POPULATION DENSITY, DIVERSITY AND DEVELOPMENTAL STAGES OF SELECTED BUTTERFLY SPECIES IN CHIMMONY WILDLIFE SANCTUARY, KERALA

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(16-02MS-001)

DISSERTATION

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POOKODE, WAYANAD,

KERALA, INDIA

DECLARATION

I hereby declare that this dissertation titled **"Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala"** is a bonafied record of research work done by me during the course of my Master's research program and that the dissertation has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Pookode **Anju V.**

Date: **(16-02MS-001)**

CERTIFICATE

Certified that this dissertation, titled **"Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala"** is a bonafied record of research work done independently by **Anju V. (16-02MS-001)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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CERTIFICATE

We, the undersigned members of the advisory committee of **Anju V. (16-02MS-001)**, a candidate for the degree of Master of Science in Wildlife Studies, agree that the dissertation titled, **"Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala"** may be submitted by **Anju V. (16-02MS-001),** in partial fulfilment of the requirement for the degree.

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EXTERNAL EXAMINER

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1. INTRODUCTION

1.1 NUMBER AND ORDERS IN INDIA WESTERN GHATS AND KERALA

Butterflies are universally popular among all fauna. They are very beautiful, and come in varied sizes, shapes and colours. Different patterns on their body enhance their aesthetic value (Gupta and Majumdar, 2012). Western Ghats can be classified into three biogeographical parts based on the status and distribution of butterflies. They are, Southern Western Ghats, Central Western Ghats and Northern Western Ghats (Gaonkar, 1996). Because of the higher levels of species endemism, the Western Ghats is coming under 34 global biodiversity hotspots (Mittermeier *et al*., 2008). The region is prominent among all other biodiversity hotspots (Myers *et al*., 2000). The butterfly species distributed in Western Ghats consists of 336 species under six families (Kunte, 2008). A total of 346 species of butterflies in Western Ghats are illustrated in the book "A guide to butterflies of Western Ghats" in which they are classified into six families (Bhakre and Ogle, 2018). The Indian butterflies represent 1/5th of fauna in the world (Kunte, 2006) with 1501 species of butterflies are recorded in India (Kehimkar, 2008).

1.2 EVOLUTION

Early known finds of Lepidoptera start from cretaceous period. The emergence of angiosperms happened more than 200 million years ago. According to a possible hypothesis by Daccordi *et al.* (1987), the butterfly larvae specialized for using plant tissues for their diet while the adults adapted to use nectar as diet, and their mouth parts evolved along with the evolution of angiosperm flowers.

1.3 CHARACTERISTICS OF BUTTERFLIES AND CLASSIFICATION

Butterflies are attractively coloured and they have clubbed antennae which are non-hairy, but may be scaly. While resting, they fold their wings over their backs and the wings are not hooked. The junction between the thorax and abdomen of butterflies is more prominent and they have thin abdomen. Most of them fly during day time. Their eggs may be round, bottle, dome or disc shaped.

Butterfly caterpillars bear three pairs of true legs, four pairs of pro-legs and a pair of claspers. Hairs or pines of caterpillars never sting. Pupae are supported by silk strands and form body bands or they may hang freely (Kunte, 2006).

Butterflies belong to a large group of insects called Lepidoptera. They are categorized into two super families. Hesperioidea having the skippers and remaining true butterflies are classified under Papilionoidea. Five families are included in the super family Papilionoidea. They are, Papilionidae (Swallow Tails), Lycanidae (Blues), Pieridae (Yellows and Whites), Nymphalidae (Brush-footed butterflies) and Riodinidae (Punches and Judies) (Kehimkar, 2016).

1.4 MORPHOLOGY OF BUTTERFLIES

Head of the butterfly consists of the sensory organs such as a pair of antennae, a pair of compound eyes, proboscis, palpi and the brain. Antenna is composed of many segments and mainly used for the sense of smell and also for balance. Compound eye is an organ for vision that consists of thousands of ommatidia to identify shapes, motion, colours and distance. Palpi are located in both sides of the proboscis composed of three segments and used for sense of taste (Bhakre and Ogle, 2018). Proboscis is a mouth like organ for feeding by aspiration and can be folded back (Kassambe, 2018). The thorax is divided into three segments and wings and legs attached to it. The fore legs are attached to the first segment, middle legs are attached to the central segment and hind legs are attached to the terminal segment, and all of them have powerful sense organs. Abdomen is the posterior end of the body composed of 10 segments and it contains organs like heart, intestines and genital organs.

1.5 SPECIAL CHARACTERS AND BEHAVIOUR

Batesian (Parasitic) and Mullerian (Mutualistic) mimicry are the two types of mimicry observed in butterflies. A total of seven mimicry rings (mimetic butterfly communities) are present in Western Ghats and 25 species have this feature. Out of this twenty five, 15 are reported as aposematic species and 10 show Batesian mimicry (Bhakre and Ogle, 2018). Butterflies have some special

behaviour such as basking, patrolling and hill-topping, gully bottoming, courtship and mudpuddling (Kehimkar, 2008, 2016).

1.6 LIFE SPAN

Butterfly lifespan may range between a week and a few months (Bhakre and Ogle, 2018). They are a short lived group of insects. Butterflies coming under the family Lycanidae live only for a few weeks but butterflies having large size like Brush- footed butterflies and Swallowtails live up to eight months. Temperature, availability of food and suitability of habitat are some ecological factors affecting the adult butterfly's lifespan (Kehimkar, 2008; 2016).

1.7 LIFE CYCLE OF BUTTERFLY

Butterflies have four stages (egg, caterpillar, pupa/chrysalis and adult) in their lifecycle. The size and shape of the eggs vary with the species. This stage may extend up to few days to weeks. The larva or caterpillar is the second stage of life cycle and this may continue for many days or even weeks. The larvae are voracious feeders and spend their remaining time resting. Most of the caterpillars are herbivores except some insectivores (*e.g.* Apefly). The development of caterpillars involves developmental stages called instars. The caterpillars undergo shedding of skin for 4 to 6 times when they are growing. The time interval between each molting is named 'instar'. The next stage of the lifecycle is pupa. The colour of the pupa usually merges with the background so that it is difficult to differentiate from the surroundings. The period of pupation may extend up to 2–3 weeks. The last stage of the cycle is the adult butterfly. It has four wings, *i.e.* two fore wings and two hind wings, and six legs. The adult butterfly can consume nectar as food from flowers (Kassambe, 2018; Bhakre and Ogle, 2018)

1.8 HIBERNATION

At any stage of butterfly life cycle, they can go into prolonged periods of resting. The reason for hibernation is mainly due to unfavorable climatic conditions. Scarcity of nectar food resources and nectar yielding plants in extreme

cold conditions are other major reasons. Hibernation is helpful for saving energy (Bhakre and Ogle, 2018).

1.9 ADAPTATION

Butterflies have developed different adaptive methods for better survival. Almost all of them lay single eggs per plant or small patches of egg per plant. Some of the caterpillars may roll the leaves around them (*e.g*. Skippers). They may have warning colouration including flash colouration. Swallowtail caterpillars look like fresh bird dropping in first instar and have false eye spots. Osmeterium caterpillars emit a foul odour and may play dead. Swallowtail larvae produce a hissing sound. Expanding periods of pupation, camouflaged pupa, dry season form & wet season form being distasteful to predators etc. are different adaptive features shown by butterflies at different stages (Kehimkar, 2016; Bhakre and Ogle, 2018).

1.10 MIGRATION

Butterflies also migrate like mammals, birds and fishes, which may usually be one-way (Kehimkar, 2016). In southern India, the migration of butterflies has been recorded from the 19th century (Williams, 1938). The migration of Monarch butterflies from northern part to southern states of USA has been well described (Blyth, 1957). Migratory behaviour is found in families of Rhopalocera. Butterfly species belongs to the families Pieridae, Danaidae and Nymphalidae were observed to migrate (Ramesh *et al*., 2012).

1.11 ECOSYSTEM SERVICES

Butterflies play important roles in balancing the ecosystem and they play many roles in addition to their intrinsic value as pollinators of flowers and crops. They are integral parts of our natural heritage, have high aesthetic value, play an educational value and act as indicators of the environmental health (Kassambe, 2018).

1.12 HOST PLANTS

Host plants of butterfly larvae play a major role in their lifecycle. The larvae directly depend on a few particular plants that are essential for their nutritional needs and requirement of specific chemicals. In the Western Ghats, 320 species of butterflies depend on 834 species of plants coming under 88 families, but the host plants of 16 species of butterflies are still unknown (Nitin *et. al.,* 2018).

1.13 NUMBER OF BUTTERFLIES IN THRISSUR AND CHIMMONY WILDLIFE SANCTUARY

The family Nymphalidae is the most dominant family with higher number of species. A detailed diversity study of butterflies in Chimmony Wildlife sanctuary has not been done yet. Previous studies reported 24 species of butterflies at Chimmony Wildlife Sanctuary (George, 2012).

Under these circumstances, a study was conducted at the Chimmony Wildlife Sanctuary to assess the population density, diversity and developmental stages of selected butterfly species of the region with the following objectives.

- To estimate population density and diversity of butterflies in relation to environmental and anthropogenic factors.
- To study the developmental stages of selected butterfly species in different host plants in relation with the nutritional composition of each host plant.
- To identify threats to the butterfly population in the sanctuary and to suggest management measures to minimize them

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 EVOLUTION

Ehrlich and Raven (1964) studied the co-evolution of butterflies and plants. They examined the relationship between butterflies and their hostplants evolution.

Durden and Rose (1978) recorded that the earliest occurrence fossil of Papilionoidea was obtained from the middle Eocene epoch. They collected the fossils of three butterflies from the Green River Shale of Colorado which proved that Rhopalocera existed 48 million years ago.

Brakefield (1984) described the seasonal colour pattern differences of butterflies in tropical forest area. The author studied seasonal polyphenism showed by the Satyrines *Melanitis leda*) and *Orsotrioena medus* and the Nymphalid *Junonia almana*. The prominent marginal eyespot was displayed by wet season forms at rest to escape from vertebrate predators but the dry season forms had no spots or very small and cryptic.

Daccordi *et al.* (1987) reported that the early known species of Lepidoptera could have appeared in Cretaceous period. The emergence of Angiosperms occurred more than 200 million years ago. According to their hypothesis, the butterfly larvae were specialized for using plant tissues in their diet. As their adults adapted to use nectar as food, mouth parts started evolving with the evolution of Angiosperm flowers.

Brower (1996) studied the mimicry in *Heliconius* butterflies and their phenotypic diversity of wing patterns. The author reported convering nature of different morphs evolved independently in and among species.

Grimaldi and Engel (2005) published a book on evolution of insects. They described their diversity, evolutionary relationships and also fossils.

Monteiro and Prudic (2010) studied the colour pattern evolution in butterflies, by examining ultimate and proximate mechanisms using multiple experimental approaches.

2.2 DIVERSITY OF BUTTERFLIES IN THRISSUR

Aneesh *et al.* (2013) studied the diversity of butterflies at Kerala Agricultural University (KAU) campus. They reported 139 species of butterflies. The dominant butterfly fauna of the campus were Nymphalidae. Among different butterfly species, nine were listed in various schedules of the Indian Wildlife (Protection) Act, 1972.

Revathy and Mathew (2014) documented the seasonal fluctuations of butterfly population in the butterfly garden at Peechi. They observed 55 species of butterflies belonging to five families and 37 genera. Family Nymphalidae had maximum number of species. They observed that the butterfly population size increased from January to December.

