CHAPTER 2

REVIEW OF LITERATURE
In the present chapter, an attempt has been made to appraise the state of art of various aspects of butterfly fauna present in different parts of the Indian subcontinent with special emphasis on their diversity, distribution, ecology, habitat preference, life cycle etc. Some efforts have also been made to consolidate the information on electron microscope studies conducted on morphological features of the butterflies.

The biosystematic studies on insects in India were initiated with the arrival of the European traders, missionaries and rulers largely from middle of the 18th century. Insects became one of the subjects of interest with the establishment of Royal Asiatic Society of Bengal in 1748. Studies of Beeson (1941) "An epitome to the National History of Insects" and "Ecology and control of forest insects in India and the neighboring countries" are excellent work from the South Asian region. Moreover, until the publication of first account of Indian butterflies in 1857 by Horsfield and Moore in their 'Catalogue of the Lepidoptera in the Museum of East India Company,' little attention was paid to Indian butterflies, though these butterflies have attracted the attention of some researchers (Talbot, 1939).

The earliest comprehensive work on butterfly diversity of Indian subcontinent was Moore's 'Lepidoptera of Ceylon,' the first volume of which appeared in 1881. In 1881, de Niceville began a series of papers in the 'Journal of the Asiatic Society of Bengal' and in the 'Journal of the Bombay Natural History Society.' In 1882, Lionel de Niceville and Major GFL Marshall published the first volume of 'The butterflies of India, Burma and Ceylon.' The second volume appeared in 1890, followed by the third in 1890. In 1890, Moore commenced the publication of the 'Lepidoptera Indica,' which ran to ten quarto volumes, of which Moore was responsible for seven before his death. The remaining three were written by Colonel Charles Swinhoe and were completed in 1913. Likewise, various studies related with the butterflies of India during British times include, Bingham (1905), Bell (1909-14), Evans (1932), and Peile (1937).
The insect fauna of India is vast. In an old estimate, Lefroy and Howlett (1909) in the monumental book 'Indian Insect Life' reported 25,700 Indian species. Beeson (1961) estimated 40,000 Indian species. Roonwal (1989) opined that insects constitute two-third of the total fauna in India and comprise nearly 1, 00,000 species, of which about half remains yet to be studied. Varshney (1997) has reported 589 families and 51450 species of insects from India. In a recent estimate Alfred et al., (1998) estimated 59353 species of insects from India belonging to 619 families.

Studies on biosystematics, ecology and behaviour of butterflies is reviewed as follows:

BIOSYSTEMATIC STUDIES

There are 84 families and 18 superfamilies of order Lepidoptera available in Indian sub-region. Of these, the butterflies belong to five major families viz., Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Hesperiidae under two superfamilies viz., Papilionoidea (including the first four families) and Hesperioidea (including the last family) and constitute about 10% of the total faunal species. The largest representative families of butterflies and moths from India are Nymphalidae (450 species) and Noctuidae (1,500 species), respectively. A few families of moths like Castniidae and Neopseustidae are very poorly known from the country (Alfred et al., 1998).

The butterflies, due to their aesthetic as well as scientific values attracted attention of many field workers, as a result, this group has been largely studied and the best worked out group amongst the class Insecta. During the eighteenth century, a large number of butterfly fauna from the Indian region including those from Western Himalaya was named and described by Linnaeus and Fabricius (Arora et al., 1995).

Studied on diversity and distribution of the butterfly fauna mainly started in nineteenth century in different parts of the country and the other major contributions were provided by Marshall and de Niceville (1882) and
de Niceville (1886) from India, Sri Lanka and Doherty (1886) from Kumaon and Mackinnon and Niceville de (1897, 1898) from Mussorie, India. Wynter-Blyth (1982) published a book entitled “Butterflies of the Indian Region” covering almost all the fauna, up to species level. Though several taxonomic changes have been made Varshney (1977 a, b, 1990), compiled all the major families and species of butterflies. Besides, the work by Hemming (1967) is a valuable contribution to the Indian butterfly fauna.

