1.

Introduction

CHAPTER I

1. INTRODUCTION

Survivor planet- the Earth, is a huge biological system where we- humans- inhabit. It's the complex globe of multiple great biomes. These biomes serve as composite market of different biological systems. Biological systems do not only involve humans but it's a marvellous blend of plants, animals, rivers, mountains and climate. If given a thought to a simple hypothetical situation that- one of the above elements is over dominated by the other, one will definitely point out the human beings lie head high to conquer these natural elements, today!!!

The diversity of life is one of the most striking aspects of our planet; hence knowing how many species inhabit Earth is among the most fundamental questions in science (Mora et al., 2011). Today, there is an urgent need of not only the in-depth research on diversity but also to induce it for conservation. Diversity studies leads to the destined path of conservation. Biodiversity is the variety of different types of life found on the Earth and the variations within species. It is a measure of the variety of organisms present in different ecosystems. The richness of biodiversity depends on the climatic conditions and area of the region.

Global diversity patterns are one of the most dynamic systems designed by nature. Truly, this is the present scenario of global biodiversity which seem to be under the threat of human beings and its related ambiguities. Insects form one of the major components of this biological diversity. By far now, they are the most successful living organisms on Earth, starting their existence from Devonian period to the present scenario dedicated for conserving biodiversity. World Wildlife Fund strictly quotes- "The world is currently undergoing a very rapid loss of biodiversity comparable with the great mass extinction events that have previously occurred only five or six times in the Earth's history" This is an alarming call of these tiny scraps of biodiversity which now have scarce appearance

surrounding the huge human kingdom. In sustainable environment, resources should be utilized in such a way that it not only satisfies the need of the present generation but also saves it for the future generations.

1.1 Prior research work in Lepidopterology

Prominent stalwarts have worked on butterflies as well as moths whose works are frequently referred even today! Numerous prior contributions were given in the field of Lepidopterology which are chronologically listed in Table 1.

Table 1: Major contributions in the field of Lepidopterology

Sr No	Year	Contributions by Stalwarts in the field of Lepidopterology
1	1880-1881	Lepidoptera of Ceylon – F. Moore
2	1883	The Butterflies of India, Burma and Ceylon Vol-I Lionel de Niceville & G. F. L. Marshall
3	1886	The Butterflies of India, Burma and Ceylon Vol-II- Lionel de Niceville
4	1890	The Butterflies of India, Burma and Ceylon Vol-I- Lionel de Niceville
5	1890	Lepidoptera Indica- Moore
6	1891	Hesperiidae Indicae- E.Y.Watson
7	1907	Lepidoptera Indica- Swinhoe
8	1924	Butterflies of India (Antram, 1924)
9	1927	Identification of Indian Butterflies, reprinted in 1932 (Evans, 1932)
10	1939	Fauna of British India- Vol-I (Talbot, 1939)
11	1947	Fauna of British India- Vol-II (Talbot, 1947)
12	1957	The Butterflies of the Indian Region (Wynter Blyth, 1957)
13	1996	Butterflies of the Western Ghats, India (including Sri Lanka): A biodiversity assessment of a threatened mountain system (Gaonkar, 1996)

With the beginning of the 21st Century, many institutes got involved in the Rhopaloceran studies and therefore, provided wide literature sources in India. In 2008, Zoological Survey of India published a classic handbook on common butterflies of Uttarakhand (Kumar, 2008). A year later, ZSI published handbook on butterflies of Himachal Pradesh (Arora et al., 2009). Later on after few years, Kerala Forest Research Institute published detailed report on butterflies of Nilgiri Biosphere Reserve (Mathew, 2011).

In the ancient Greek *'lepido'* means scales and *'ptera'* means wings, hence the term Lepidoptera means insects with scaly wings. The term 'Lepidoptera' was coined by Linnaeus in 1735.

Order Lepidoptera is considered to be one of the largest orders of Class Insecta, comprising of moths and butterflies. The scientific study of Lepidoptera is known as Lepidopterology.

1.2 Butterfly Diversity in Indian Sub-continent

Butterflies were no longer unknown to the naturalists and keen researchers. Diversity studies of butterflies were not known until the early 19th century.

Approximately, 1,74,250 lepidopteran species are described, of which estimated number of butterfly species are 17,950 and rest make up for moths (Palot et al., 2012). Majority of the butterfly species occupy the tropics, but certain diversity has also been observed other continents around the globe, except Antarctica. The numerical family wise distribution of butterflies around the World, Indian region and Western Ghats is shown in Table 2.

Researchers, academicians and amateurs have started studying the butterfly diversity in different parts of India. In 2012, team of academicians conducted the studies on biodiversity of butterflies in Ambasamudram taluka of Tirunelveli district of Tamil Nadu and recorded a total of 23 species belonging to 19 genera, of which, members of family Nymphalidae was found to be maximum (Elanchezhyan et al., 2012).

Table 2: Family-wise distribution of butterflies recorded from the World, Indian region & Western Ghats

Sr No	Families	World	Indian Region	Western Ghats
1	Papilionidae	573	107	19
2	Pieridae	1200	109	35
3	Nymphalidae	6000	522	97
4	Lycaenidae	6000	443	103
5	Hesperiidae	3050	321	80
Total		16823	1502	334

(Source: Butterflies (Lepidoptera: Rhopalocera) of Western Ghats, Zoological Survey of India, Calicut)

Collaborative team of authors have studied butterfly diversity in 9 different talukas of Tiruvallur district of Tamil Nadu and recorded a total of 97 species from 63 genera, of which members of family Nymphalidae were found to maximum (Prabakaran et al., 2014). Academicians from University of Madras also carried out studies on butterfly diversity in the city of Chennai and observed a total of 47 species of butterflies (Thangapandian et al., 2014).

Studies on biodiversity of butterflies was conducted at four different sites in Eastern Ghats and a total of 70 butterfly species were identified (Venkata Ramana, 2010). The author also observed the migratory butterflies along with the mating behaviour of butterflies.