Puthur *et al.* (2015) examined the ecology and family wise distribution of butterflies at Thumboormuzhi river garden. The butterflies' abundance was higher in areas with higher densities of host plants. They found 89 butterfly species belonging to five families and 62 genera. The area was dominated by family Nymphalidae (34 species).

George *et al*. (2016) recorded 22 species of butterflies belonging to four families from Vimala College, Thrissur. Maximum species richness was observed in the family Nymphalidae.

Panicker *et al.* (2016) conducted a survey on the butterfly diversity in the College of Veterinary and Animal Sciences campus, Mannuthy. They documented 71 species of butterflies belonging to five families. They observed seasonal variation in the butterflies of the campus.

2.3 DIVERSITY OF BUTTERFLIES IN KERALA

Sudheendrakumar *et al.* (2000) conducted a survey on butterflies at different habitats of Parambikulam Wildlife Sanctuary. They recorded 124 species in five habitat types in the sanctuary. Among different butterflies, 15 species were habitat specific. The greatest butterfly diversity was observed in tropical wet evergreen forests.

Sreekumar and Balakrishnan (2001) reported elevation and habitat variation in abundance at Aralam Wildlife Sanctuary. In total 71 species were reported, of which nine species were endemic. The butterfly diversity was low at the lower elevation when compared to the mid elevation, which could be related to anthropogenic activities such as fuel wood collection and cattle grazing.

Nair (2002) surveyed the butterflies of the Government College campus, Madappally, Kozhikkode. They have observed 73 species of butterflies with higher number of species from the family Nymphalidae.

Arun and Azeez (2003) conducted a study on the butterflies of Puyamkutty forests of Iduki district. They reported 32 species including endemic and rare butterflies.

Xavier (2006) studied the butterflies of Government Arts and Science College campus, Kozhikkode and listed 32 species of 27 genera.

Shamsudeen and Mathew (2010) conducted a two-year survey in Shendurny Wildlife Sanctuary and they documented 73 species of which five were scheduled species and three were endemic.

Swapna and Sushama (2011) studied butterfly diversity using line-transect method in two selected sites in Palakkad district and they reported 35 species of butterflies.

Narayanankutty *et al*. (2014) reported butterfly diversity and regional distribution in Shendurney Wildlife Sanctuary.

Jose *et al.* (2015) studied species richness of butterflies in *Myristica* swamps of South Western Ghats, Kerala. They reported 80 species of butterflies belonging to five families.

Antony *et al.* (2016) surveyed the butterfly species richness and diversity at Kariavattom Campus, Kerala University, Thiruvananthapuram. They identified hundred and five species of butterflies. The family Nymphalidae possessed the maximum number of species. Species richness was higher in monsoon period than dry season. Among different species recorded, 29 were listed in schedule and nine species were endemic to Western Ghats.

Jose and Senthilkumar (2016) reported the diversity of butterflies of Muttom Panchayath, Idukki District, from July to December 2015. They found 52 species of butterflies belonging to five families.

Meghana and Deviprasad (2016) documented seasonal diversity of butterfly species in the Bela village of Kasargod district in different seasons. They recorded 72 species of butterflies, dominated by the family Nymphalidae.

Bhaskar *et al.* (2017) studied butterfly diversity of lateritic biotopes of Kaveri River Basin from February 2013 to January 2015. They selected different types of habitats such as sacred groves, laterite hills, riparian ecosystem, and kanams for sampling. They reported 145 species from the sampling site, and family Nymphalidae represented the maximum number of species. They have observed the richness of butterfly fauna in unique ecosystems and microhabitats of lateritic biotopes in relation to butterfly diversity. They studied impact of mining, habitat fragmentation and change in the land-use system on butterfly species communities.

Sarath *et al.,* (2017) studied the diversity and abundance of butterflies of the Kole Wetlands in Ramsar sites of Kerala. They identified 58 species in five families and some of them were endemic and some others were listed in various schedules of Wildlife (Protection) Act 1972.

2.4 BUTTERFLY DIVERSITY IN WESTERN GHATS

Kunte (1997) monitored four butterfly population in tropical forest along different gradient of distance in northern Western Ghats. Seasonal variation in the butterflies species abundance were reported using line-transect method. Grazing and forest fire influenced species richness and composition.

Nayak *et al.* (2004) documented the species composition of butterflies in heterogeneous landscapes of eight localities in Western Ghats of India. They used belt transect method for sampling of sites and identified 169 species of butterflies. Butterfly diversity was observed to be maximum in natural habitats when compared to modified ones.

Dolia *et al.* (2007) studied adult butterfly communities in coffee plantations of Western Ghats using transect and fruit bait traps. They reported that butterfly richness was inversely proportional to canopy cover of the forest.

Mathew (2011) described 282 butterflies in the "Handbook on Butterflies of Nilgiri Biosphere Reserve". Details of butterflie's distribution and number of species listed under various schedules were described.

Murugesan and Muthusamy (2011) reported the butterfly diversity in three tropical habitats of the eastern part of Western Ghats. Hundred and three butterfly species were classified under five families and out of that, Nymphalidae and Pieridae dominated. Butterfly population and its distribution were maximum in the months of March-April and the monsoon seasons (September-November) and were lower during December-January. They observed that there was a close relationship between occurrence and distribution of butterflies and availability of their larval and adult host plants. They reported human interference in the habitats and that destruction of host plants would contribute to the decrease in the population of a species.

Padhye *et al.* (2012) studied the influence of latitude on butterfly faunal diversity at Western Ghats. Among 14 latitudinal zones studied, totally 334 species were reported.

Kassambe (2018) published an e-book titled "Butterflies of Western Ghats" and described 322 butterflies of the Western Ghats. The book describe about individual species development and key identification features. Further, their importance in conservation and butterfly hotspots in the Western Ghats and basics of butterfly gardening were explained.

2.5 BUTTERFLIES OF INDIA

Gay (1992) published a book on common butterflies of India. It included Rhopaloceran life cycle, brief description on species coming under different families in India, their larval food plants of some of these species, morphological and behavioral variations, mimicry, migration and conservation. The methods

used for observation of butterflies, their rearing and photographing were described in this book.

In the book “Butterflies of India” by Antram (2002), the collection, preservation and family wise classification of butterflies of India were described.

Kehimkar (2016) published a text book on Indian butterflies. It included information on butterfly identification, butterfly watching, photography and establishment of butterfly gardens. They described seven hundred and thirty five butterflies present in the Indian subcontinent.

Sharma and Joshi (2009) studied the butterfly species diversity at Dholbaha Dam, surrounded by a moist deciduous forest in Hoshiarpur district of Punjab from 2002 to 2004. They recorded 41 butterfly species belonging to five families. They also recorded the maximum species of butterflies from the family Nymphalidae. The authors found *Eurema hecabe* to be the dominant species of butterflies.

Amala *et al.* (2011) documented thirty six species of butterflies at Siumalai Hills with more number of species from family Pieridae and Nymphalidae.

Singh (2011) published a book titled “Butterflies of India”. It contained details of two hundred and fifty five butterfly species found in India and more than six hundred and fifty colour photographs. The book provided information on status and distribution, abundance and significant characteristics of butterflies.

Thakur and Bhardwaj (2011) reported forty butterfly species belonging to six families and thirty genera and ninety one host plants belonging to forty four families in Shiwalik Hills. Family Nymphalidae dominated with more number of species.

Majumder *et al.* (2012) conducted a six-month study on butterfly fauna at Trishna Wildlife Sanctuary in South Asia. Totally 59 butterfly species were observed out of which nine were listed under the threatened category. When compared to vegetation poor habitats, there was high similarity in species composition in vegetation rich habitats.

Kumar (2013) studied butterfly diversity from three sites of Jhagadia, Ankleshwar, District-Bharuch, Gujarat. The author reported fifty eight species belonging to nine families. Pieridae was found as the family having maximum number of species.

Bora and Meitei (2014) done a survey on butterflies at Assam University from June 2013 to May 2014 using line transect method and reported 96 species. Out of the total species recorded, thirteen were recorded under rare category. Family Nymphalidae represented maximum number of species.

Arya *et al.* (2014) reported species richness and diversity of butterflies from sub temperate forest ecosystems in and around Kumaun University, Uttarakhand. They identified twenty seven species of butterflies coming under eight families. Pieridae was reported as the dominant family. During the rainy season, the authors recorded maximum number of species and individuals followed by that in summer and winter.

Dayananda (2014) documented the diversity of butterfly fauna in and around Gudavi Bird Sanctuary, Karnataka. The author recorded a total of 115 species belonging to five families. Nymphalidae was recorded as the dominated family. Availability of adult nectar plants and larval host plants are found as major reasons for the butterfly diversity and abundance.

Kumar and Murugesan (2014) conducted an inventory survey on butterflies and habitat association of Kudamkulam, Tamil Nadu from 2011 to 2013 and reported 64 species.

Palei and Rath (2014) surveyed butterflies diversity of Sunabeda Wildlife Sanctuary, Odisha. They reported hundred and one species of butterflies. They selected five different transects in the sanctuary for their five months study. Number of species prevalent was more under the family Nymphalidae.

Santhosh and Basavarajappa (2015) studied the butterfly community at agricultural area of Karnataka by using visual count and line transect methods from 2012 to 2013. They observed ninety five species belonging to five families except Rhiodinidae. A total of 12 of all the species were listed under Wildlife Protection Act, 1972.

Ghosh and Mukherjee (2016) studied butterfly diversity at suburban green patches during post monsoon season in different habitats including tree canopy, shrub, herbs, climbers and grasses. They used line transect method to record species richness and abundance. They observed thirty eight butterfly species belonging to five families. Family Rhiodinidae was not reported.

Bowalkar *et. al.* (2017) reported 98 butterfly species of seventy two genera from Taleigao Plateau. Family Nymphalidae shared maximum number of species.

Kumar *et al.* (2017) observed a total of fifty seven species of butterflies from Environmental Centre campus of Manonmaniam Sundaranar University, Tamil Nadu, during one year diversity study of butterflies in relation to climatic factors and twenty species were present throughout the year with dominant family Nymphalidae. Out of all the species, six were recorded as endemic. Species abundance increased from the beginning of early winter and mid-October to February and decreased from late March to September.

Narayana *et al.* (2017) documented butterfly diversity in forest habitats of Warangal district, Telangana. They recorded twenty species of butterflies belonging to five families. Family Nymphalidae shared maximum number of species.

2.6 DIVERSITY OF BUTTERFLIES IN SOUTH ASIA

Prajapati *et al.* (2000) reported sixty five species of butterflies under forty eight genera and eight families from Daman Area of Makawanpur District, Central Nepal. Nymphalidae and Lycaenidae were dominant families of butterflies with more species.

Koh (2007) published a review paper on impact of land utilization and their impact on butterfly population in south-east Asia.

Khandokar *et al.* (2013) studied butterfly species inventory survey at Lawachara NP, Bangladesh from April 2010 to March 2011. They recorded hundred and fifty nine species using transect count method. Family Nymphalidae dominated with maximum number of species and the authors also reported three

new butterfly species. During summer season, maximum number of butterflies were observed.

Shihan and Prodhan (2014) carried out a study on butterflies of Rema-Kalenga Wildlife Sanctuary, Bangladesh, from September 2013 to October 2014. They reported seventy four species of butterflies coming under six families. Nymphalidae was reported as the most abundant family.

Khan *et al.* (2015) published a review paper on diversity of butterfly fauna of Pakistan. They recorded 400 species of butterflies and moths.

Batool and Hussain (2016) published a review paper on the diversity and distribution of butterflies in different areas of Pakistan. They recorded 70 species of butterflies coming under 19 families from Bhawalpur, which had the highest diversity.

