 22	overcast but humid
118	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			30 minutes	4:40 PM	December 22	overcast but humid
119	Little black and white striped	735 (16 gb)		Nymphalidae	Metamorpha	elissa elissa				30 minutes	4:40 PM	December 22	overcast but humid
120	White with orange patch near body	734 (16 gb)		Pieridae	Melete	leucanthe				30 minutes	4:40 PM	December 22	overcast but humid

121	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuchytia	cucullina	Frequent	By River: Farther up towards sumaco (#3)	Open rocks with large tree washed up creating pool	10 minutes	10:30 AM	December 22	very hot and sunny with possible chance of rain
122	Blue morpho	Blue_morpho		Nymphalidae	Morpho	helenor				10 minutes	10:30 AM	December 22	very hot and sunny with possible chance of rain
123	Brown crinkle wings with p	712 (16 gb)		Hesperiidae	Ebrietas	anacreon				10 minutes	10:30 AM	December 22	very hot and sunny with possible chance of rain
124	Small pure white			Pieridae	Leucidia	brephos				10 minutes	10:30 AM	December 22	very hot and sunny with possible chance of rain
125	Black swallowtail with white tail and blue stripes	201 (16 gb)		Papilionidae			Frequnt			20 minutes	10:40 AM	December 22	very hot and sunny with possible chance of rain
126	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuchytia	cucullina	Frequnt			20 minutes	10:40 AM	December 22	very hot and sunny with possible chance of rain
127	Cream white with single black spot on wing	734 (16 gb)		Pieridae	Melete	leucanthe				20 minutes	10:40 AM	December 22	very hot and sunny with possible chance of rain
128	Yellow sulphur	899 (16 gb)		Pieridae	Phoebis	philea				20 minutes	10:40 AM	December 22	very hot and sunny with possible chance of rain
129	Iridescent green	903 (16 gb)		Riodinidae	Caria	mantinea				30 minutes	10:50 AM	December 22	very hot and sunny with possible chance of rain
130	Orange and purple that kept landing on me	837 (16 gb)		Nymphalidae	Temenis	laothoe				30 minutes	10:50 AM	December 22	very hot and sunny with possible chance of rain
131	orange at centre with green wings with black edges. White inside	361 (16 gb)		Pieridae	Melete	lycimnia lycimnia				30 minutes	10:50 AM	December 22	very hot and sunny with possible chance of rain
132	White swallowtail with black detailing and black tail		?	Papilionidae	Neographium	agesilaus				30 minutes	10:50 AM	December 22	very hot and sunny with possible chance of rain
133	Elongated orange wings	328 (16 gb)		Nymphalidae	Dryas	?				30 minutes	10:50 AM	December 22	very hot and sunny with possible chance of rain
134	small glasswing with orange	842 (16 gb)		Nymphalidae	Pseudoscada	florula aureola		On trail by river (#1)	Open with plantains and low shrubs	10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
135	Big black with hot pink spots along lower wing		?	Nymphalidae	Cithaerias	phantoma				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
136	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuchytia	cucullina				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
137	Elongated on plantain leaf	848 (16 gb)		Nymphalidae	Hypanartia	lethe				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
138	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
139	Small brown with dark markings	858 (16 gb)		Hesperiidae	Staphylus	minor minor				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
140	Elongated with orange band and spots	861 (16 gb)		Nymphalidae	Heliconius	numata bicoloratus				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
141	Elongated with cheetah spots	862 (16 gb)		Nymphalidae	Heliconius	numata				10 minutes	11:03 AM	December 22	very hot and sunny with possible chance of rain
142	Orange and purple that kept landing on me	837 (16 gb)		Nymphalidae	Temenis	laothoe				20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
143	Black with yellow bands		?	Nymphalidae	Heliconius	charithonia				20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
144	Elongated with orange and yellow		?	Nymphalidae	Eresia	eunice				20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
145	Black an white spotted	715 (16 gb)		Hesperiidae	Milanion					20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
146	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuchytia	cucullina	Frequent			20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
147	Elongated wings striped with lime green and black	905 (16 gb)		Nymphalidae	Philaethria	dido				20 minutes	11:13 AM	December 22	very hot and sunny with possible chance of rain
148	Brown skipper	868 (16 gb)		Hesperiidae						30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
149	Stripes	735 (16 gb)		Nymphalidae	Metamorpha	elissa elissa				30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
150	Elongated orange wings	328 (16 gb)		Nymphalidae	Dryas	?				30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
151	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuchytia	cucullina	Frequent			30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
152	Yellow swallowtail	443 (16 gb)		Papilionidae	Heraclides	torquatus				30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
153	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain
154	Small brown with tiny white dots	703 (16 gb)		Hesperiidae	Staphylus	[illegible]				30 minutes	11:23 AM	December 22	very hot and sunny with possible chance of rain