Biosystematic studies on butterfly fauna have been carried out extensively in different continents of the world (Varley, 1949; Janzen and Schoener, 1968; Elton, 1973; Neumann, 1978; Pollard et al., 1986; Gaston and Hudson, 1994; Varley et al., 1975; Huston, 1999; Hutcheson and Jones; 1999; Simberloff, 1999). Some investigations on different aspects of butterfly fauna like diversity, distribution, behaviour, ecology etc. have been carried out in different ecogeographic zones of India (Beeson, 1941; Roonwal, 1954; Mathur and Singh, 1959; Vats and Kaushal, 1980-81; Vats and Mittal, 1983, 1984, 1991; Kaushal and Vats, 1984; Thakur, 1991; Ananthakrishnan, 1994; Ghosh, 1996; Joshi and Sharma, 1998 and Joshi et al., 1999). However, only a few research workers have tried to study the butterfly fauna of the Himalayan region including Himachal Pradesh (Philipe de rhe, 1931; Mani and Singh 1962 a, b, c; Kumar. and Juneja, 1977; Mani, 1986; Chandel, et al., 1995, 1998; Uniyal and Nagesh,1997; Uniyal and Mathur, 1998; Arora, 2000; Saraswat, 2002; Thakur, et al., 2002; Mehta, et al., 2002, 2003).

In the recent past, studies pertaining to bio-systematics, biology, ecology, density and diversity of butterflies in different parts of India have been conducted by a number of workers like Nandi (1987) studied the Lepidopteran fauna of Orissa; Gupta and Thakur (1990) explored the butterflies of Gujarat; Ghosh (1991) reviewed the distribution of some butterflies from different regions of India; Mandal (1991) has studied butterfly diversity from Lakshadweep; Mandal and Maulik (1991) and Nandi (1993) from Orissa; respectively. Similarly, Bhattacharya (1997) and Ghosh et al. (1997
a, b) studied the taxonomic composition of 39 species of Satyridae, 32 species of Hesperiidae and 25 species of Pieridae from West Bengal, respectively. Moreover, Gupta (1997 a, b, c) studied the taxonomic account of butterfly from Delhi and West Bengal; Mandal et al. (1997) from West Bengal and Delhi; Ghosh and Chaudhary (1998 a, b) and Mandal (1998) from Meghalaya; and Mandal et al. (2000) from Tripura.

Besides diversity, other important parameters of butterfly fauna like migration, seasonal variation, pollination efficiency etc. have attracted the attention of various workers in different parts of country viz., Bharos (2000) studied the migration of *Catopsilia pomon*; Chaturvedi (2001) reviewed the phenomenon of migration in *Limenitis procries*; Haribal (2001) studied the overpopulation of *Danaus genutia* in Sanjay Gandhi National Park, Mumbai. Butterflies as pollinators of different crops were reported by Abrol (1993) from Jammu & Kashmir. Similarly, Mitra et al. (2002 a, b) studied the efficacy of butterflies as potential pollinators from West Bengal and Himachal Pradesh. Moreover, seasonal variations in *Melanitis leda ismena* were studied by Walia (2002), whereas, Sharma (1997) explained this phenomenon of seasonal variation on some species of Satyridae family.

India has a well developed Protected Area Network (PA's) comprising 89 National Parks (covering an area of 37,530.76 km², or 1.14 % of the country's geographical area) and 489 Wildlife Sanctuaries (1,17,042.04 Km², or 3.56 % of the country's geographical area). Put together the 578 PA’s cover about 4.70 % of the country’s geographical area. Studies on butterfly diversity of different protected areas have been undertaken in detail by various workers like Larsen (1987) who explored the Nilgiri mountains for butterfly fauna; Mathew et al. (1993) from Silent valley National Park, Kerala; Arora (1994) from Rajaji National Park; Chaudhary (1995) studied the butterflies of Indravati Tiger Reserve; Chandra and Khatri (1995) explored the butterflies of Great Nicobar Island; Athreya (1996) studied in Namdapha; Arora (1997) explored Nanda Devi Biosphere Reserve; Khatri (1997) from Nicobar;

