Section-V
5.1. **Summary and Conclusion**

The insect groups, Butterflies and moths (Order: Lepidoptera) offer good opportunities for studies on population dynamics and community ecology. Many species are strictly seasonal, preferring only a particular set of habitats. In spite of this, butterflies have been generally neglected by community ecologists and there are very few studies available on their community structures, population dynamics and the eco-climatic factors which affect them. Being good indicators of climatic conditions as well as seasonal and ecological changes, they can serve in formulating strategies for conservation of wildlife. Butterflies provide economic, ecological, environmental and aesthetic benefits to human society. Such beneficial and valuable insects have been under severe threat of population declines and species extinctions throughout the world. Hence, their conservation management is receiving global attention.

The present study was undertaken with a view to know the butterflies of Papilionidae family in the Mid Western Ghats of Shimoga district, relative abundance in arbitrary terms as rare, less common, common, abundant and the seasonal distribution of the nineteen butterflies was determined. The plant species on which the various butterfly species foraged as adults were enlisted, and their seasonal availability was determined. Further, based on such parameters as flower, colour, and nectar characteristics were assessed and other parameters include locating and identifying the oviposition host plants, egg laying patterns, collection of freshly laid eggs for study in the laboratory which included hatching time of eggs, rearing of larvae, determining the number of instars, their duration and
characters including their weight, pupal characters and the time of adult emergence. In addition, larval performance instar-wise was assessed in terms of food consumption, growth and food utilization efficiencies. The study also assessed some of the biochemical parameters and enzyme kinetics of four Papilionidae butterflies studied under laboratory conditions. The entire findings of the present study is given as follows:

1. In the present investigation nineteen species of butterflies were identified and studied along the Mid Western Ghats of Shimoga district. All the reported species were represented in one of the study site i.e. Jog falls, this site include the India’s largest southern bird wing (*Troides minos* Cramer), 4 species were endemic to Western Ghats (*Pachliopta pandiyana* Moore, *Papilio dravidarum* WM, *Troides minos* Cramer and *Papilio liomedon*) and also includes 2 species that shared endemic to peninsular India and Sri Lanka (*Papilio polymnestor* Cramer and *Pachliopta hector* L.).

2. The butterfly populations of the Mid Western Ghats of Shimoga district were monitored in 6 localities and 6 vegetation types. These data were computed and various diversity indices were determined as follows.

- The natural vegetation types had relatively high diversities compared to human impacted vegetation types such as scrub and grasslands. In the present study Jog falls area which comes under ever green forest, a total of 19 species were enumerated. The area shares highest endemism of 6 species. Shannon’s and Simpson’s diversity indices showed higher values of 4.12 and 0.93 respectively.
Least species richness of 11 was observed in Lion-Tiger safari (Thyavarekoppa) where much of the area comes under dry deciduous type of forest with some monoculture plantations and human interference. Hence comparatively low diversity index was evidenced. (Shannon and Simpson index values revealed 2.91 and 0.86 respectively).

The butterfly species similarity among the study sites in evaluated on the basis of Jaccard's Similarity and Sorenson's Similarity index which revealed that, the similarity was relatively higher for the natural forests area of Jog falls and Hosbale (Soraba) with 94% and 97% similarity respectively. Least similarity was observed in Lion-Tiger safari area compared to other areas at 68 and 81% Jaccard's Similarity and Sorenson's Similarity indices respectively. Remaining study sites namely Kuppalli, Nagarkoduge (Hosanagar) and Umblebyle showed similarity values of 88, 84, 83 and 72% of Jaccard's Similarity and 91, 94, 90 and 83% for Sorenson's Similarity indices respectively.

The dendrogram plotted by clustering the Jaccard's similarity shows distinct grouping of natural habitat from human influenced area. There were five distinct clusters. Clusters of above 40 % are considered for interpretation. 70% cluster has two sites Jog falls and Nagarkoduge (Hosanagar), whereas cluster of 85 % comprises of Jog falls and Hosbale (Soraba). 90% cluster has shown linkage between Jog falls and other sites Kuppallli, Hosbale (Soraba) and Nagarkoduge (Hosanagar). All the sites are influenced by Jog falls and Lion-Tiger safari (Tyavarakoppa) which belong to lowest cluster.

The present analysis also intended to reveal the seasonal patterns in butterfly populations. Though butterflies were in flight all through the year, they were more abundant during wet season than in the dry seasons. This particular
seasonal trend was related to the luxuriant growth of vegetation especially the herbaceous flora on which the adults oviposit and to the availability of a greater number of floral hosts in peak bloom in the wet season.

4. All the 19 species were found collecting nectar from the flowers of one or the other of 42 plant species belonging to 22 families. Of these 42 species, 31 occur spontaneously at Shimoga district and in its environs, and the other 11 are garden plants. Twenty of the 42 plant species bloomed spontaneously i.e. throughout the year and 5 of the 11 garden plants effloresced throughout the year.