Not only in India, but studies on butterfly diversity is also being carried out in neighbouring countries of India. Studies on butterflies were conducted in Chuadanga district of Bangladesh and total of 49 species were recorded for the first time (Shihan, 2014). Team of authors from Azad Jammu and Kashmir in Pakistan also carried out studies on diversity of butterflies and reported a total of 28 species from 7 families and also showed that maximum diversity of butterflies was observed in Shaeed Gali and Gari Dopatta whereas lower diversity was observed in Kohala (Khan et al., 2004).

1.3 How habitat fragmentation will affect Rhopaloceran existence?

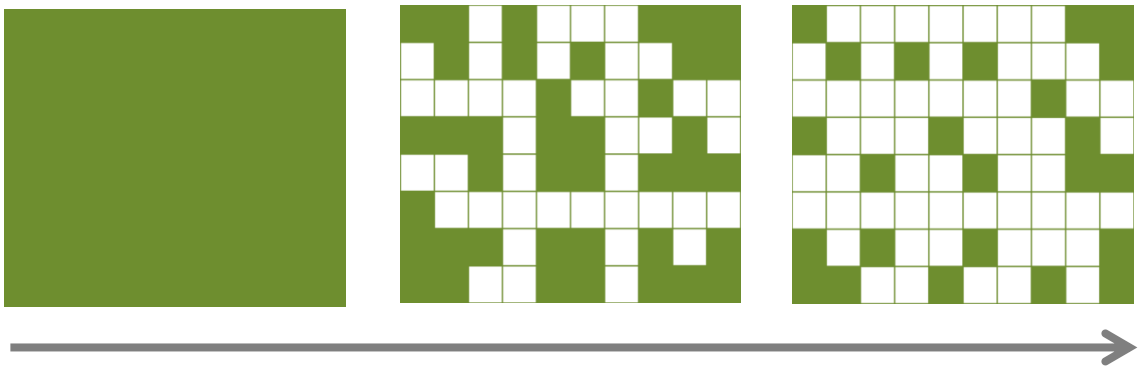


Figure 1: Schematic Representation for Process of Habitat Fragmentation
(The process of habitat fragmentation where a large area of habitat is transformed in to a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original. Green areas represent habitat and white areas represent matrix)

Habitat destruction and fragmentation pose a major threat on the biodiversity around the globe. Habitat fragmentation comprises discrete five phenomena: (i) Decrease in the total area of the habitat (ii) Decrease of the interior : edge ratio (iii) Separation of one habitat fragment from other areas of habitat (iv) Breaking up of one patch of habitat into several spatches (v) Reduction in the average size of each patch of habitat (Didham, 2010).

The development of discontinuities in an organism's preferred habitat causes population fragmentation and ecosystem decay is designated by habitat fragmentation. The layout of the physical environment is altered by geological processes and leads to habitat fragmentation. Moreover, human activities like land transformation can alter the environment and causes eliminations of many species.

Natural reasons and effects

Indication of habitat destruction through natural processes such as volcanism, fire, and climate change is found in the fossil record. For example, habitat fragmentation of tropical rainforests in Euramerica 300 million years ago led to a great loss of amphibian diversity, but simultaneously the drier climate spurred on a burst of reptiles diversity (Sahney et al., 2010)

Human reasons

When native vegetation is cleared due to human activities like (i) agriculture, (ii) rural development, (iii) urbanization and (iv) the creation of hydroelectric reservoirs causes habitat fragmentation. The continuous habitats get divided into small fragments.

After exhaustive clearing, the separate fragments tend to be very small islands isolated from each other by cropland, pasture, pavement, or even barren land. The barren land results from slash and burn farming in tropical forests. 90% of the native vegetation has been cleared from the wheat belt of NSW, Australia whereas in North America over 99% of the tall grass prairie has been destroyed, resulting into extreme habitat fragmentation.

Implications

One of the main actions of habitat fragmentation leads to the reduction in existing habitat such as (i) oceans (ii) marshlands (iii) boreal forests (iv) rainforests which are utilized by various organisms as their niche affects the biodiversity. Habitat destruction is caused by habitat fragmentation. Sessile organisms like plants in these fragmented habitats are directle damaged and destroyed. Wheareas the mobile animals can relocate themselves into remaining habitat patches which leads to increase in competition and crowding effects.

The remaining habitat fragments may be smaller or adjusted from than the original habitat. Species can move between fragments which use more than one fragment and can survive normally but with no change in breeding activity. Species that cannot move between fragments evolve through a process known as Speciation.

Speciation occurs when a group within a species separates from other members, as a result of habitat fragmentation from its original species and hence develops its own unique characteristics to survive in the new environment. The characteristics of the members of the new fragment along with the hassels of a different environment will differentiate the new species from their families before fragmentation occurred.

Reduced viability

Area is the main factor of the number of species in a fragment. The present number of species is affected by the size of the fragment and also affects the will affect the ability of these species to persist in the fragment. Such small fragments can support small populations of plants and animals, which are more prone to extinction. The large populations are not much affected by the climatic fluctuations, resources or any other factors but can prove to disastrous in the small, isolated populations. Thus, fragmentation of habitat is an important cause of species extinction.

Furthermore, habitat fragmentation leads to edge effects. The ecology around the fragment along with the interiors and exteriors of the fragment are altered by the microclimatic changes in light, temperature and wind. The areas with lower humidity along with high temperatures and wind levels experiences fires. Such disturbed environments show the occurrences of pest species and the natural ecology is also affected by the cattle. Moreover, the habitat along the edge of a fragment exhibits varied climate and harbours different species as compared to that from the interior habitat. Small fragments are therefore disapproving for species which require interior habitat.

Conservation implications

Habitat fragmentation is often a reason of species becoming near threatened or threatened. The survival of any species is dependent on the existing available habitat whereas the remaining fragmented habitat becomes a significant concern for the conservation biologists to look upon.

One solution to the problem of habitat fragmentation is to link the fragments by preserving or planting corridors of native vegetation. Mitigation to the sepeartion problem is such preservation which does not result into habitat loss. Another mitigation measure is the development of small habitat patches which increases interior habitat. This may be impractical since developed land is often more expensive and could require significant time and effort to restore.