Studies pertaining to Lepidopteran fauna in Northern India have been undertaken by different workers like Mussoorie area has been explored for butterfly fauna by Mckinnon and de Niceville (1897) and Ollenbach (1930-31); Kumaon region of Uttaranchal by Hannynton (1910-11); different parts of Haryana by Stempffer (1952), Bernardi (1952), Lesse (1952); Gharwal region of Western Himalaya by Arora and Mandal (1977), Chaturvedi (1981), Mandal (1984), Mani (1986), and Arora (1995); various parts of Uttaranchal by Kumar and Juneja (1977) and Arora (1995). Similarly, butterfly diversity of Punjab has been explored by Rose et al. (1994), Uniyal and Mathur (1998), Rose (1997) and Rose and Sidhu (2001).

Himachal Pradesh, a part of Western Himalaya has been explored during British period because of the presence of the Imperial Summer capital at Shimla. These studies mainly started from Shimla hills by Philipe de Rhee (1931) and Wynter-Blyth (1982). In the recent past, exploration of different parts of Himachal Pradesh for Lepidopteran fauna have been undertaken by some workers like Arora (2000) studied the butterfly fauna of Renuka wetland; Mehta et al. (2002) explored Pong dam wetland; Thakur et al. (2002) studied the butterfly diversity of Kalatop-Khajjiar wildlife sanctuary of Himachal Pradesh. Singh (2007) conducted detailed studies on the diversity and distribution of butterfly species of different agroclimatic zones of Shiwalik hills. He found a total of 87 species belonging to 64 genera and 10 families. Maximum number of species belonged to Lycaenidae (18) followed by Nymphalidae, Pieridae and Hesperiidae (16 species each), Satyridae (9), Danaidae (5), Papilionidae (4) and Acraeidae, Erycinidae and Riodinidae (1 each). He also studied the wing venation of families Papilionidae, Pieridae, Danaidae, Satyridae, Nymphalidae, Lycaenidae and Hesperiidae.
ECOLOGICAL AND BEHAVIOURAL STUDIES

Insect diversity in terrestrial ecosystem generally decreases with increase in altitude. Insect communities in lower altitude are more diverse as compared to the ones on higher altitude. Therefore, very low species diversity is observed at high altitudes (Kikkawa and Williams, 1971). Similarly, tropical insect species provide a good indication of the degree of species richness and is well understood in butterflies and dragonflies. The global distribution of species richness increases with decreasing latitude, i.e. there are far more species per unit area in the tropics than in temperate regions, and more species in temperate regions than in polar-regions (Duellman, 1988; Gentry, 1988). In tropical forests, diversity may be higher at mid altitudes than in lower areas, but there is no substantiating data. However, this has been noted in Desert Mountains of Arizona where diversity at lower and higher altitude is believed to be limited by aridity and low temperature, respectively (Brown, 1988).

Temperature plays a very important role as a diversity controlling factor in all the major ecosystems of the world. The effect of temperature and its relation with lepidopteran fauna of a forest ecosystem have been studied by various workers (Schneider, 1980; Spitzer and Leps, 1988; Stamp and Bowers, 1990; Golthard, 1998). Similarly, other major factors are rainfall, light and altitude. Effect of these factors on Lepidoptera have been studied by Reddy and Alfred (1983), Pollard (1988, 1991), Dudt and Shure (1994), Vickery (1995), Gutierrez and Menendez (1998), Golthard et al. (1999) and Sudheendrakumar et al. (1999).

The conservation oriented approach on sustainable management of forests conserving the fragile ecosystem and rich flora and fauna of natural forests have been studied by different workers in different forest ecosystems (Lusigi, 1981; Leach and Mearns, 1988; Porwal and Pant, 1989; Porwal, 1991; Leach, 1994; Porwal et al., 1994; Badola, 1995; Fiallo and Jacobson, 1995; Pimbert and Pretty, 1995; Strudsrud and Wegge, 1995; Badola, 1997, 1998).
Flora of an area is an important limiting factor in deciding the richness of diversity of an area. These studies in India started with Sevastopulo (1933, 1935, 1940, 1941, 1946, 1959) who provided valuable information on the host plants of many butterfly species. Subsequently, Sevastopulo (1973, 1975) compiled the checklists of the larval food plants of the Indian and the East Africa butterflies, respectively. Later Dickson (1953) prepared the inventory of the food plants of various Lepidopterous larvae including those of butterflies from Cape. Thomas and Malloricie (1985) published an account on the oviposition behaviour and larval food plants of butterflies in the Atlas Mountains of Morocco.