Irungbam and Chib (2016) documented diversity of butterflies and their conservation in Tsirang District, Bhutan. They recorded two hundred and forty one butterfly species belonging to hundred and thirty one genera and five families from various habitat types. Nymphalidae was recorded as the dominant family.

2.7 MIGRATION OF BUTTERFLIES

Mathew and Binoy (2002) observed the migration of five species of butterflies in the Amarambalam reserve forest. They recorded peak hours of activity to be between 12.00 hrs and 13.00 hrs with greater than 150 butterflies being sighted per minute.

Kunte (2005) studied Danaid butterfly species composition and migration at Chinnar Wildlife Sanctuary, Kerala. The estimated number of butterflies in this swarm was more than 1,75,000 over three days. The author suggested that migration could help butterflies to avoid heavy rainfall in evergreen forest of Western Ghats.

Ramesh *et al.* (2012) published a paper on migration of butterflies in south-eastern region of India, at Kalpakkam in monsoon period. They observed a total of 34,556 individuals of butterflies with 12.00 to 13.30 hrs as the peak

activity time of migration. They speculated that migration was to avoid intra specific competition and could be to use host plant at distant locations.

2.8 MUD PUDDLING

Boggs and Jackson (1991) studied the mud puddling behaviour of butterflies. They observed difference in puddling activity of both sex with males tend to congregate at puddles.

Molleman *et al*. (2004) studied mud puddling behaviour of butterflies in relation to size, sex differences, preparation of (Na) Sodium as nuptial gift.

2.9 MIMICRY IN BUTTERFLIES

Ohsaki (2005) published a paper on the evolution of female limited and both sex batesian mimicry in butterflies.

2.10 HOST PLANTS OF BUTTERFLIES

Balakrishnan *et al.* (2006) reported new host plant species for butterfly species such as Short-banded Sailer and the Chestnut-streaked Sailer.

Naik and Mustak (2015) reported some additional larval host plants of Indian butterflies from Dakshina Kannada.

Nitin *et al.* (2018) reported eight hundred and thirty four larval host plants of three hundred and twenty butterfly species. There were 16 butterfly larval host plants which were not yet reported.

2.11 EFFECT OF HOST PLANTS ON GROWTH OF LARVAE

Scriber (1977) reared *Hyalophora cecropia* on leaves of wild cherry *Prunus sero tina* and observed the effect of water content on the Nitrogen use, energy gained and larval development. The author noted the larvae which fed on leaves having lower amount of water reduced development of larvae, low use of biomass.

Rausher (1981) studied the role of nutrition in host plant selection by *Battus philenor*. The author observed poor larval growth on mature leaves having toughness due to low nitrogen content.

Stamp and Bowers (1990) studied the phenology of differences in nutritional composition of young and mature leaves and its influence on growth of caterpillars. The third instar larvae fed tender leaves in early June had higher relative growth rate when compared to those fed mature leaves.

Fischer and Fiedler (2000) examined the Copper Butterfly's (*Lycaena tityrus*) response towards increased leaf nitrogen in natural food plants. They found that the growth rate increased with nitrogen content. However, pupal and larval mortality were increased and adult size was decreased.

Hwang *et al.* (2008) studied host plant nutrient content influence on Pieridae butterflies. They found that the larvae that fed on foliage having high nutritional components had increased growth rate.

Morehouse and Rutowski (2010) documented developmental response of a butterfly to variable composition of diet including nitrogen, carbohydrate and genotype. They observed that the larvae feeding diet having minimum nitrogen exhibited less relative growth rates and longer development times, whereas larvae that fed on diet having minimum carbohydrate maintained normal developmental times.

Shobhana *et. al.* (2010) studied the influence of nutritional composition of five different host plants on feeding, growth and reproduction of *Papilio polytes.* They observed maximum growth rate on *Murraya koenigii* followed by *Toddalia asiatica*, *Citrus medica*, *Glycosmis pentaphylla* and *Aegle marmelos*.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in Chimmony Wildlife Sanctuary which spread geographically within the longitudes of 26' N and 10° 26' N longitude 76° 37' E in Thrissur district of Kerala state (George, 2012). The sanctuary was notified in the year 1984. The sanctuary consisted of parts of Kodassery Reserve with an extent of 85.07 sq. km. It was bounded by Nelliampathy Reserve Forest in the eastern side, Peechi-Vazhani Wildlife Sanctuary in the north-west and Sholayar Reserve Forest in the south (Fig. 1). The mean annual rainfall was 3130 mm. The sanctuary had tropical humid climate, with three distinct seasons, dry season (December to March) followed by the south-west monsoon (April to July) and north-east monsoon (August to November). Temperature varies from 38.5°C to 15.6°C during different seasons. The minimum temperature fell below 15.6°C during December. The area was also vulnerable to forest fires during dry season. The sanctuary had more than 250 streams and six man made waterholes. Previous studies in the sanctuary reported only 24 species of butterflies (George, 2012). Diverse vegetation and favorable climatic conditions in the sanctuary could support many species of butterflies.

3.2 BUTTERFLY ABUNDANCE ESTIMATION

Butterfly species abundance was estimated using fixed width transect method in the Chimmony Wildlife Sanctuary from April 2018 to August 2018. A strip transect of two kilometers was selected along paths with two meter width on either side of transect and sampled twice. The surveys were conducted between 9.30 AM and 1.30 PM when the butterflies were most active. The butterflies observed in the field were photographed for further clarification and easy identification. Butterflies were identified using field guides (Kunte, 2006; Kehimkar, 2008; 2016; Palot, 2015; Bhakre and Ogale, 2018) and experts were consulted in case of uncertainty in identification of species. The butterflies were photographed using Nikon 3100 D with 18-50 mm and 70-300 mm lens. The butterfly survey routes were marked with GPS.

3.3 LIFE CYCLE OF SELECTED BUTTERFLY SPECIES

Complete life cycle of Nilgiri Grass Yellow (*Eurema nilgiriensis*) on Red Creeper *Ventilago* sp. were studied. The length and characteristic changes in butterfly larva were noted every day.

Developmental stages of selected butterfly species such as Grass demon (*Udaspes folus*) and Nilgiri Grass Yellow (*Eurema nilgiriensis*) were studied since there no earlier published literature on development of these species. Both species are more abundant in the study area. Growth rate and developmental periods of Grass Demon in three different host plants were noted and the growth rate compared with the nutritional composition of the host plants. Fresh egg samples of *U. folus* were collected and the larvae were reared on three different host plants coming under Zingiberaceae family. The host plants with the larvae were enclosed in a cage of dimension 1x1x1.5m and covered with net to avoid parasitic attack. The larvae were fed with Red ginger (*Alpinia purpurata),* Turmeric (*Curcuma longa)* and Ginger (*Zingiber officinale).* To keep the leaves fresh, a moist piece of cotton was placed around their petioles and wrapped with aluminum foil.

The comparative rate of development of Grass demon *Udaspes folus* on different host leaves was studied based on the total body length, weight and duration of post-embryonic development. To calculate the duration of larval development, the fresh eggs collected were kept separately and the date on which the larva emerged were noted. The weight of the larvae were determined using an American weighing scale 0.1-100 g. Larval weight was noted from their third week of age and length of the larvae were recorded every day of the larval stage. The quality of food ingested was estimated by biochemical analysis of leaves such as total protein, total nitrogen, total lipid and total water content (Anon, 2005).

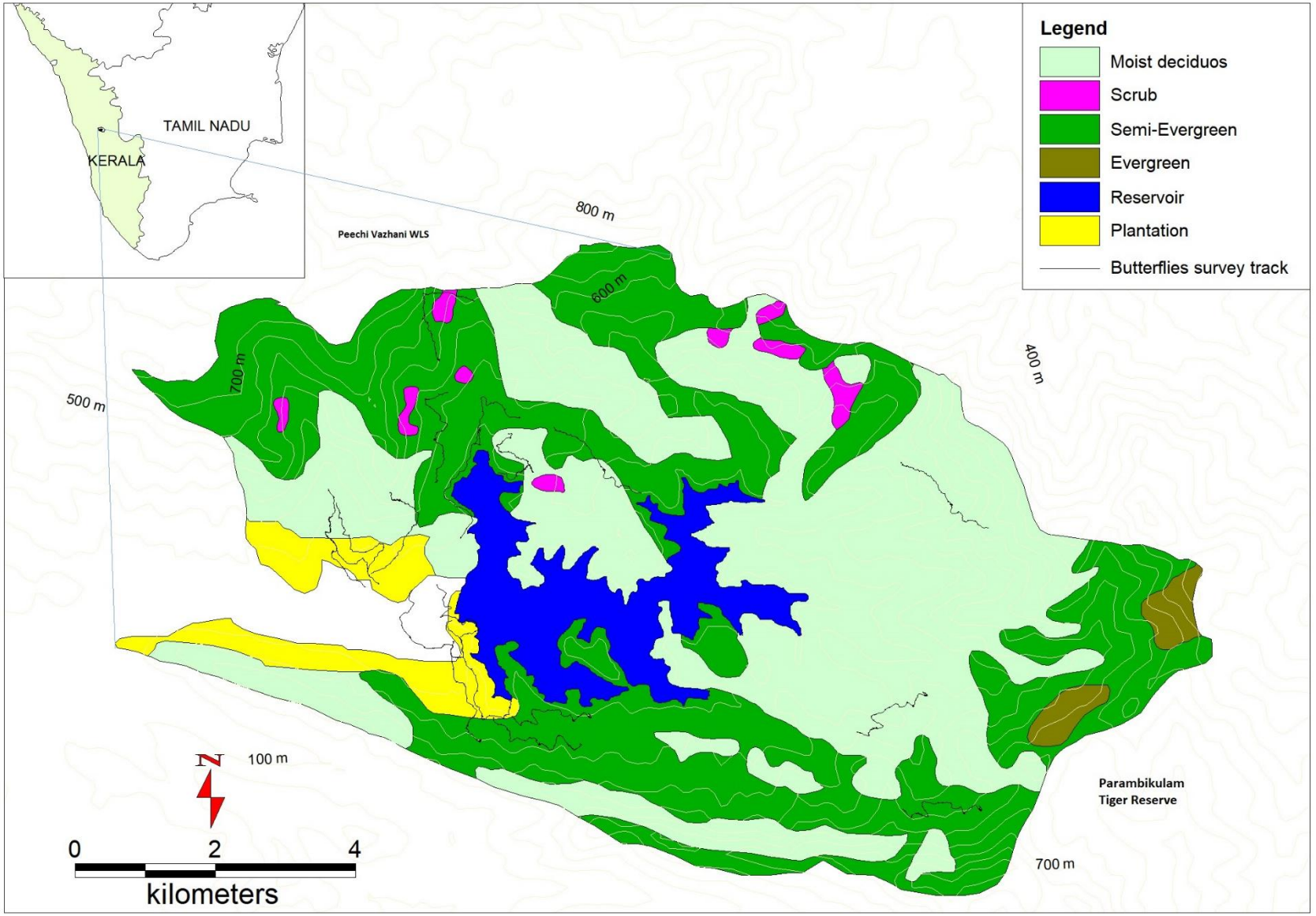


Figure-1: Map showing the Chimmony Wildlife Sanctuary and butterfly survey routes in the study area

3.4 NUTRIENT CONTENT OF HOST PLANT SAMPLES

Nutrient content (total nitrogen, crude protein, total ash, crude fat, moisture content) and protein, of host plant species of the butterflies *i.e*. *Alpinia purpurata*, Curcuma longa and *Zingiber officinale* were estimated as per Analysis of Official Analytical Chemists (2005).