The diverse vegetation types in the Peninsular India have their geographical significance and importance to butterflies. Habitats range from the tall evergreen forests to semi-evergreen forests, from dry and moist deciduous forests to the scrub and savannahs. Habitat type also includes the riparian forests to Shola forests and Bamboo forests (Kunte, 2000).Researchers have carried out multiple studies in different habitats of India. Variety of habitats shows the existence of rhopalocerans depending on the type of forests and vegetation. Lone author carried out studies on butterfly diversity studies in the tropical moist deciduous sal forests of Ankua reserve forest of Saranda division in Jharkhand and revealed a total of 71 species belonging to 5 families and 56 genera. The author also suggested for the long term conservation of these forests and hence ensuring the protection of biodiversity (Singh, 2010).

Further in the north, study was conducted on butterflies of Kedarnath Musk Deer Reserve in Garhwal Himalaya and prepared a checklist of 147 species belonging to 5 families (Singh, 2009). Along with its checklist preparation, the author also focused on their seasonality, altitudinal distribution and relative abundance. Lone author carried out studies on butterfly diversity in Sanjay Gandhi National Park, which is situated in one of the most populated cities of India- Mumbai and prepared a comprehensive checklist of 172 species of butterflies belonging to 5 families (Kasambe, 2012) and also studied the range extension of Dark Blue Tiger *Tirumala septentrionis*.

Butterfly diversity in Mangrove forest in Bangladesh was also studied (Hossain, 2014) and recorded a total of 37 species of butterflies and put forth the idea to continue butterfly study in that particular mangrove forest. Butterfly diversity at Dachigam National park in Jammu and Kashmir was also studied (Qureshi et al., 2014) and total of 27 species distributed in 24 genera were recorded. Tropical Forest Research Institute at Jabalpur Madhya Pradesh was no exception in studying the butterfly diversity (Tiple, 2012) and total of 66 species were recorded belonging to 47 genera and 5 families and also suggested that favourable changes in garden landscaping and maintenance can increase the butterfly diversity. It’s always a pleasure to know that to present status of butterflies is excellent when studied in such reserve forests and wildlife sanctuaries. But as we always say, a coin has two sides and hence, there is a need to study this form of diverse

insects in the fragmented habitats. Global diversity is under a major threat of habitat fragmentation (Saunders et al., 1991). Study was conducted on the butterfly community structure in fragmented habitats of 33 calcareous grasslands in Southern Lower Saxony near Gottingen in Germany and revealed a total of 54 species of butterflies and 193 species of plant in selected grasslands. The author have suggested on the conservation of large fragmented habitats for butterfly diversity whereas for certain 'specialized' species are more affected by the habitat fragments and hence face threat of being endangered.

1.4 How climatological seasonal factors will influence distribution of Rhopalocerans?

The India Meteorological Department (IMD) designates four climatological seasons:

Winter, occurs from December to March. The year's coldest months are December and January, when temperatures average around 10–15 °C in the northwest; temperatures rise as one proceeds towards the equator, peaking around 20–25 °C in mainland India's southeast.

Summer or **pre-monsoon** season lasts from April to June (April to July in northwestern India). In western and southern regions, the hottest month is April; for northern regions, May is the hottest month. Temperatures average around 32–40 °C in most of the interior.

Monsoon or **rainy** season lasts from July to September. The season is dominated by the humid southwest summer monsoon, which slowly sweeps across the country beginning in late May or early June. Monsoon rains begin to recede from North India at the beginning of October. South India typically receives more rainfall.

Post-monsoon or **autumn** season lasts from October to November. In northwestern India, October and November are usually cloudless. Tamil Nadu receives most of its annual precipitation in the northeast monsoon season.

Climate change is one the major factors affecting the developmental as well as physiological changes in insects. Amongst varied insects, butterflies are one such group

which is sensitive to the environment. In West Bengal, seasonal diversity of butterflies was studied in Upper Neora Valley National Park and revealed a total of 161 species of butterflies (Sengupta et al., 2014) and showed that members of family Nymphalidae were maximum and concluded that autumn followed by monsoon showed high species richness due to abundance in vegetation which provides food to larval stages.

Along with climate, the altitudinal gradient also affects the butterfly diversity. Duo authors from Kolkata (Ghorai & Sengupta, 2014) studied distribution of papilionid butterflies along with their larval host plants and explored a total of 26 species of butterflies and 35 species of plants serve as larval host plants for these butterflies. Along with that the authors also reported monophagous nature of butterflies.

Climate change has also affected the lepidopteran behavior. Migration plays an important role in life of lepidopterans. Such an important behavior of lepidopterans is highly influenced by climate change. Study in UK was conducted on the migratory species of lepidopterans and showed that migration in lepidopterans is strongly influenced with the rising temperatures (Sparks et al., 2007).

Hence with the increase in temperature, there is an increase in the migratory species of lepidopterans which will have strong invasion consequences. Multiple factors affect the community structure of lepidopterans.

Duo authors from Hungary in detailed reviewed the major climatic factors influencing the existence of lepidopteran species including the temperatures, atmospheric CO_2 concentration, drought, etc. (Hufnagel & Kocsis, 2011). They also concluded with a view that there are certain adaptable species and also conditions necessary for successful invasion to new territories.

Combining factors like climate change and habitat type play very important role in diversity of butterflies. Collaborative team of authors conducted study on seasonal population and migration of butterflies in coastal plains of Kalpakkam of South India (Ramesh et al., 2013) and revealed a total of 66 species of butterflies and showed that the butterfly diversity was higher during the beginning and end of North east Monsoon.

1.5 Life cycle of a butterfly

Unlike other insects, butterflies do not show nymph stage. Hence, being one of those holometabolous insects, butterfly undergoes complete metamorphosis. The life span of a butterfly shows four distinct stages in their life cycle- Egg, Larva, Pupa and Adult. Larva of a butterfly is known as caterpillar and pupa is also known as chrysalis. Butterflies have short life spans of nearly one month but again it is dependent on the species. Butterfly tends to show one or more broods per year and hence exhibit multivoltinism.