155	Black swallowtail with white tail and blue stripes	201 (16 gb)		Papilionidae			Frequent			10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
156	Small pure white			Pieridae	Leucidia	brephos				10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
157	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
158	Elongated with cheetah spots	662 (16 gb)		Nymphalidae	Heliconius	numata				10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
159	Small elongated orange wings with orange streaking (5 cm)		?	Nymphalidae	Heliconius	xanthocles				10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
160	Brown with 2 stripes and eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
161	Large brown	472 (16 gb)		Nymphalidae	Pierella	?				10 minutes	11:41 AM	December 23	very hot and sunny with possible chance of rain
162	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina	Frequent			20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
163	Cream white with single black spot on wing	734 (16 gb)		Pieridae	Melete	leucanthe				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
164	Elongated with cheetah spots	662 (16 gb)		Nymphalidae	Heliconius	numata				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
165	Small brown with tiny white dots	703 (16 gb)		Hesperiidae	Staphylus	oeta				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
166	Elongated orange wings	328 (16 gb)		Nymphalidae	Dryas	?				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
167	Small brown skipper	504 (16 gb)		Hesperiidae	Callimormus	corades		Trail: towards sumaco (#2)	tall trees in secondary forest but muddy due to traffic	20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
168	Blue morpho	Blue_morpho		Nymphalidae	Morpho	helenor				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
169	Red lined one from net	455 (16 gb)		Riodinidae	Amarynthis	meneria				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
170	Elongated wings striped with lime green and black	900 (16 gb)		Nymphalidae	Philaethria	dido				20 minutes	11:53 AM	December 23	very hot and sunny with possible chance of rain
171	Cream white with single black spot on wing	734 (16 gb)		Pieridae	Melete	leucanthe				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
172	Blue morpho	Blue_morpho		Nymphalidae	Morpho	helenor				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
173	Orange with streaky wings	891 (16 gb)		Nymphalidae						30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
174	Elongated wings striped with lime green and black	900 (16 gb)		Nymphalidae	Philaethria	dido				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
175	Blue body with white streak	666 (16 gb)		Erebidae	Hypocrita	?				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
176	Little brown with eye spots	246 (16 gb)		Nymphalidae	Hermeuptychia	cucullina				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
177	Black and big with elongated wings with yellow spot on top wing and red power wing			Papilionidae	Mimoides	xynias				30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain
178	Big brown with white band and orange spots	893 (16 gb)		Nymphalidae						30 minutes	12:03 PM	December 23	very hot and sunny with possible chance of rain

APPENDIX III: LEPIDOPTERA COUNT DATA

Nymphalidae		
Genus	Species	Sum
Adelpha	*cytherea*	6
Anartia	*jatrophae*	7
Archaeoprepona	*amphimachus*	1
Cissia	*terrestris*	1
Cithaerias	*phantoma*	1
Dryas	sp.	4
Dynamine	sp.	1
Eresia	*eunice*	1
Euptychoides	*griphe*	1
	albofasciata	2
Haetera	*piera*	1
Heliconius	*erato emma*	4
	wallacei	1
	doris	1
	charithonia	1
	numata bicoloratus	1
	numata	3
	xanthocles	1
Hermeuptychia	*cucullina*	28
Historis	*odius*	1
Hypanartia	*lethe*	1
Junonia	*genoveva*	3
Megeuptychia	*antonoe*	3
Metamorpha	*elissa elissa*	3
Methona	*confusa*	1
Morpho	*helenor*	6
Philaethria	*dido*	5
Pierella	sp.	5
Pseudoscada	*florula aureola*	1
Pteronymia	*sao*	2
Taygetis	*cleopatra*	1
Temenis	*laothoe*	2
Tithorea	*harmonia*	1
Unknown		5
27		106