3.5 STATISTICAL ANALYSIS

Basic statistics *viz.* arithmetic mean, standard deviation and standard error were calculated for all the replicative variables and are given as X±1SD or X±SE. Statistical analysis was performed by using Windows based statistical package *viz.* Microsoft Excel, PAST (Hammer *et al*., 2001) and SPSS. Checklist of the observed butterflies were made and percentage composition of each families were calculated and represented as pie diagram. The frequency of species in different families were tested using Chi-square test. The diversity indices such as Simpson and Shannon- Wiener index of butterfly species from each habitat were analysed with the help of software PAST.

Butterfly size difference among different families were tested using One-way Analysis of variance (one-way ANOVA). The factors that determine detection of butterflies, such as abundance, size of butterflies were tested using multiple regression. Linearity was examined by plotting the relationship between response variable (number of detections) and each predictor variable (abundance and size) using Lowess Plot. To investigate multi collinearity between the environmental covariates, a correlation analysis was conducted before using multiple regressions to assess the relationships between the response variable and predictor variables, thereby providing valid parameter estimates and p values. Pairwise comparison of larval growth in different host plant were tested using paired t-test. The data were analyzed using SPSS Statistics 21 (IBM SPSS Inc., Chicago, Illinois, USA).

RESULTS

4. RESULTS

Butterflies species inventory survey and developmental stages of selected species were carried out in the Chimmony Wildlife Sanctuary from April 2018 to June 2018.

4.1 SPECIES COMPOSITION OF BUTTERFLIES ACROSS FAMILIES

Totally 141butterfly species were documented in Chimmony Wildlife Sanctuary. Butterflies species composition varied among different families, with Nymphalidae and Lycanidae constituting 62% (Fig. 2). Families such as Hesperidae, Papilionidae and Pieridae were constituted 16.3%, 12.8% and 8.5% respectively. Only one species (Double-banded Judy) was recorded in Riodinidae family. Thus there is significant variation in the species composition among different families (χ^2=67.3; df=5; p<0.01). The majority of butterfly species belongs to Nymphalidae and Lycanidae in Chimmony Wildlife Sanctuary (Plate-1 to 5).

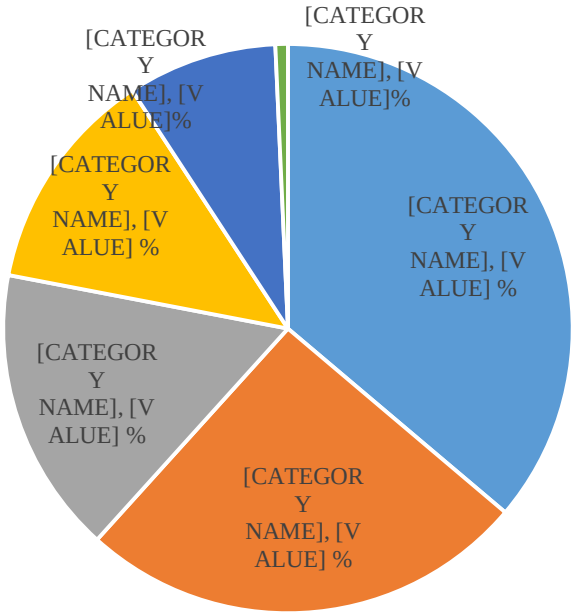


Figure-2: Per cent composition of different families of butterfly species at Chimmony Wildlife Sanctuary

4.2 BUTTERFLY SPECIES DIVERSITY

A total of 141 species composed of 1986 individuals of butterflies were documented in the study area. Butterflies species richness varied among habitats with higher number of species in the Semi-evergreen forest (114) followed by Plantation (84) and Moist Deciduous forest (82). Species dominance was higher in the Moist Deciduous forest (0.09). Both diversity measures (Simpson and Shannon) were more in the Semi-evergreen forest 0.97 and 4.04 respectively. Thus species richness and diversity was higher in the Semi-Evergreen forest. A few species were dominating more in moist deciduous forest. A total of 54 species were recorded in all three habitats and 32 species from exclusively in the Semi-evergreen forest, followed by plantation and Moist deciduous forest with 13 and 11 species respectively.

Table-1: Butterflies species richness, diversity, dominance and evenness in Chimmony Wildlife Sanctuary

Parameters	Semi Evergreen	Moist Deciduous Forest	Plantation	Overall
Number of species	**114**	82	84	141
Individuals	**866**	455	665	1986
Dominance (D)	0.03	**0.09**	0.06	0.04
Simpson index	**0.97**	0.91	0.94	0.96
Shannon (H')	**4.04**	3.42	3.38	3.93
Evenness	**0.50**	0.37	0.35	0.36

4.3 BUTTERFLIES SPECIES ABUNDANCE

A total of 141 species of butterflies were recorded in the Chimmony Wildlife Sanctuary of which 15 species are found to be endemic to Western Ghats region (Table-2). Butterfly species such as Indian ace, Orchid Tit, Shiva sunbeam, Blue oakleaf, Danaid eggfly, Gladeye bushbrown, Malabar tree nymph, Tailed Palmfly, Tamil Catseye, Southern birdwing, *etc*., were endemic species (Plate-1 to 5). There are four species of butterflies such as Orchid Tit, Malabar banded

swallowtail, Crimson Rose and Danaid Eggfly are enlisted in the Schedule I of Indian Wildlife Protection Act (1972). In total there are 20 species of butterflies are catalogued in Schedule of IWPA and provide protection of butterflies. Thus, only 14.2% of butterflies of recorded.

Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in Chimmony WS. There were more than 100 individuals of all these butterflies were recorded in the study area. The other species such as Common Mormon, Chocolate Pansy, Narrow-banded blue bottle, Blue Mormon, Tailless Lineblue, Three-spot Grass Yellow and Great Orange Tip were recorded more than 50 individuals (Table-2). There were 42 species were recorded only once during the time of survey.

Table-2: Butterfly species and their abundance recorded in Chimmony Wildlife Sanctuary

S. No.	Family/ Common Name	Species	Abundance of butterflies	IWPA - Schedule		
				I	I,II	II,IV
	Hesperidae					
1	Bevan's Swift	*Pseudoborbo bevani*	1			
2	Brown Awl	*Badamia exclamationis*	1			
3	Chestnut Angle	*Odontoptilum angulate*	4			
4	Chestnut Bob	*Iambrix salsala luteipalpis*	6			
5	Common Banded Demon	*Notocrypta paralysos mangla*	5			
6	Common Red Eye	*Matapa aria*	1			
7	Common Small Flat	*Sarangesa dasahara dasahara*	1			
8	Common Spotted Flat	*Celaenorrhinus leucocera*	3			
9	Dark Palm-dart	*Telicota bambusae bambusae*	1			
10	Demon sp.	*Notocrypta* sp.	10			
11	Dusky Partwing	*Psolos fuligo*	8			
12	Golden Angle	*Caprona ransonnettii*	6			
13	Grass Demon	*Udaspes folus*	1			
14	Indian Ace**	*Halpe homelea hindu*	1			1
15	Indian Dartlet	*Oriens goloides*	1			
16	Pygmy Scrub Hopper	*Aeromachus pygmaeus*	1			
17	Restricted Demon	*Notocrypta curvifascia*	1			
18	Spotted Small Flat	*Sarangesa purendra hopkinsi*	1			
19	Suffused Snow Flat	*Tagiades gana silvia*	1			
20	Tamil Grass Dart	*Taractrocera ceramas*	1			
21	Tricoloured Pied Flat	*Coladenia indrani indra*	1			
22	Water Snow Flat	*Tagiades litigiosa*	7			
23	Wax Dart	*Cupitha purreea*	1			
	Lycanidae					
24	Angled Pierrot	*Caleta decidia*	21			
25	Apefly	*Spalgis epeus*	1			

26	Banded Blue Pierrot	*Discolampa ethion*	3			
27	Common Cerulean	*Jamides celeno*	8			
28	Common Hedge Blue	*Acytolepis puspa felderi*	5			
29	Common Imperial	*Cheritra freja butleri*	12			
30	Common Lineblue	*Prosotas nora*	240			
31	Common Pierrot	*Castalius rosimon*	29			
32	Common Silverline	*Spindasis vulcanus*	1			
33	Cornelian	*Deudorix epijarbas*	1			
34	Dark Cerulean	*Jamides bochus*	5			
35	Dark Pierrot	*Tarucus ananda*	3			1(IV)
36	Dingy Lineblue	*Petrelaea dana*	2			
37	Fluffy Tit	*Zeltus amasa*	9			
38	Forget-me-not	*Catochrysops Strabo*	1			
39	Gram Blue	*Euchrysops cnejus*	3			1
40	Indian Sunbeam	*Curetis thetis*	2			
41	Indigo Flash	*Rapala varuna*	1			1
42	Large Oakblue	*Arhopala amantes*	2			
43	Lesser Grass Blue	*Zizina Otis*	26			
44	Lime Blue	*Lampides boeticus*	1			1
45	Malayan	*Megisba Malaya*	1			
46	Many-tailed Oakblue	*Thaduka multicaudata Kanara*	8			1
47	Metallic Cerulean	*Jamides alecto*	8			
48	Monkey Puzzle	*Rathinda amor*	15			
49	Orchid Tit**	*Chliaria othona*	1	1		
50	Plain Hedge Blue	*Celastrina lavendularis lavendularis*	1			
51	Plains Cupid	*Chilades pandava*	10			
52	Pointed Lineblue	*Ionolyce helicon viola*	1			1
53	Quaker	*Neopithecops zalmora*	29			
54	Redspot	*Zesius chrysomallus*	1			
55	Shiva Sunbeam**	*Curetis siva*	3			
56	Slate Flash	*Rapala manea*	1			
57	Tailless Lineblue	*Prosotas dubiosa*	60			
58	Tiny Grass Blue	*Zizula hylax*	44			
59	Yamfly	*Loxura atymnus atymnus*	12			
	Nymphalidae					
60	Angled Castor	*Ariadne Ariadne*	9			
61	Autumn Leaf	*Doleschallia bisaltide*	6			1
62	Black Prince	*Rohana parisatis*	2			
63	Black Rajah	*Charaxes solon*	1			
64	Blackvein Sergeant	*Athyma ranga*	2			1
65	Blue Admiral	*Kaniska canace*	1			
66	Blue Oakleaf**	*Kallima horsfieldii*	8			
67	Blue Tiger	*Tirumala limniace*	10			
68	Brown King Crow	*Euploea klugii*	1			
69	Bushbrown Sp.	*Mycalesis* sp.	18			
70	Chestnut-streaked Sailer	*Neptis jumbah*	3			
71	Chocolate Pansy	*Junonia iphita*	71			
72	Clipper	*Parthenos Sylvia*	45			1
73	Commander	*Moduza procris*	4			
74	Common Castor	*Ariadne merione*	24			
75	Common Crow	*Euploea core*	168			
76	Common Evening Brown	*Melanitis leda*	18			
77	Common Five-ring	*Ypthima baldus*	1			
78	Common Four-ring	*Ypthima huebneri*	45			
79	Common Lascar	*Pantoporia hordonia*	2			