Egg

After mating, adult female search for a suitable food plant to lay eggs. Most butterfly species lay eggs on one or few selected plant species, either singly and others in batches. Generally adult female lays egg on the underside of the host plant's soft and tender leaves. Butterfly eggs can be in a shape of tall jar or wicker basket, spherical, disc shaped or button shaped while some are spiny. Fact is an egg can be as small as a pin head (Kehimkar, 2008). Many butterfly species exhibit specific ornamentations on the surface of the eggs. These ornamentations comprises of tiny ridges and pits and polygonal cells (Kunte, 2000). Slightly hardened exterior covering of an egg protect the new life developed inside it. This egg shell is tough, consisting of chitin, is also known as chorion. The chorion is lined with a thin coat of waxy adhesive which fixes the egg when laid on the underside of the leaf. On top of the egg is the minute opening known as the micropyle which is situated in the micropylar pit.

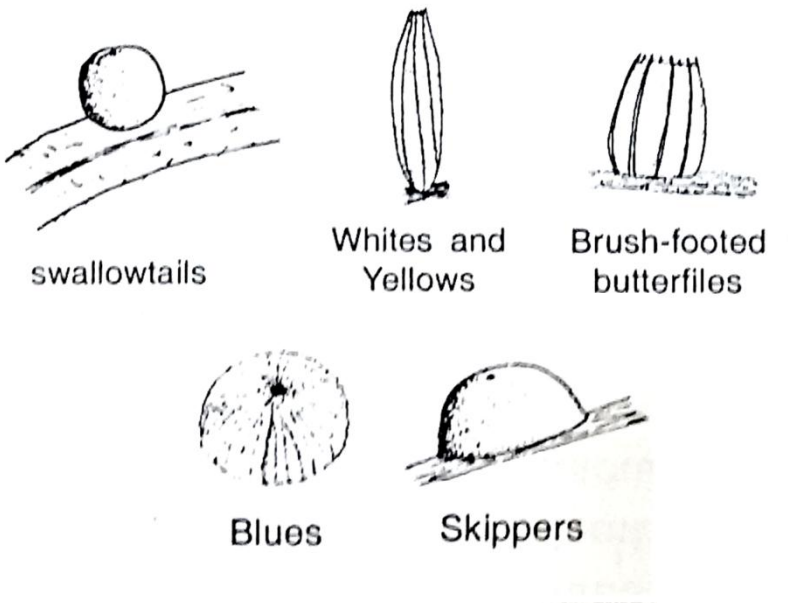
Micropyle plays a very crucial role in the life cycle of a butterfly. Micropyle serves as holes which allow the sperms to enter and fertilize the egg. Moreover, it's the site from where the caterpillars hatch. The egg is filled with nutritive fluid and possesses a transparent shell which becomes pale with the developing caterpillar inside. Before hatching, one can see the developing caterpillar inside the egg.

Larva- Caterpillar

Usually fertilized egg takes three days to one week to hatch. Biting through the egg shell, the caterpillar emerges from the egg. The caterpillars are considered as the swollen bag stuffed with organs, devoid of any hardened structures, except head (Kunte, 2000). Moreover, it is also said that caterpillars are multi-legged eating machines (Parasharya & Jani, 2007). As soon as the caterpillar emerges from the egg, the first food it consumes is its own egg shell. Thereafter, it feeds on its associated food plant. Caterpillars practically eat all the time in search of food and demolish every food plant. Most of the times, caterpillars spend time feeding on the food plant and in few days increases its weight several times. But during meagre availability of larval host plant, full growth is ceased. Hence food shortage, results into development of dwarf adult butterfly. Presence of a caterpillar on the food plant is indicated by the bitten leaves and small droppings (Kunte, 2000). Moreover, a few lycaenids are reported to be carnivorous. Lycaenids form mutual associations with ants and communicate with the ants through vibrations transmitted through chemical signals. The caterpillars of Lycaenids receive protection from ants and gather honeydew secretions.

Most of the caterpillars have smooth bodies. Certain species possess hairs, tufts or bristles. This stage is considered to be most vulnerable in a butterfly's life as they are predated by lizards, birds, spiders, assassin bugs and young hunting wasps (Kehimkar, 2008). The caterpillar's body grow rapidly but the skin attached along with it does not grow. The skin is considered to be the only binding and supporting structure of the caterpillar which is devoid of skeletons. This skin stretches so as to accommodate the developing caterpillar to its limit. Just before the process of apolysis, caterpillar stops feeding on the food plant and comes to rest. Caterpillars undergo a process of apolysis and mature through a series of stages called instars. During apolysis, cuticle is released from the epidermis and forms a new cuticle beneath. The larva moults out the old cuticle at the end of each instar. Apolysis initiates with the split behind the head of which the larva crawls out of it. A new cuticle is formed which hardens and become pigmented and hence the caterpillar resumes its feeding activity again. The process of molting usually takes place three to four times during its development.

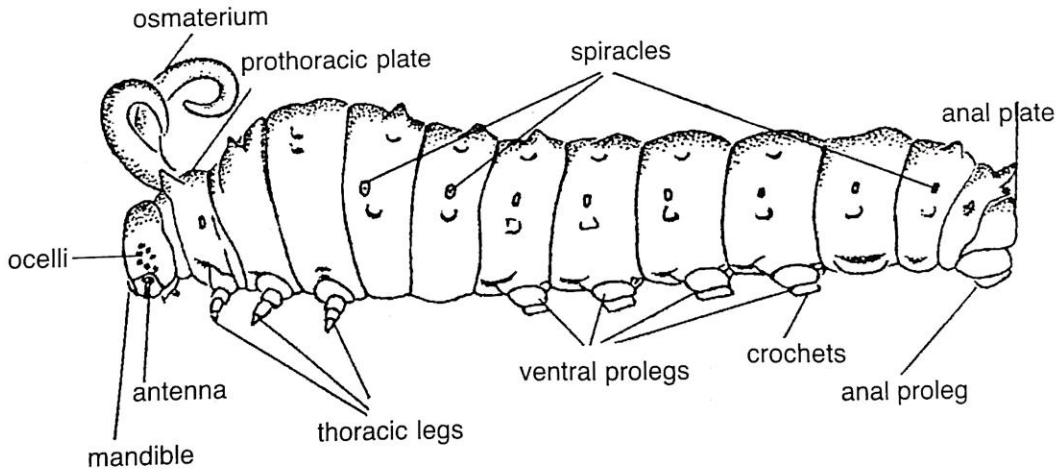
Stage: Egg



(Picture Courtesy: Butterflies of Gujarat, Parasharya & Jani, Anand Agricultural University, 2007, Page No: 4)