5. The plant species enlisted in the present study was utilized by more than one butterfly species. Each butterfly species is either oligolectic or polylectic. The plant species such as *Vitex negundo*, *Bougainvillea spectabilis*, *Tridax procumben*, *Jasminuin angustifolium*, *Duranta repens*, *Lantana camera*, etc. were utilized by many Papilionidae butterfly species and provided nectar sources throughout the year.

6. The floral characteristics of nectar plant species with regard sugar types and presence of proteins indicate the presence of common sugars *viz.*, glucose, fructose and sucrose in 22 plant species. In fourteen flower species 'sucrose' was found to be the dominant sugar and in 8 species 'glucose' was dominant. Further, the 22 nectar host plants estimated have been found to contain proteins.

7. A total of 38 larval host plants for all the 19 Papilionidae butterflies were listed, belonging to 22 families. The host plants included is mostly trees followed by shrubs and herbs of these, *Citrus aurantifolia*, *C. grandis*,
C. limon, C. sinensis are the exclusive host plants for 7 butterflies, Polyalthia longifolia, Thottea sidiqusa Xanthoxylum rhetsa for five butterflies, Murraya koenigii, Thottea sidiqusa for four butterflies, Cinamomum. Macrocarpum, Aristolochia indica for three butterflies Annona lawii, Gylcosmis arborea, A.tagala, Aristolochia bractiola and Michelia champaka for two butterflies. The most abundant larval host plants are Polyanthia longifolia, Aristolochia indica, Polyalthia cerasoides, C. limon, Murraya koenigii, Citrus grandis and Michelia champaka. The remaining larval host plants occur either scattered or represented by a few individuals.

8. The period of distribution of the life stages - eggs, larvae, pupae, of the four Papilionidae butterfly species studied are: Graphium agamemnon, Papilio demoleus, Papilio polytes and Graphium doson. Among the oviposition host plants, the most commonly used plant species was used for rearing the larvae. These plant species included Annona lawii, Polyalthia longifolia, Cinamomum macrocarpum, Michelia champaka, Citrus aurantifolia, Citrus grandis, C. limon, C. sinensis and Murraya koenigii.

9. The span of life from egg to adult emergence as found in the laboratory for Graphium agamemnon 29-35, Papilio demoleus 31-39.5, Papilio polytes 35-40 and Graphium doson 31-36 days respectively. Each butterfly species studied, passed through five distinct instars. The development time from egg to adult is thus rather moderate; this behavior agrees with the behaviour of most tropical butterfly species. On the assumption of adult life span, coupled with the distribution of life stages and length of life cycle, these four butterfly species are thus multivoltine.
10. The quantity food consumed by each of the five instars and the weight gained by the respective instar showed a straight-line relationship between these two variables. The study calculated instar performance indices: growth rate (GR), consumption index (CI), approximate digestibility (AD), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD). The quantity of food consumed across the instars increased gradually or steeply from instar to instar. The weight gained was in accordance with food consumption, it being the highest in the last two instars for all the four species studied. But relative rates, both CI and GR, were the highest in instar I and the values declined as the larval growth progressed. The values of approximate digestibility (AD) across the instars are in inverse relationship with the quantity of food consumed. The AD values ranged between 78.0 - 99.0%, the value declined as the larvae aged; the decline in AD value is attributed to the less selective feeding behaviour of advanced instars on the foliage supplied.

11. An inverse relationship occurred between assimilation efficiency AD and efficiency of conversion of digested food (ECD). The values of ECD (8.12 - 21.08%) obtained are low compared to AD values (78.0 - 99%), but are within the range of 2.87% reported for forb foliage feeding.

12. The efficiency of conversion of ingested food ECI varied between 3.50-20.3%; the values are within the range of 1-78% reported for forb foliage feeders. Since, ECI is dependent on how AD and ECD compensate each other, no definite trend of increase or decrease is expected for the values of ECI across the instars.
13. The estimation of biochemical parameters and enzyme kinetics revealed that the protein content in both outdoor and indoor reared larvae was significant in Papilio demoleus and Graphium doson and it was insignificant in Graphium agamemnon and Papilio polytes. The glycogen content in both outdoor and indoor reared larvae was significant in Graphium agamemnon, Papilio polytes and Papilio demoleus and it was insignificant in Graphium doson.

14. In the present study the optimum conditions for the activity of amylase, such as temperature, optimum pH and incubation time were obtained. The optimum conditions for the activity of trehalase, such as optimum pH found in our study was markedly similar with that of various insects found for trehalases. In the present investigation activity of enzyme i.e. amylase in the larval mid gut tissue of V instar larvae of outdoor and indoor reared showed higher amylase activity was observed in outdoor reared larvae. In the present study a high content of trehalase was observed in the outdoor reared worms, on the other hand low activity was observed in indoor reared larvae.

Finally the study emphasized information on diversity of Papilionidae butterflies of Shimoga district, seasonal variations, larval host plants and adult nectar sources. The study also provides knowledge on life cycles of four Papilionidae butterflies in terms of food consumption, growth, and food utilization, life span from egg to adult emergence, Enzyme kinetics, and some biochemical parameters. All these data may be profitably utilized in the successful conservation and management of these butterflies. The study may also be involved in the conservation of forests and wildlife including the magnificent butterflies.