80	Common Nawab	*Polyura athamas*	8				
81	Common Sailer	*Neptis hylas*	7				
82	Common Three-ring	*Ypthima asterope*	1				
83	Cruiser	*Vindula erota*	7				
84	Danaid Eggfly**	*Hypolimnas misippus*	2		1		
85	Dark Blue Tiger	*Tirumala septentrionis*	8				
86	Dark Evening Brown	*Melanitis phedima*	3				
87	Dark-branded Bushbrown	*Mycalesis mineus*	3				
88	Double-branded Crow	*Euploea Sylvester*	1				
89	Extra Lascar	*Pantoporia sandaka*	6				
90	Gladeye Bushbrown**	*Mycalesis patina*	4				
91	Glassy Tiger	*Parantica aglea*	7				
92	Great Eggfly	*Hypolimnas bolina*	13				
93	Great Evening Brown	*Melanitis zitenius*	1				1
94	Grey Count	*Tanaecia lepidea*	3				1
95	Grey Pansy	*Junonia atlites*	4				
96	Lemon Pansy	*Junonia lemonias*	7				
97	Malabar Tree Nymph**	*Idea malabarica*	1				
98	Medus Bushbrown	*Orsotriaena medus*	2				
99	Peacock Pansy	*Junonia almanac*	1				
100	Plain Tawny Rajah	*Charaxes psaphon*	1				
101	Plain Tiger	*Danaus chrysippus*	10				
102	Red-spot Duke	*Dophla evelina*	1				1
103	Rustic	*Cupha erymanthis*	21				
104	Striped Tiger	*Danaus genutia*	12				
105	Tailed Palmfly**	*Elymnias caudate*	5				
106	Tamil Catseye**	*Zipaetis saitis*	2				1
107	Tamil Lacewing**	*Cethosia mahratta*	10				
108	Tamil Yeoman	*Cirrochroa thais*	46				
109	Tawny Coster	*Acraea terpsicore*	1				
110	Yellow Pansy	*Junonia hierta*	3				
	Papilionidae						
111	Blue Mormon	*Papilio polymnestor*	64				
112	Common Banded Peacock	*Papilio crino*	1				
113	Common Jay	*Graphium doson*	16				
114	Common Mime	*Papilio clytia*	2				
115	Common Mormon	*Papilio polytes*	73				
116	Common Rose	*Pachliopta aristolochiae*	4				
117	Crimson Rose	*Pachliopta hector*	1	1			
118	Five-bar Swordtail	*Graphium antiphates*	11				
119	Lime	*Papilio demoleus*	5				
120	Malabar Banded Swallowtail**	*Papilio liomedon*	4	1			
121	Malabar Raven**	*Papilio dravidarum*	10				
122	Malabar Rose**	*Pachliopta pandiyana*	5				
123	Narrow-banded Bluebottle	*Graphium teredon*	65				
124	Paris Peacock	*Papilio paris*	11				
125	Red Helen	*Papilio helenus*	15				
126	Southern Birdwing**	*Troides minos*	20				
127	Spot Swordtail	*Graphium nomius*	2				
128	Tailed Jay	*Graphium Agamemnon*	19				
	Pieridae						
129	Common Albatross	*Appias albino*	22				
130	Common Emigrant	*Catopsilia Pomona*	112				
131	Common Grass Yellow	*Eurema hecabe*	53				
132	Common Wanderer	*Pareronia hippia*	24				

133	Great Orange Tip	*Hebomoia glaucippe*	50			
134	Lesser Gull	*Cepora nadina*	11			1
135	Mottled Emigrant	*Catopsilia pyranthe*	3			
136	Nilgiri Grass Yellow**	*Eurema nilgiriensis*	28			
137	One-spot Grass Yellow	*Eurema andersonii*	18			1
138	Psyche	*Leptosia nina*	3			
139	Spotless Grass Yellow	*Eurema laeta*	1			
140	Three-spot Grass Yellow	*Eurema blanda*	55			
	Riodinidae					
141	Double-banded Judy	*Abisara bifasciata*	3			

****** Endemic species

Table-3: Size of butterfly species belongs to different families recorded in Chimmony Wildlife Sanctuary

Family	N	Mean size (mm)	SD	Minimum (mm)	Maximum (mm)
Papilionidae	45	102.8	23.0	75.0	165.0
Nymphalidae	100	70.1	20.1	32.5	135.0
Pieridae	30	57.7	16.2	35.0	90.0
Riodinidae	1	45.0		45.0	45.0
Hesperidae	32	37.5	7.9	21.0	52.5
Lycanidae	67	30.6	7.2	20.0	51.0
Total	**275**	**60.6**	**29.8**	**20.0**	**165.0**

The size of butterflies varies among families with largest sized butterflies recorded from Papilionidae and Nymphalidae (102.8±23 and 70.1±20.1 respectively). Hesperidae and Lycanidae are the smallest sized butterflies. Pieridae and Riodinidae are the medium sized butterflies. There is significant difference in the size of butterflies among different families ($F=118.20$; $df=5$; $p<0.001$).

4.4 FACTORS THAT DETERMINE DETECTION OF BUTTERFLIES

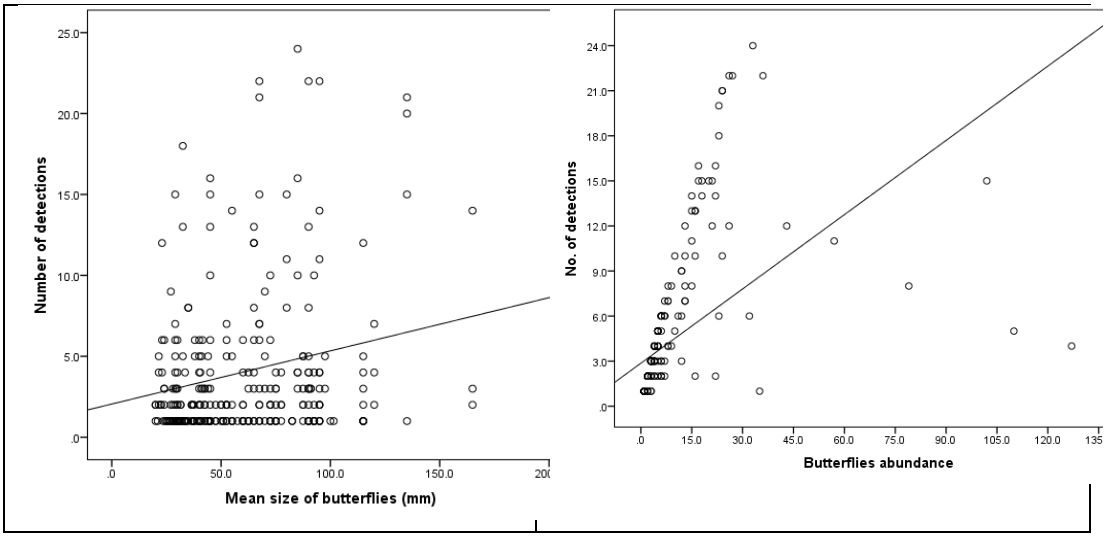
The relationship between the number of detections, abundance and size of butterflies were tested using multiple regression. The variation among habitat was controlled by entering habitat as a dichotomous variable. Number of detection had linear relation with abundance and size of the butterflies. The model was highly significant and explained 31.3% variation in the detection of butterflies ($F=41.08$; $df=3$; $p<0.00$; Tabe-4). Both abundance and size positively influenced number of

detections. From the standardized partial regression, it was inferred that abundance had the primary influence on the detections, followed by size of the butterflies. The relation between mean size of butterflies (mm) and abundance were shown in the graph (Fig 3).

Table-4: Multiple regression to investigate the detection of butterflies in Chimmony Wildlife Sanctuary

Independent Variable	Predictor	Coefficients ± S.E.M[a]		SPRC[b]	p	Model (r^2)	model (p)
Number of detections	(Constant)	0.20	0.79		0.80	0.313	F=41.08; df=3; p<0.00
	Abundance	0.16	0.02	0.51	0.00		
	Size (mm)	0.03	0.01	0.21	0.00		
	Habitat	0.32	0.28	0.06	0.24		

a- S.E.M- Standard error of mean; b-Standardized Partial Regression Coefficient



Figure–3: Relation between mean size of butterflies, abundance and number of detections at Chimmony Wildlife Sanctuary

4.5 DEVELOPMENT OF SELECTED BUTTERFLY SPECIES

Developmental stages of selected butterfly species, Grass demon *(Udaspes folus)* and Nilgiri Grass Yellow *(E. nilgiriensis)* were investigated. These two

species were selected because there were no earlier reports of developmental stages of these butterflies.

4.5.1 NILGIRIS GRASS YELLOW

Nilgiri grass yellow (*Eurema nilgiriensis*) butterfly developmental stages were studied to find out the developmental stages and duration for the development on Red Creeper *Ventilago* sp. Adult females were observed on the day that they lay eggs and eggs were marked and monitored continuously. Eggs were hatched on third day and the first larva was 0.2 cm size. The mean size increase of larva was 0.15cm that ranges from 0.05 cm to 0.8 cm (Fig. 4). There were two rapid growth phase were recorded, they are in between 10-12 day and 13-14. Complete developmental period took 21 days, three days prior to pupation, larva stops growing in fact reduced in size and enter into pupal stage (Plate-6).

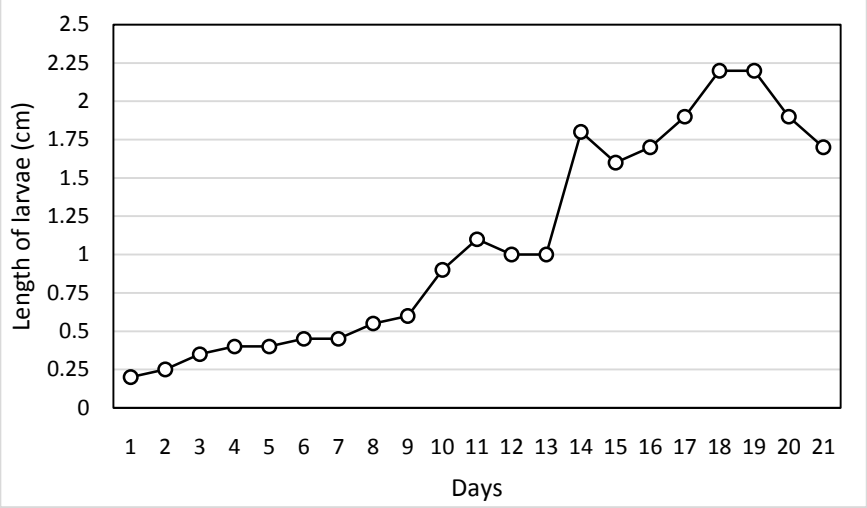


Figure-4: Growth of Nilgiri Grass yellow caterpillar (length in cm) across days

4.5.2 GRASS DEMON

The development of grass demon Grass demon (*U. folus*) was monitored in different host plant such as Ginger, Red ginger and Turmeric. The number days for the development varied in different host plant with lowest in Red ginger, followed by Turmeric and Ginger with 18, 20 and 23 days. The larva immediately hatched out from egg was 0.2 cm (Plate-7). The mean increase in size was the lowest in Ginger (0.208 cm). Both Red ginger and Turmeric had

similar mean growth rate 0.27 cm (Fig. 5). Thus, larval growth in the host plant ginger had prolonged duration (23 days), but mean size of the larva is small (0.208 cm). Larval growth was curtailed to 18 days in Red ginger with large sized larvae. Growth in turmeric was intermediate.