Figure 2: Egg Stage of Butterfly

Stage: Larva-Caterpillar



(Picture Courtesy: The Book of Indian Butterflies, Issac Kehimkar, Bombay Natural History Society, 2008, Page No: 11)

Figure 3: Larva-Caterpillar Stage of Butterfly

Caterpillars spend time feeding on the food plant and in few days increases its weight several times. But during meagre availability of larval host plant, full growth is ceased. Hence food shortage, results into development of dwarf adult butterfly. Presence of a caterpillar on the food plant is indicated by the bitten leaves and small droppings (Kunte, 2000). Generally caterpillars are herbivores like *Ariadne merione* whereas certain species are entomophagous like *Feniseca tarquinius* which predates on the ant-tended homopterans (Youngsteadt & DeVries, 2005). Moreover, a few lycaenids are reported to be carnivorous. Lycaenids form mutual associations with ants and communicate with the ants through vibrations transmitted through chemical signals. The caterpillars of Lycaenids receive protection from ants and gather honeydew secretions.

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The body of a caterpillar is cigar shaped and comprises of 14 segments. The 1st segments is the head, the second third and fourth are thoracic segments and 5th to 14thare the abdominal segments. The head is bilobed, separated by a central groove, produces small points or long horns on top. Surface of the head may be smooth, granular and plane or tubercled. Butterfly caterpillars possess biting and chewing types of mouth parts wherein the jaws works sideways. Behind the jaws is the silk producing organ known as the

'spinneret'. Caterpillars possess simple eyes which appeared as small bumps. It can sense light and darkness and detect shape and movement through simple eyes.

The second thoracic segment can be narrow and serve as neck which can twist and turn to its greater extent. A pair of small, true and jointed legs is present on each thoracic segment. These legs are used to grip the leaves on which the caterpillar feeds.

The abdominal segments 7^{th} to 10^{th} each possess pair of fleshy pro-legs which are present only during the caterpillar stage. These prolegs aid in holding the silk threats on the surface on which the caterpillar rests. An additional larger and fleshy pair of prolegs is present on the 14^{th} segment known as the 'claspers'. They are employed when the caterpillar suspended for pupation. The anus is covered with a fleshy flap and hence anus becomes invisible. Spiracles are situated on the lower side of the 2^{nd} and 5^{th} to 14^{th} segments. Spiracles are small pores which open inside the body through a network of microscopic tubes and communicate with the various body parts. The caterpillar and the adult breathe through spiracles. The heart and nervous system are spread throughout the body. A caterpillar cannot hear but can fill the vibration through food plant.

Pupa

When the caterpillar is fully grown, it ceases its feeding activity and wanders restlessly in search of a suitable pupation site. Pupa stage (Chrysalis) is considered to be the outline representation of the adult butterfly (Kunte, 2000). Before the last instar stops at its pupation spot, it removes the undigested food so as to clear its digestive tract. For the next 8-10 hours or longer, the caterpillar remains immobile. Caterpillar spins a pad of silk which firmly anchors itself to perch with the help of last pair of sucker legs. The caterpillar wriggles while attaching itself firmly to the pupation spot. While wriggling, the larval skin splits from tops of its head, extends backward and discarded. Mouthparts and legs are shed off along with the skin. The body becomes smaller in size, a bit stouter and in couple of hours it is entirely different from the caterpillar stage. Early pupal stage appears pale and soft which gradually darkens and hardens. Different species of butterflies forms pupa of a peculiar shape and pattern. During the pupal stage, the wings

are small and are closed to thorax on the lower side. The proboscis is straightened which lie in between the wing cases. All body parts along with the compound eyes, labial palpi and legs are clearly defined and differentiated in the pupa stage. Externally the pupa appears lifeless but a great activity and physiological changes takes place in the inner side. The duration of the pupal stage depends on vegetation season and weather conditions. Under suitable weather conditions and availability of adequate food plants pupal stage may last for one or two weeks. But the pupal stage may enter into the resting stage for few months or till next season under scarce availability of food plants so as to prevent desiccation.

This stage is also vulnerable in a butterfly's life but pupa protects themselves by developing certain devices. The pupal stage is completely immobile and hence to escape predation, they camouflaged to look like a leaf or a broken dry twig. While some other species shine conspicuously e.g. Pupa of a common crow which warns predators for its distaste full contents.