Riodinidae			Pieridae			Papilionidae		
Genus	Species	Sum	Genus	Species	Sum	Genus	Species	Sum
Amarynthis	*meneria*	2	*Anteos*	*menippe*	2	*Heraclides*	*torquatus*	2
Calospila	*emylius*	1	*Heliopetes*	*alana*	4	*Mimoides*	*xynias*	3
Caria	*mantinea*	1	*Leucidia*	*brephos*	3	*Neographium*	*agesilaus*	1
Eurybia	*caerulescens*	1	*Melete*	*lycimnia lycimnia*	1	Unknown		4
Lasaia	*arsis*	1		*leucanthe*	7			
Rhetus	*dysonii*	1	*Phoebis*	*philea*	4			
Unknown		2						
6		9	5		21	3		10

Hesperiidae		
Genus	Species	Sum
Callimormus	*corades*	3
Ebrietas	*anacreon*	2
Heliopetes	*alana*	1
Milanion	sp.	2
Nisoniades	*evansi*	1
Pompeius	*pompeius*	2
Pyrgus	*orcus*	1
Staphylus	*oeta*	3
	minor minor	1
Urbanus	*teleus*	4
Vehilius	*stictomenes*	1
Unknown		6
10		27

Geometridae			Lycaenidae			Uraniidae			Erebidae		
Genus	Species	Sum	Genus	Species	Sum	Genus	Species	Sum	Genus	Species	Sum
Erateina	*staudingeri*	1	*Theritas*	*hemon*	1	*Urania*	*leilus*	1	*Hypocrita*	spp.	1
1		1	1		1	1		1	1		1

APPENDIX IX: UNIQUE LEPIDOPTERA AT EACH SITE TYPE DATA

Open Field					Secondary Forest					Trail					River Edge				
Family	Genus	Species	Family	Count	Family	Genus	Species	Family	Count	Family	Genus	Species	Family	Count	Family	Genus	Species	Family	Count
Riodinidae	**Calospila*	*emylius*	Riodinidae	1	Nymphalidae	**Archaeoprepona*	*amphimachus*	Nymphalidae	5	Nymphalidae	**Cithaerias*	*phantoma*	Nymphalidae	7	Pieridae	**Anteos*	*menippe*	Pieridae	2
Nymphalidae	**Dynamine*	spp.	Nymphalidae	8	Nymphalidae	**Cissia*	*terrestris*	Riodinidae	2	Nymphalidae	**Eresia*	*eunice*	Erebidae	1	Riodinidae	**Caria*	*mantinea*	Riodinidae	1
Geometridae	**Erateina*	*staudingeri*	Geometridae	1	Nymphalidae	**Haetera*	*piera*			Nymphalidae	**Heliconius*	*numata bicoloratus*	Hesperiidae	1	Hesperiidae	**Ebrietas*	*anacreon*	Hesperiidae	1
Nymphalidae	**Euptychoides*	*griphe*	Pieridae	1	Riodinidae	**Lasaia*	*arsis*			Nymphalidae	**Heliconius*	*numata*			Nymphalidae	**Heliconius*	*doris*	Nymphalidae	1
Nymphalidae	**Euptychoides*	*albofasciata*	Hesperiidae	5	Nymphalidae	**Methona*	*confusa*			Nymphalidae	**Heliconius*	*xanthocles*			Pieridae	**Melete*	*lycimnia lycimnia*	Papilionidae	1
Nymphalidae	**Heliconius*	*wallacei*	Lycaenidae	1	Riodinidae	**Rhetus*	*dysonii*			Nymphalidae	**Hypanartia*	*lethe*			Papilionidae	**Neographium*	*agesilaus*		
Pieridae	**Heliopetes*	*alana*	Uraniidae	1	Nymphalidae	**Taygetis*	*cleopatra*			Erebidae	**Hypocrita*	spp.							
Nymphalidae	**Historis*	*odius*								Nymphalidae	**Pseudoscada*	*florula aureola*							
Nymphalidae	**Junonia*	*genoveva*								Hesperiidae	**Staphylus*	*minor minor*							
Nymphalidae	**Megeuptychia*	*antonoe*																	
Hesperiidae	**Nisoniades*	*evansi*																	
Hesperiidae	**Pompeius*	*pompeius*																	
Hesperiidae	**Pyrgus*	*orcus*																	
Lycaenidae	**Theritas*	*hemon*																	
Nymphalidae	**Tithorea*	*harmonia*																	
Uraniidae	**Urania*	*leilus*																	
Hesperiidae	**Urbanus*	*teleus*																	
Hesperiidae	**Vehilius*	*stictomenes*																	