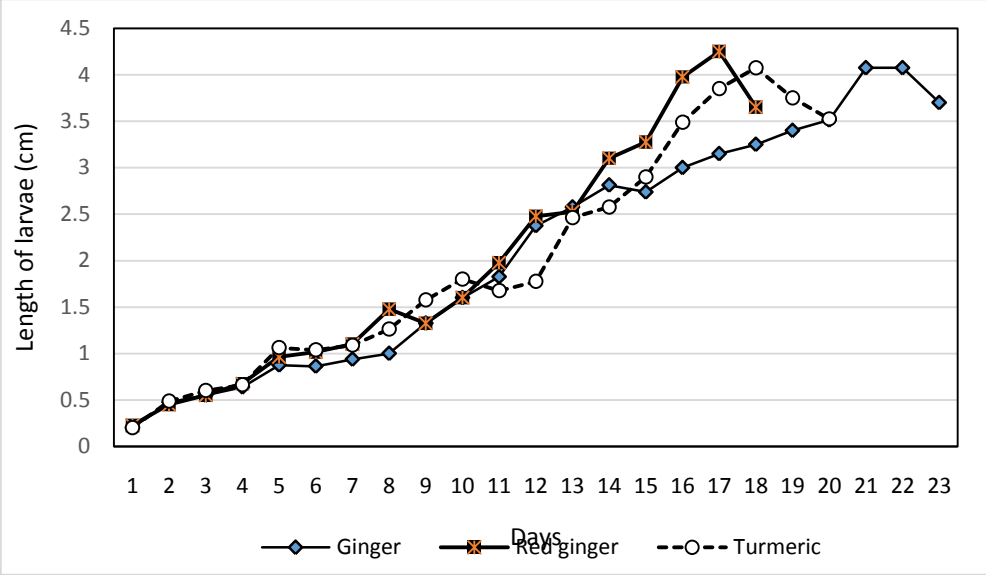


Figure-5: Growth of Grass Demon larva across days in three different host plants

Table-5: Paired t test to find the difference in the larval growth in different the host plant species

Pair-wise comparison	Paired Differences				t	df	P
	Mean	SE	95% Confidence Interval of the Difference				
			Lower	Upper			
Ginger - Turmeric	-0.14	0.07	-0.29	0.01	-1.95	19	0.07
Ginger – Red ginger	-0.25	0.08	-0.41	-0.08	-3.09	17	0.01*
Turmeric – Red ginger	-0.11	0.07	-0.26	0.04	-1.60	17	0.13

*-Significant

Pair-wise comparison of larval growth of Grass Demon (*Udaspes folus*) in different host plants indicated that there were significant difference in the larval growth (caterpillar size) between the Ginger and Red ginger ($t=-3.09$; $df=17$; $p<0.01$; Table-5). But there were no difference in between Ginger and turmeric, similarly in Turmeric and Red ginger.

Table-6: Host plant nutrient content, days of development and average size increase in Grass Demon butterfly larva

Host plant	Crude protein (%)	Total ash (%)	Crude fat (%)	Moisture content (%)	Days of development	Average size increase in larva
Red ginger	12	10.44	1.49	78.04	18	0.208
Turmeric	12.81	13.92	2.68	86.79	20	0.268
Ginger	17.40	13.96	2.89	80.85	23	0.278

Nutrient content of host plants such as crude protein, total ash, crude fat and moisture content were higher in Ginger, followed by Turmeric and Red ginger. Days of development was more in Ginger and least in Red ginger. Average size increase was 0.278 in Ginger, followed by Turmeric and Red ginger. Thus higher protein content (17.4%) in Ginger could have resulted in the increased average size of larva (0.278) and higher longer developmental period (23 days).

4.6 THREATS

The major threats for the butterfly species recorded were the invasion of weed plants, fire and cattle grazing that threatens the host plant abundance in the study area. Though weed considered as threats to butterfly host plants but they act as food source to certain butterfly species. The incidences of fire during summer season threatens abundance of host plants and butterfly density in the study area. Further cattle grazing influence the host plant abundance and threatens species abundance and diversity.

Plate-1a: Papilionidae

Southern Birdwing *(Troides minos)*

Blue Mormon *(Papilio polymnestor)*

Red Helen *(Papilio helenus)*

Common *Mormon (Papilio polytes)*

Common Rose *(Pachliopta aristolochiae)*

Malabar Rose *(Pachliopta pandiyana)*

Paris Peacock *(Papilio paris)*

Malabar Raven *(Papilio dravidarum)*

Plate-1b: Papilionidae

Common Mime *(Papilio clytia)*

Lime *(Papilio demoleus)*

Narrow-banded Bluebottle *(Graphium sarpedon)*

Common Jay *(Graphium doson)*

Tailed Jay *(Graphium Agamemnon)*

Malabar Banded Swallowtail *(Papilio liomedon)*

Five-bar Swordtail *(Graphium antiphates)*

Spot Swordtail *(Graphium nomius)*

Plate-2a: Pieridae

One-spot Grass Yellow *(Eurema andersonii)*

Common Grass Yellow *(Eurema hecabe)*

Nilgiri Grass Yellow *(Eurema nilgiriensis)*

Three-spot Grass Yellow *(Eurema blanda)*

Spotless Grass Yellow *(Eurema laeta)*

Common Albatross *(Appias albino)*

Mottled Emigrant *(Catopsilia pyranthe)*

Common Emigrant *(Catopsilia Pomona)*

Plate-2b: Pieridae

Psyche *(Leptosia nina)*

Lesser Gull *(Cepora nadina)*

Great Orange Tip *(Hebomoia glaucippe)*

Plate-3a: Nymphalidae

Dark Blue Tiger *(Tirumala septentrionis)*

Blue Tiger *(Tirumala limniace)*

Glassy Tiger *(Parantica aglea)*

Striped Tiger *(Danaus genutia)*

Plain Tiger *(Danaus chrysippus)*

Blue Admiral (Kaniska canace)

Great Eggfly *(Hypolimnas bolina)*

Danaid Eggfly *(Hypolimnas misippus)*

Plate-3b: Nymphalidae

Yellow Pansy *(Junonia hierta)*

Grey Pansy *(Junonia atlites)*

Chocolate Pansy *(Junonia iphita)*

Peacock Pansy *(Junonia almanac)*

Lemon Pansy *(Junonia lemonias)*

Clipper *(Parthenos sylvia)*

Blue Oakleaf *(Kallima horsfieldii)*

Autumn Leaf *(Doleschallia bisaltide)*

Plate-3c: Nymphalidae

Tailed Palmfly *(Elymnias caudate)*

Red-spot Duke *(Dophla evelina)*

Angled Castor *(Ariadne Ariadne)*

Common Castor *(Ariadne merione)*

Common Crow *(Euploea core)*

Double-branded Crow *(Euploea Sylvester)*

Brown King Crow *(Euploea klugii)*

Black Prince *(Rohana parisatis)*

Plate-3d: Nymphalidae

Cruiser *(Vindula erota)*

Plain Tawny Rajah *(Charaxes psaphon)*

Tamil Yeoman *(Cirrochroa thais)*

Rustic *(Cupha erymanthis)*

Great Evening Brown *(Melanitis zitenius)*

Dark Evening Brown *(Melanitis phedima)*

Common Evening Brown (*Melanitis leda*)

Common Nawab *(Polyura athamas)*

Plate-3e: Nymphalidae

Extra Lascar *(Pantoporia sandaka)*

Common Lascar *(Pantoporia hordonia)*

Common Sailer *(Neptis hylas)*

Chestnut-streaked Sailer *(Neptis jumbah)*

Blackvein Sergeant *(Athyma ranga)*

Malabar Tree Nymph (Idea malabarica)

Commander *(Moduza procris)*

Grey Count *(Tanaecia lepidea)*

Plate-3f: Nymphalidae

Medus Bushbrown *(Orsotriaena medus)*

Dark-branded Bushbrown *(Mycalesis mineus)*

Common Four-ring *(Ypthima huebneri)*

Common Five-ring *(Ypthima baldus)*

Plate-4a: Hesperidae

Golden Angle *(Caprona ransonnettii)*

Chestnut Angle *(Odontoptilum angulate)*

Water Snow Flat *(Tagiades litigiosa)*

Suffused Snow Flat *(Tagiades gana silvia)*

Tricoloured Pied Flat *(Coladenia indrani indra)*

Common Small Flat *(Sarangesa dasahara)*

Spotted Small Flat *(Sarangesa purendra hopkinsi)*

Common Red Eye *(Matapa aria)*

Plate-4b: Hesperidae

Common Banded Demon *(Notocrypta paralysos)*

Restricted Demon *(Notocrypta curvifascia)*

Grass Demon *(Udaspes folus)*

Brown Awl *(Badamia exclamationis)*

Indian Ace (Halpe homelea hindu)

Pygmy Scrub Hopper *(Aeromachus pygmaeus)*

Wax Dart *(Cupitha purreea)*

Tamil Grass Dart *(Taractrocera ceramas)*

Plate-4c: Hesperidae

Indian Dartlet *(Oriens goloides)*

Chestnut Bob *(Iambrix salsala luteipalpis)*

Riodinidae

Double-banded Judy *(Abisara bifasciata)*

Plate-5a: Lycanidae

Angled Pierrot *(Caleta decidia)*

Banded Blue Pierrot *(Discolampa ethion)*

Common Pierrot (Castalius rosimon)

Dark Pierrot *(Tarucus ananda)*

Common Hedge Blue *(Acytolepis puspa)*

Plain Hedge Blue *(Celastrina lavendularis)*

Malayan (Megisba malaya)

Quaker *(Neopithecops zalmora)*

Plate-5b: Lycanidae

Tiny Grass Blue *(Zizula hylax)*

Lesser Grass Blue (Zizina Otis)

Lime Blue *(Lampides boeticus)*

Forget-me-not *(Catochrysops Strabo)*

Gram Blue (Euchrysops cnejus)

Common Cerulean *(Jamides celeno)*

Dark Cerulean *(Jamides bochus)*

Plains Cupid *(Chilades pandava)*

Plate-5c: Lycanidae

Common Lineblue *(Prosotas nora)*

Dingy Lineblue *(Petrelaea dana)*

Pointed Lineblue *(Ionolyce helicon viola)*

Tailless Lineblue *(Prosotas dubiosa)*

Large Oakblue *(Arhopala amantes)*

Many-tailed Oakblue *(Thaduka multicaudata)*

Common Silverline *(Spindasis vulcanus)*

Monkey Puzzle *(Rathinda amor)*

Plate-5d: Lycanidae

Common Imperial *(Cheritra freja butleri)*

Fluffy Tit *(Zeltus amasa)*

Yamfly *(Loxura atymnus atymnus)*

Redspot *(Zesius chrysomallus)*

Orchid Tit *(Chliaria othona)*

Shiva Sunbeam *(Curetis thetis)*

Slate Flash *(Rapala manea)*

Cornelian *(Deudorix epijarbas)*

Plate-6: Developmental stages Nilgiri Grass Yellow *(Eurema nilgiriensis)*










Plate-7: Developmental stages of Grass Demon *(Udaspes folus)*









DISCUSSION

5. DISCUSSION

Butterfly species inventory survey, composition, diversity in the Chimmony Wildlife Sanctuary and developmental stages of selected butterfly species and influence of nutrient content of host plant in the development were studied from April 2018 to June 2018.

5.1. BUTTERFLIES SPECIES COMPOSITION ACROSS FAMILIES

Composition of butterflies varied among different families. A total of 141 species of 1986 individuals were observed from Chimmony Wildlife Sanctuary during the period of study. The number of species recorded in Chimmony WS were more than other protected areas in Kerala, Sudheendrakumar *et al*., (2000) recorded 124 species at adjacent Parambikulam Tiger Reserve, 71 species from Aralam WS (Sreekumar and Balakrishnan, 2001), 73 species in Shendurny WS (Shamsudeen and Mathew, 2010) and 139 species at Kerala Agricultural University Campus (Aneesh *et al*., 2013). Thus the number of butterfly species were higher in the study area. Family Nymphalidae and Lycanidae were represented 62% of the total. Families such as Hesperidae, Papilionidae and Pieridae were comparatively less. They are, 16.3%, 12.8% and 8.5% respectively. Out of two butterflies in the family Riodinidae of Kerala and Western Ghats, one species (Double-banded Judy) were recorded from the study area during the period of study. There is a significant variation in the species composition among different families. Family Nymphalidae were dominated over other families. In almost all the studies conducted in butterflies of Western Ghats (Sudheendrakumar *et al*., 2000; Sreekumar and Balakrishnan, 2001; Shamsudeen and Mathew, 2010; Aneesh *et al*., 2013) Nymphalidae is the family showing maximum number of species because this is the family representing more number of species in Western Ghats.