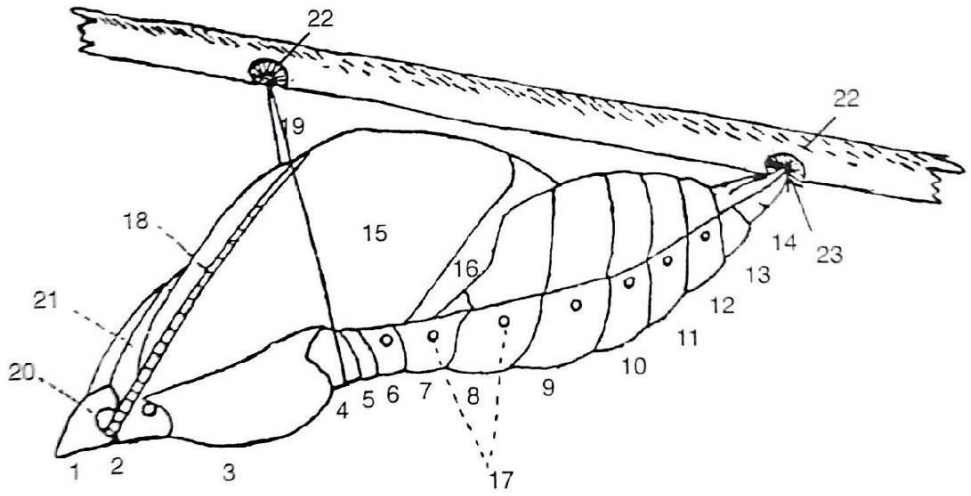
Adult

Soon after emergence from the pupa, butterfly's life enters into the most crucial phase of adult. The emergence of a butterfly from its pupa is one of the most fascinating sights of nature. The pupal case became transparent a night before its emergence, which allows the butterfly's wing to be seen. The colors of the wings grow dark by the morning and the pupal case splits open at the head.

The body of an adult butterfly is composed of head and 13 segments. The insect body is divided into head, thorax and abdomen.

A pair of club shaped antenna present on the **head** acts as receptors to scent the presence of the opposite sex. The segmented antennae are associated with the sense of smell. A pair of large compound eyes, a long tubular proboscis and a pair of labial palpi forms the major structure on the head. The compound eyes occupy most of the facial surface. It consists of large number of hexagonal lenses which covers the ommatidia. They are useful in detecting short range movements. Despite of presence of numerous lenses, the

Stage: Pupa

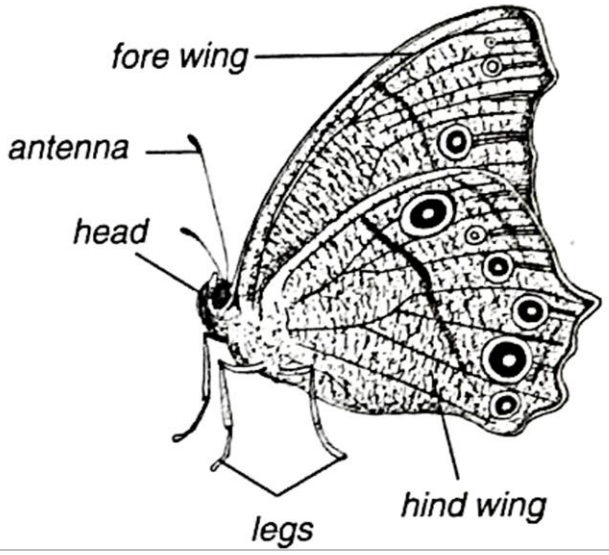


1. Head 2 to 4, Thorax 5 to 14. Abdomen, 15. Forewing, 16. Hindwing, 17. Spiracles, 18. Antenna, 19. Body band, 20. Eye, 21. Palpus, 22. Pads of Silk, 23.Cremaster

(Picture Courtesy: The book of Indian Butterflies, Issac Kehimkar, Bombay Natural History Society, 2008, Page No: 13)

Figure 4: Pupa stage of Butterfly

Stage: Adult



(Picture Courtesy: India-Lifescape Butterflies of Peninsular India, K. Kunte, University Press, 2000, Page No: 9)

Figure 5: Morphology of an adult butterfly

Butterfly has poor sight compared to the human vision. It can perceive ultraviolet light. Long tubular proboscis is made up of two highly modified mouth parts which are held together by series of hooks and spikes like zip chain. It helps in sucking the liquid food. The proboscis is kept coiled in front of its face. The proboscis is usually hidden, completely or partly, between the hairy labile palpi.

A short thin delicate and membranous neck attaches the head to the thorax region. The **thorax** appears to be compact and superficial externally but actually it's made up of three segments fused together. The first two segments of the thorax possess pair of wings each comprising the forewings and the hind wings. The wings are rigid but delicate. The wings are supported by the network of veins through which the blood circulates. These butterflies are majorly characterized by the presence of minute scales covering the wings. These minute scales are responsible for the coloration of butterfly wings. These scales have varied shape and sizes like long hair like appearance, rounded plates or broadly flattened. Being pigmented with melanin, these scales give black and brown colour to the wings. The red, green, blue other colours are not created by the pigments but the results of scattering light on the microscopic structure of the scales. Among such minute scales are the scent scales which help in chemical communication with the sexes. These scent scales are known as the androconia, which are attached to the scent gland in the wing membrane. These scent gland releases scent or pheromone to attract female during mating.

On the ventral side of the thorax each segment possesses a pair of legs**.** The legs are used for gripping. Each leg is comprised of multiple segments namely the hip joint known as the coxa at the base, a thigh known as the femur, a shank known as tibia and a foot which forms the tarsus, which possess 5 joints and the last bearing a pair of claws. These claws firmly hold the surface when the butterfly rest or suspend itself upside down. The foot possess the taste organs while some other species possess a spur with a brush of hair on the shank region used to clean the antenna e.g. members of family Nymphalidae the first pair of legs is highly reduced, imperfectly formed, small, clawless and not utilized for walking. Also other species like the forefeet of male Lycaenid possess only one claw whereas female Lycaenid have 2 claws.

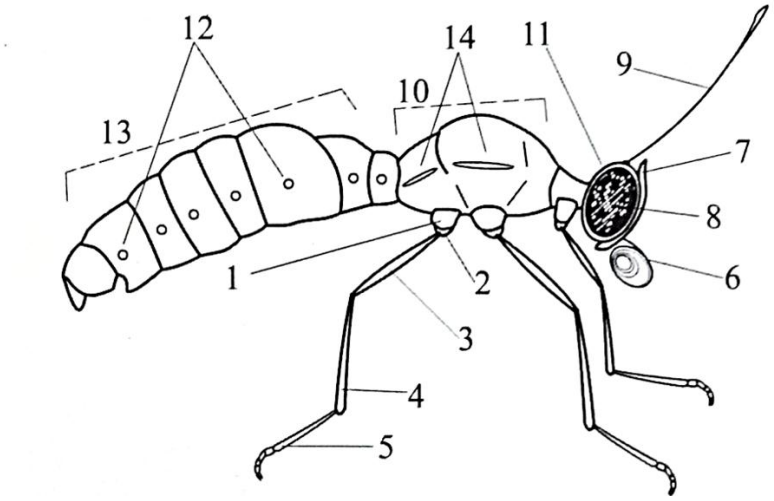
The butterfly wings are triangular in shape. The two sets of internal muscles, located in the thorax, control the movement of the wings. The raising and lowering of the wings is controlled by the contraction of the thorax by one set of muscles and expansion of the thorax by the another set. The small muscles present at the base of the wings control the direction and angle of wings during each stroke.

The wings have areas which have specific names. The specific areas are the *costa* which forms the leading edge, the *apex* which is the upper tip of the wing, following the apex is the *termen* which is the outer edge, *tornus* is almost at the right angle, *dorsum* forms the trailing edge and the *base* is the point where the dorsum joins the thorax region. In the hind wing region, the tornus forms the lowest point whereas the dorsum is the inside edge. The number, arrangement and distribution of veins in the wings are considered as an important tool for identification and taxonomy. '*Cell*' is a closed, oblong and large empty space, closed to the beginning of the wing. 10 to 12 thin black veins spread out from the base across the butterfly's wing. The '*marginal*' area is present along the termen and between the marginal area and cell is the '*disc*' or the '*discal*' area.

The forewing possesses the costal and subcostal vein that runs parallel to the costa. Radial, medial, cubital and anal veins are the branched veins that are distributed below the costal and subcostal veins. The forewings overlap the hindwings the humeral lobe situated at the base of the hindwing held both the pair of the wings in position. In case of moths, the wing coupling organ is the frenulum.

The **abdomen** of the adult butterfly is long cylindrical and slim. The abdomen comprises of 10 segments. Within this segmented abdomen are the organs of digestion, respiration, excretion and reproduction. The body of a butterfly is filled with fluid i.e. blood flow through the entire body and not in veins or arteries. This 'blood' does not carry oxygen but freely moves among the internal organs and supply nourishment throughout the body. Presence of the tubular heart helps blood to move along the entire body. All the organs of the body are supplied with oxygen through the network of tubules known as the trachea which opens to outside at body surface in form of pores known as the spiracles. Spiracles are located along both the sides of the abdomen. The visible abdomen is made of only

External morphology of an Adult Butterfly

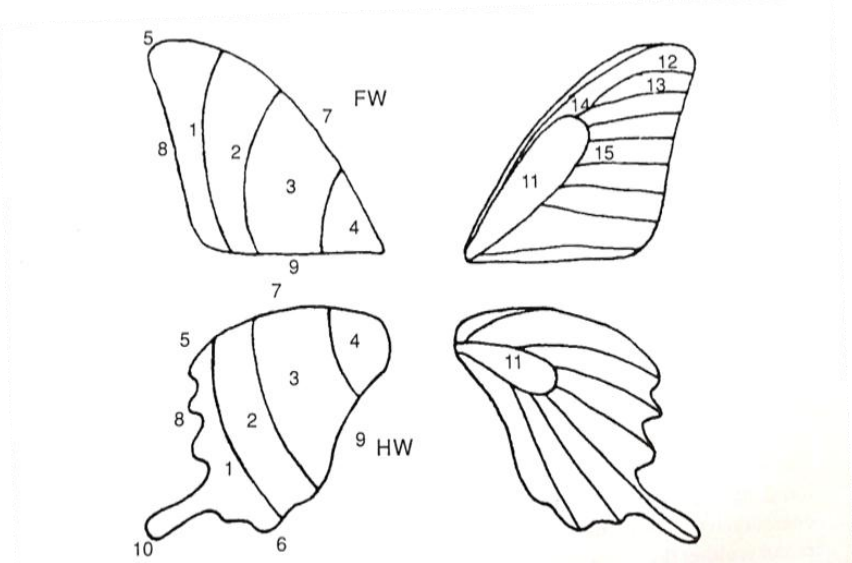


1. Coxa, 2. Trochanter, 3. Femur, 4. Tibia, 5. Tarsus, 6. Proboscis, 7. Palpus, 8. Eye, 9. Antenna, 10. Thorax, 111. Head, 12. Spiracles, 13. Abdomen, 14. Wing bases

(Picture Courtesy: The book of Indian Butterflies, Issac Kehimkar, Bombay Natural History Society, 2008, Page No: 4)

Figure 5: External Morphology of an adult butterfly

Wing Venation



1. Submarginal, 2. Postdiscal, 1&2. Distal, 3. Discal, 4. Basal, 5. Apex, 6. Anal angles or tornus, 7. Costa or costal region, 8. Termen or outer margin, 9. Dorsum or inner margin, 10. Tail, 11. Cell, 12. Apical, 13. Subapical, 14. Subcostal, 15. Median

(Picture Courtesy: The book of Indian Butterflies, Issac Kehimkar, Bombay Natural History Society, 2008, Page No: 6)

Figure 6: Wing and Wing Venation in an adult butterfly

7 - 8 segments. The last 2 segments form the reproductive organs. The reproductive organs of butterflies have specific 'lock and key' arrangement between male and female organs of a species which prevents cross mating between the species. The male reproductive organs comprises of the pair of claspers, ejaculatory organ and aedegus. Claspers are hooked structures present on sides of the 9^{th} segment that grasp the abdominal tip of female butterflies, hence keep the mating pair in correct position. Aedegus (sheath) encloses an ejaculatory organ, which is present between the bases of the claspers and functions in passing the spermatozoa to the female. These spermatozoa are stored in spermatheca, sac like structure, inside the body of female and released during egg fertilization.