5.2. BUTTERFLIES SPECIES DIVERSITY

Richness of butterflies also varied among habitats with higher number of species in the Semi-evergreen forest (114) followed by Plantation (84) and Moist

deciduous forest (82). Similarly, the greatest diversity of butterfly was reported in tropical wet-evergreen forest followed by semi-evergreen and moist deciduous habitats of Parambikulam TR (Sudheendrakumar *et. al.*, 2000). Further the natural habitats harbor higher species richness and diversity than disturbed areas (Nayak *et al*., 2004). Both diversity measures (Simpson and Shannon) and evenness were higher in the Semi- evergreen forest. Thus species richness and diversity was higher in the Semi-Evergreen forest. The presence of riparian vegetation, flowering plants and abundance of host plants could be the factors that contributed higher species richness in the Semi-evergreen forest. The species dominance was higher in the Moist Deciduous forest (0.09), indicating a few species were dominant in this habitat.

5.3. BUTTERFLY SPECIES ABUNDANCE

Out of 141 species of butterflies were recorded in the Chimmony Wildlife Sanctuary, 15 species are recorded as endemic to Western Ghats, which was higher than earlier studies in the study area (George, 2012). Butterfly species such as Indian ace, Orchid Tit, Shiva sunbeam, Blue oakleaf, Danid eggfly, Gladeye bushbrown, Malabar tree nymph, Tailed Palmfly, Tamil Catseye, Southern birdwing, *etc*., were endemic species. Only a few species were listed in the various schedules and enjoy the protection of Indian Wildlife Protection Act (IWPA 1972). Species such as Orchid Tit, Malabar banded swallowtail, Crimson Rose and Danaid Eggfly are the four butterfly species listed in the Schedule I of IWPA. In total there are 20 species of butterflies are listed in various Schedules of IWPA that provide protection of these butterflies. Only 14.2% of butterflies of recorded species are protected under IWPA. Hence it is important to include all the endemic species in the IWPA and butterflies which are more charismatic and rapidly declining species were needs to be listed under the schedules.

Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in Chimmony WS. The other species such as Common Mormon, Chocolate Pansy, Narrow-Banded Blue Bottle, Blue Mormon, Tailless Lineblue, Three-spot Grass Yellow and Great Orange Tip were recorded.

Similar species composition is recorded in Parambikulam TR (Sudheendrakumar *et al*., 2000) and Aralam WS (Sreekumar and Balakrishnan, 2001).

5.4. FACTORS THAT DETERMINE DETECTION OF BUTTERFLIES

There is a relationship between the number of detections and abundance and size. Number of detection had direct relation with abundance and size of the butterflies. The model was highly significant and explained 31.3% variation in the detection of butterflies. Both abundance and size positively influenced number of detections. From the standardized partial regression, abundance had the primary influence on the detections of butterflies, followed by size. Similar species wise differences in the detection of butterflies were reported in the studies carried out in United Kingdom (Isaac *et al*., 2011). But there were no studies were done in India to find out the relative detectability of butterflies in the diversity and population studies.

5.5. OTHER OBSERVATIONS

Common Jay butterfly were observed lay egg on the leaves of *Polyalthia fragrans*, which was not reported as its host plant (Nithin *et. al*. 2018). A large number of caterpillars having different developmental stages were also observed on *P. fragrans*. Further developmental studies of Common Jay caterpillars fed the leaves of *P. fragrans* pupated and successfully emerged from the larva. One of the larva had 89 days of pupation period, which was higher than earlier reports

Parasites of Braconidae and Chalacididae family were observed to parasitize larva and pupa of Grass demon (*Udaspes folus).* Further studies on the parasitoid abundance, number of butterflies infected and influence of host plant on parasitoid will give more insight into how the parasitoids influence butterfly density and diversity. Further earlier studies on plant phytochemicals indicated that the plants damaged by herbivores may start producing phytochemicals for attracting parasitoids (Turlings *et al*., 1995).

5.6. DEVELOPMENT OF SELECTED BUTTERFLY SPECIES

Developmental stages of selected butterfly species (Grass demon and Nilgiri Grass Yellow) were investigated.

5.6.1 Nilgiri Grass Yellow

The developmental stages of Nilgiri grass yellow (*Eurema nilgiriensis*) butterfly were studied to find out different stages of their development and duration taking for the development. Adult females were observed on the day that they lay eggs on the plant *Ventilago sp*. and eggs were marked and monitored continuously. Eggs were observed on or under the tender leaves at the top. Adult plant was climbing over other plants. Eggs were hatched on third day and the first larva was 0.2 cm size. The mean size increase of larva was 0.15cm that ranges from 0.05 cm to 0.8 cm. There were two rapid growth phase were recorded, they are in between 10-12 day and 13-14. Complete developmental period took 21 days. Larva stops growing and reduced in size three days prior to pupation and then entered into pupal stage. A photographic record of lifecycle of Nilgiri Grass Yellow is done by Balakrishnan Valappil (2018) and that is published in the Book "A guide to the Butterflies of Western Ghats written by Milind Bhakre and Hemand Ogle (2018) and in the magazine Malabar Trogon (2018).

5.6.2 Grass Demon

There is no study on development of grass demon (*Udaspes folus*) in different host plant such as Ginger, Red ginger and Turmeric. The number of days for the development varied in different host plant with lowest in Red ginger, followed by Turmeric and Ginger with 18, 20 and 23 days. The larva immediately hatched out from egg was 0.2 cm. The mean increase in size was the lowest in Ginger (0.208 cm). Both Red ginger and Turmeric had similar mean growth rate 0.27 cm. In the host plant ginger, the larval growth had prolonged duration (23), but mean size of the larva is small (0.208 cm). Larval growth was curtailed to 18 days in Red ginger with large sized larvae. Growth in turmeric was intermediate. A similar study was done by Shobhana *et. al*. (2010) on larval

host plant influenced on the feeding, growth and reproduction of Common Mormon (*Papilio polytes).*

Pair-wise comparison of larval growth in different host plants indicated that there were significant difference in the larval growth between the Ginger and Red ginger ($t=-3.09$; $df=17$; $p<0.01$. But there were no difference in between Ginger and turmeric, similarly in Turmeric and Red ginger.

Correlation with the growth of grass demon butterfly (*Udaspes folus*) and the nutritional composition of larval host plants such as red ginger (*Alpinia purpurata),* Turmeric *(Curcuma longa) and* ginger *(Zingiber officinale)* were analysed. The amount of nutrient elements in the feed of the herbivorous insects may varies with the plant (Jeyabalan and Murugan, 1996). The quality of feed determines the rate of growth and time period of development of insects feeding on plants (*Levesque et. al.*, 2002). Low amount of water in the feed may reduce the growth rate of larva (Murugan and George, 1992). The chemical components and physical conditions play a major role in controlling the growth of larva (Bernays and Chapman, 1975). The feed containing more protein will produce successful insects (Mattson, 1980).

SUMMARY

6. SUMMARY

Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala was studied from April to June 2018. Butterfly species recorded were 141 species of two orders, six families and 103 genera were observed during study, 15 species were recorded as endemic and 20 species were reported under various schedules. The majority of butterfly species were belong to family Nymphalidae and Lycanidae. The species richness and species diversity was observed higher in Semi-evergreen forest (114) and the dominance was higher in the moist deciduous forest (0.09). Endemic species recorded were Indian Ace, Orchid Tit, Shiva sunbeam, Blue oakleaf, Danaid eggfly, Gladeye bushbrown, Malabar tree nymph, Tailed palmfly, *etc*. Common lineblue and Common crow and Common Emigrant are most abundant butterflies in the study area.

The size of butterflies varies significantly among families with the largest sized butterflies recorded in Papilionidae and Nymphalidae and smallest sized butterflies from Hesperidae and Lycanidae. The factors that determine the butterfly detection during the count was determined using multiple regression. The number of detections had linear relation with abundance and size of the butterflies. The model was highly significant and explained 31.3% of variation in the detection of butterflies ($F=41.08$; $df=3$; $p<0.00$). Abundance had primary influence on detection followed by size of the butterflies. In present study only size and abundance showed significant influence on detection. Further studies on relative detectability of difference species of butterflies in the diversity and abundance estimation would help in refining methods of assessment.

Developmental stages of Grass demon (*Udaspes folus)* and Nilgiri Grass Yellow (*Eurema nilgiriensis*) were studied. Nilgiri grass yellow butterfly eggs development on Red Creeper *Ventilago* sp. were studied. The eggs were hatched on third day and there were two rapid growth phase and complete development took 21 days.

Development of Grass demon was monitored in three different host plant Red ginger (*Alpinia purpurata*), Ginger (*Zingiber officinale*) and Turmeric (*Curcuma longa*). The number of days for the development varied in different host with lowest in Red ginger followed by Turmeric and Ginger with 18, 20 and 23 days. There were significant difference in the larval growth between the Ginger and Red ginger ($t=-3.09$; $df=17$; $p<0.01$).

Nutrient content of host plants of Grass demon were determined using standard procedure. Nutrient content of selected host plants such as crude protein, total ash, crude fat and moisture content were higher in Ginger followed by Turmeric and Red ginger. The mean size increase of caterpillar was higher 0.278 in Ginger than other two host plants, but the number of days took for development was higher. Higher protein in the host plant could have resulted in the increased size of the caterpillar and longer duration of development. Parasites of Braconidae and Chalacididae family were observed to parasitize larva and pupa of Grass demon.

The major threats for the butterfly species recorded were the invasion of weed plants, fire and cattle grazing that threatens the host plant abundance and butterfly abundance in the study area.

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ABSTARACT

POPULATION DENSITY, DIVERSITY AND DEVELOPMENTAL STAGES OF SELECTED BUTTERFLY SPECIES IN CHIMMONY WILDLIFE SANCTUARY, KERALA

ANJU V.
(16-02MS-001)

Abstract of Dissertation Submitted in Partial Fulfilment of the Requirement for the Degree of

MASTER OF SCIENCE
(Wildlife Studies)

Faculty of Veterinary and Animal Sciences
Kerala Veterinary and Animal Sciences University

2018

CENTRE FOR WILDLIFE STUDIES
COLLEGE OF VETERINERY AND ANIMAL SCIENCES
POOKODE, WAYANAD, KERALA, INDIA

ABSTRACT

Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala was studied from April to June 2018. A total of 141 species of butterflies belonging to two orders, six families and 103 genera were recorded. Among different butterflies, 15 species were recorded as endemic and 20 species were reported under various schedules. The majority of butterfly species were belong to family Nymphalidae and Lycanidae. The species richness and species diversity was higher in Semi-evergreen forest (114) and the dominance was higher in the moist deciduous forest (0.09). Endemic species recorded were Indian Ace, Orchid Tit, Shiva sunbeam, Blue oakleaf, Danid eggfly, Gladeye bushbrown, Malabar tree nymph, Tailed palmfly, *etc*. Common lineblue and Common crow and Common Emigrant are the most abundant butterflies in the study area.