The female reproductive organs comprises of ovipositor and ovaries. The 9^{th} and 10^{th} segments of the female abdomen fuses together to form a tube-like structure called as ovipositor, opening just below the anus. Eggs, produced by ovaries located anteriorly, are passed on to the ovipositor. Eggs are fertilized by the spermatozoa and hence laid through the posterior opening. It is said that in primitive species, the same opening is utilized for copulation while in advanced species copulation takes place through opening known as 'ostium bursae' which is located on the posterior surface of the 8^{th} surface (Kehimkar, 2008).

The complex nature of reproductive organs of butterflies play crucial role in identification of certain groups of butterflies. Subtle differences in genitalia structure may prevent mating between individuals of the same species, thus giving rise to two sexually isolated groups in a species. These structural differences in genitalia then maintain differences in other characters among closely related groups. These eventually become different species although outwardly they may look similar.

The antenna of male & female butterflies is similar. They always hold their antenna in front of their face. When at rest butterflies always fold their wings over their back holding them erect except skippers. The butterflies have prominent waist and usually thinner abdomen. Most of the butterfly species are diurnal in activity with certain exceptions which become active during dusk.

1.6 Rhopaloceran Study in Gujarat: THEN and NOW

Gujarat state was no such exception in observing rhopalocerans. Since the beginning of 20th century, observational studies on butterfly species gained its speed in entire Gujarat. A total of 46 species of butterflies was reported from Cutch (now known as Kachchh) especially Bhuj (Nurse, 1900). Later on from the Kathiawar region, total of 78 species of butterflies were reported mainly from Bhavnagar (Mosse, 1929). Somewhere in mid of 20th century, 59 butterfly species were reported from Kaira district (now known as Kheda district) from Central Gujarat (Aldrich, 1946). Post 1950s, extensive studies on documentation of butterflies started in Gujarat especially South Gujarat. Total of 145 species of butterflies were reported from South Gujarat along with 7 additional female species (Shull, 1963). Later after one year 5 more species were added upon to the previous list and thus made up for total of 150 species of butterflies (Shull, 1964).

With the commencement of 21st century, documentation of butterflies was carried out in full fledge in the wildlife sanctuaries of Gujarat. Research team from Saurashtra University carried out multiple documentation studies of butterflies and reported total of 62 species from Vansda National Park, 44 species from Ratanmahal Wildlife sanctuary and 34 butterfly species from Narayansarovar Wildlife sanctuary (Bhalodia et al., 2002a) (Bhalodia et al., 2002b) (Bhalodia et al., 2002c).Where as in North Gujarat, documentation of butterflies was carried out at Jessore Sloath Bear Sanctuary of Banaskantha district and listed a total of 26 butterfly species during their study (Suresh et al., 2001). Later on, after 2010, budding researchers started focusing on association of nectar resources with butterflies. Duo researchers from Arid Forest Research Institute of Jodhpur revealed total of 67 butterfly species from the dry deciduous forests habitats of Gir Protected Area, Sasan in Junagadh district (Sharma & Ahmed, 2013). Similarly studies on nectar resources which were utilized by butterflies, was also conducted in Gir Wildlife Sanctuary, Sasan. The study inferred that out of the total 50 butterfly species observed during study, 27 species utilized the floral nectar resources whereas the rest used the non-floral resources like mud, wet soil and cow dung (Sharma & Sharma, 2013).

Associative studies between butterflies and plants were carried out in different corners of Gujarat. Trio authors revealed a total of 43 species of butterflies belonging to 5 families were found to be associated with 110 plant species in Gandhinagar (Mali et al., 2014). The study also suggested that conservation of butterflies can be achieved when they are allowed to flourish in their own plant world and hence a healthy environment can be maintained. Some couple of years back, researchers have been focusing on the fragmented pockets of Gujarat to study the butterfly diversity. Duo authors from Kotak Institute of Science, Rajkot documented total of 15 species of butterflies from Hingolgadh area of Jasdan (Bhambhania & Vaghela, 2014). In their study, the authors suggested that with the increase in vegetation, there is an increase in butterfly diversity too.

A compiled checklist of 193 butterfly species was published in form of a book by Anand Agricultural University (Parasharya & Jani, 2007). The book clearly depicts that South Gujarat leads the list of maximum number of 74 butterfly species exclusive of that part of Gujarat. Along with it, 87 species of Central Gujarat, 78 species of butterflies from Saurashtra, 47 butterfly species from Kachchh and the least from North Gujarat i.e. 26 butterfly species being mentioned in the list. Extensive lepidopteran studies have already been carried out in Gujarat with respect to protected areas and wildlife sanctuaries. But no work has been focused on fragmented habitats like agricultural landscapes or industrial zones. Scarce work on fragmented habitats has been conducted in different parts of India. For example, a total of 41 lepidopteran species were reported from the industrial and non-industrial areas of West Bengal, India (Jana et al., 2006). Moreover, the authors also revealed that out of 41 lepidopteran species, 15 species exhibited a clear demarcating habitat choice between the industrial and non-industrial area. Apart from that, earlier lepidopteran diversity studies were least combined with their seasonal occurrence or their habitat preferences. Thus, with this above noteworthy related studies, the present research work focuses on studying rhopalocerans, their habitat preferences and seasonal distribution in such few selected fragmented habitats from Gujarat.

1.7 Aim and Objectives

Aim: To study and evaluate Rhopaloceran diversity with respect to habitat preference and seasonal variation in various selected habitats of Gujarat

Objectives:

1. To identify documented Rhopaloceran species taxonomically from selected fragmented habitats of Gujarat

2. To evaluate & compare Rhopaloceran species with respect to various selected habitats of Gujarat i.e. Urban Residential (Vadodara City), Agricultural Landscapes (Chhani), Industrial Vicinity (Ankleshwar), Botanical Garden (Waghai) and Hill Station (Saputara)

3. To evaluate effects of major climatological seasonal factors i.e. maximum average temperature and average monthly rainfall on observed number of Rhopaloceran species with respect to selected habitats of Gujarat i.e. Urban residential (Vadodara City), Agricultural Landscapes (Chhani), Industrial Vicinity (Ankleshwar), Botanical Garden (Waghai) and Hill Station (Saputara)