The size of butterflies varies significantly among families with the largest sized butterflies recorded in Papilionidae and Nymphalidae and smallest sized butterflies from Hesperidae and Lycanidae. The factors that determine butterfly detection during the count was determined using multiple regression. The number of detections had linear relation with abundance and size of the butterflies. The model was highly significant and explained 31.3% of variation in the detection of butterflies ($F=41.08$; $df=3$; $p<0.00$). Abundance had primary influence on detection followed by size of the butterflies. Further studies on relative detectability of difference species of butterflies in the diversity and abundance estimation would help in refining methods of assessment.

Developmental stages of Grass demon (*Udaspes folus)* and Nilgiri Grass Yellow (*Eurema nilgiriensis*) were studied. Nilgiri grass yellow butterfly eggs were hatched on third day and there were two rapid growth phase and complete development took 21 days. Development of Grass demon was monitored in three different host plant Red ginger (*Alpinia purpurata*), Ginger (*Zingiber officinale*) and Turmeric (*Curcuma longa*). The number of days for the development varied in different host with lowest in Red ginger followed by Turmeric and Ginger with

18, 20 and 23 days. There were significant difference in the larval growth between the Ginger and Red ginger ($t=-3.09$; $df=17$; $p<0.01$).

Nutrient content of host plants of Grass demon, such as crude protein, total ash, crude fat and moisture content were higher in Ginger followed by Turmeric and Red ginger. Crude protein, total ash and crude fat and moisture content was higher in the Ginger. The mean size increase of caterpillar was higher 0.278 in Ginger than other two host plants, but the number of days took for development was higher. Higher protein content in the host plant could have resulted in the increased size of the caterpillar and longer duration of development.

The major threats for the butterfly species recorded were the invasion of weed plants, fire and cattle grazing that threatens the host plant abundance and butterfly abundance in the study area.

APPENDICES

KERALA VETERINARY AND ANIMAL SCIENCES UNIVERSITY

Centre for Wildlife Studies

PROGRAMME OF RESEARCH WORK FOR DISSERTATION FOR MASTERS DEGREE

(Vide Rule 25(b) of Post Graduate Regulations 1998)

1. Title of Dissertation

Population density, diversity and developmental stages of selected butterfly species in Chimmony Wildlife Sanctuary, Kerala

2a. Title of departmental/KVASU research project of which this forms a part

Nil

2b. Code No. if any, and order by which the departmental/KVASU research project is approved

Nil

3a. Name of the student

Anju V.

3b. Admission No.

16-02MS-001

4a. Name of the Major Advisor (Guide)

Dr. Biju S.

4b. Designation

Officer in Charge,
Centre for Wildlife Studies,
College of Veterinary and Animal Sciences, Pookode, Wayanad – 673576

5. Objectives of the study

1. To estimate population density and diversity of butterflies in relation to environmental and anthropogenic factors in Chimmony Wildlife Sanctuary
2. To study the developmental stages of selected butterfly species in different host plants in relation to nutritional composition of host plant
3. To identify threats to the butterfly population in the sanctuary and to suggest management measures to minimize them

6. Practical/Scientific utility

Butterflies are essential part of any natural ecosystem as their adults perform pollination and larvae act as primary herbivores thereby transferring radiant energy trapped by plants to the next trophic level, thereby rendering dual roles as pollinators and as energy

transferors. Butterflies are good indicator species to monitor ecological changes in a habitat (Sreekumar and Balakrishnan, 2001). Among insects, butterflies are the most studied group (Larsen, 1988).

A preliminary survey on literature revealed that there was no previous study or research on the topic in Chimmony Wildlife Sanctuary. The sanctuary, with its varied habitat, stands as one of the important areas for conservation of a wide variety of butterflies. Hence, the present study is designed to estimate diversity and abundance of the butterfly species of the sanctuary. The estimated population size can be used as baseline data for further monitoring and to assess population trend.

7. Important publications on which the study is based

Larsen (1988) observed that maximum number of species was observed at low and middle elevations.

Rodriguez and Baz (1995) observed that abundance and species richness were highest at low elevations and declined with increasing altitude.

Kunte (1997) studied seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. The species richness was highest in late monsoon and early winter. Majority of the butterfly species also showed abundance peaks in these seasons. Fire played a significant role in determining species composition in fire-affected areas and affected flight periods of some species, but did not affect species richness. Grazing had a major impact on species composition and favoured only those Lycaenids and Nymphalids whose caterpillars fed on herbs.

Sreekumar and Balakrishnan (2001) studied habitat and altitude preferences of butterflies of Aralam Wildlife Sanctuary. The low diversity levels observed at the low elevation when compared to the mid elevation ranges might be due to cattle grazing, fuel wood collection and related man-made activities which affected larval food plants.

Shobhana *et al.* (2010) observed the feeding, growth and reproductive behaviour of *Papilio*

polytes (Common Mormon Butterfly) on five different host plants, *Murraya koengii*, *Toddalia asiatica*, *Glycosmis pentaphylla*, *Aegle marmelos* and *Citrus medica*. The growth rate of *P. polytes* was fastest on *M. koengii* followed by *T. asiatica*, *C. medica*, *G. pentaphylla* and *A. marmelos*. They related this to nutrient contents of five plants. The plants *T. asiatica* and *C. medica* had higher water content, which influenced the growth rate of the insect. *M. koengii* was found to contain high quantities of carbohydrate. *M. koengii*, *T. asiatica* and *C. medica* were also rich in protein when compared to *A. marmelos* and *G. pentaphylla*. Total amino acid levels were comparatively higher in *M. koengii*, *T. asiatica*, *C. medica* rather than *A. marmelos* and *G. pentaphylla*. They examined the influence of host plants on feeding, growth and reproduction of the Common Mormon.

Majumder *et al*. (2012) observed that mature secondary mixed moist deciduous forests showed maximum diversity and species richness, while exotic grasslands showed minimum diversity and species richness.

Many studies revealed that species diversity had strong relationship with habitat types. Species richness in five different habitat types was found to be comparatively different. The highest species diversity was recorded in scrub lands, followed by river beds and lowest along roads (Nidup *et al*., 2014)

Gallien *et al.* (2017) observed that biological invasions were the second-largest global threat for biodiversity. Once introduced, exotic plant species could modify ecosystem composition, structure and dynamics, eventually driving native species to local extinction. Among the groups of organisms, most likely to be directly affected by exotic invasive plants were herbivorous insects, such as butterflies, which strongly depended on plants throughout their life cycle. However, it remained unclear whether invasive plants had a negative or a positive effect on butterfly diversity at a landscape scale.

8. Outline of the technical programme

i. Study area

Chimmony Wildlife Sanctuary lies within the geographical extremes of longitudes of 26' N and 10 degree 26' N longitude 76 degree 37' E in Thrissur district of Kerala state, Mukundapuram Taluk (George, 2012). It was formed in 25th September 1984. The sanctuary consists of parts of Kodassery Reserve with an extent of 85.07 sq. km. The mean annual rainfall is 3130 mm. The sanctuary has tropical humid climate, with three distinct seasons, dry season (December to March) followed by the South-west monsoon (April to July) and North-east monsoon (August to November). Temperature varies from 38.5℃ to 15.6℃ in different seasons. The minimum temperature falls below 15.6℃ during December. The area is also vulnerable to forest fires during dry season. The sanctuary has more than 250 streams and six man made water holes (George, 2012). Previous studies in the sanctuary reported 24 species of butterflies. Diverse vegetation, climatic condition could support many species of butterflies, hence the present study is planned in the Chimmony Wildlife Sanctuary.

ii. Population density and diversity

The study area will be stratified based on habitat types and square grids of one square kilometer will be overlaid in the sanctuary area map. In total 25 percent of grids cells will be selected. In each habitat, transects of 500m will be laid in the selected grid cells to estimate butterfly density and diversity. The adequacy of sample size will be determined based on species-area accumulation curve. In addition to transect surveys, butterflies mudpuddling and congregation sites will be surveyed to maximize the species detection. Systematic butterfly counts in transects will be carried out to estimate butterfly population density form April 2018 to June 2018. Environmental variables such as habitat, fire, altitude, grazing, weed density and climatic condition will be assessed. The factors such as habitat, transect, environmental variables and their effect on species density and diversity will be elucidated.

iii. Developmental stages of selected butterfly species

Larval growth and developmental stages of selected butterfly species will be studied in different host plants. When adult female of selected butterflies lays eggs, its location, host plant and number of eggs will be recorded. Eggs will be monitored until hatching on a daily basis. After hatching of eggs, larval stage photographs, morphometric measurements and weight gain will be taken for every day and for each instar stages until pupation. The pupae will be monitored until emergence to calculate duration of pupal stage. The host plant nutritional components will be assessed by subjecting the leaves to various biochemical analysis. The compounds such as total protein, lipids, carbohydrates, amino acids, nitrogen and water content will be estimated using standard protocol (Shobhana *et al*., 2010). The relation between growth rate of caterpillars and host plant biochemical components will be analysed.

iv. Threats

Threats due to management activities and the anthropogenic factors will be assessed to suggest better management practices that promote butterflies conservation of butterflies in Chimmony Wildlife Sanctuary. Each butterfly species response to invasive plants (*i.e.* positive, neutral or negative) will be assessed and the functional characteristics of these different groups of species will be assessed.

9. Main items of observations to be made

1. Population and diversity of butterfly species in Chimmony Wildlife Sanctuary
2. Effect on environmental factors on butterfly density
3. Threats to butterfly species and methods to minimize them

10. Facilities

a. **Existing**: Camera

b. **Additional facilities required**: Field guide/ Tracker, Reference Books on butterflies, Mini Digital Weighing Pocket Scale

11. Duration of study: One Semester

12. Financial estimate

S. No	Materials	Co

		st
1	Forest tracker	15 000
2	Reference books	22 00
3	Digital scale (100g × 0.01g)	20 00
4	Miscellaneous	40 00
5	Total	23 200

13. Signature of student

14. Signature of Major Advisor

Place: Pookode

Date:

15. Name, designation and signature of members of the Advisory Committee

1. Dr. Biju S. (Guide)
Assistant professor
Department of Livestock Production and Management,
College of Veterinary and Animal Sciences, Mannuthy

2. Dr. Senthil Murugan
Assistant professor
Department of Animal Nutrition,
College of Veterinary and Animal Sciences,
Pookode

3. Dr. George Chandy
Officer in Charge,
Centre for Wildlife Studies,
College of Veterinary and Animal Sciences,
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Appendix I

References

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Appendix II

Time frame of Work

Semester IV

1. Field observations
2. Lab work for analysis of components in host plants
3. Data collection and analysis
4. Interpretation of results
5. Dissertation writing

APENDIX II

Time frame of Work

Semester I
Collection of literature
Planning and preparation of
Programme of research work

Semester II
Collection of literature

Semester III
Collection of literature
Review of literature

Semester IV
Collection of data and analysis of results
Interpretation of results
Preparation of results and submission

CERTIFICATE

Certified that the research project has been formulated observing the stipulations laid down under the Prevention of Cruelty to Animals Act (Amendment, 1998).

Place: Pookode **Dr. Biju S**.

Date: **Guide**

CURRICULUM VITAE

Name of Candidate	**: Anju V.**
Date of Birth	**: 15-5-1995**
Place of Birth	**: Kerala**
Marital Status	**: Unmarried**
Major Field of Specialization	**: Wildlife Science**
Permanent Address	**: Valiyaparampil (H)** **Ramankary P.O.** **Alappuzha** **Pin: 689595**
Educational Status	**: B.Sc. Zoology**
Professional Experience	**:**
Number of Publications	**: NIL**
Membership in Professional Bodies	**: NIL**