Behavioural studies in butterflies has been a subject of interest for various field workers like Ilse (1937, 1956) while describing the oviposition behaviour in butterflies, pointed out the significance and influence of various colours in their egg laying attitudes. Deither (1941; 1959 a, b; 1970; 1973; 1980) gave generalised account of various factors affecting the oviposition behaviour and the distribution of the larvae of different species of butterflies with special reference to their food plants. Hardy (1951) made observations on the mating behaviour of *Euploea corinnia* Macleay. Peterson (1954) made observations on the oviposition behaviour and habitat selection in some species of butterflies. Pivnick and Mc Neil (1985, 1986) described the mating behaviour of a Hesperiid, *Thymelicus lineola* Oschsenheimer and noted the sexual differences in thermoregulatory behaviour in this species. Damman and Ferry (1988) explained the oviposition behaviour of the larvae *Eurytides marcellus* (Cramer) of the family Papilionidae.

Johanson (1951) studied the food plant preference by the larvae of *Pieris brassicae* (Linn.). Iwase (1953, 1954, 1955, 1964) explored different food resources of the larvae belonging to the family Lycaenidae from Japan. Kundu and Gupta (1984) discussed the damage caused by the larvae of *Zizeeria lysimon* Hubner to Soyabean in India. Uchida (1984, 1985) prepared the inventories of the larval food plants of forty five (45) and seventeen (17)


Similarly, Ayre (1958) and Hitchon (1968) examined different aspects of myrmecophily and predation by ants in some lycaenid larvae from British Columbia in their respective publications. In a series of publications, Brower (1958 a, b; 1963) and Brower and Brower (1961) explored the phenomenon of mimicry in danaid and papilionid butterflies from North America. Urquhart (1960) made detailed study of migration in the monarch butterfly *Danaus plexippus* Linn. Alexander (1961a, b) made observations on the larval behaviour, moulting, pupal behaviour and eclosion of butterflies belonging to subfamily Heliconiinae from Trinidad. Tsubakki (1973) discussed certain factors like environment, food, parasites and predators affecting the natural mortality of the immature stages in the population of a swallowtail butterfly, *P. xuthus* Linnaeus.

Similar studies on ecology and behaviour of butterflies have been undertaken in India by some workers like Pant and Chatterjee (1950) enlisted about 365 species of Indian Rhopalocera; Narayanan (1954) gave an account of
butterflies as seasonal pests of crops; Norman (1976) prepared a list of the larval food plants of Indian butterflies; Wynter-Blyth (1982) described and enlisted the larval food plants of two hundred and ninety eight species of Indian butterflies; Bean (1961, 1988) recorded the life history, habits and myrmecophilous behaviour in some Lycaenid representatives of Nacaduba complex from Poona district (India); David and Gardiner (1961, 1962, 1966) made significant contribution on the hatching of the eggs and feeding behaviour in larvae of Pieris brassicae (Linn.).

Relative palatability of different butterfly species by avian predators has been studied in detail by Alock (1965). Detailed studies on the mating, mimicry, predation and migration in the danaid butterflies have been made by Brower et al. (1965), Brower and Brower (1972), Brower (1984, 1995, 1996). Similar studies on different aspects of butterflies have been made by many workers like Cottrel (1965, 1984, 1987) studied the entomophagous behaviour of Lycaenid butterflies; Elfferich (1965) investigated the biology of Lycaenid butterfly, Plebejus argus Linn., from Berlin; Clench (1966) discussed in details the thermoregulatory behaviour and postures adopted by different butterfly species; Duffy (1968) studied the ecology of the large copper, Lycaena dispar batavus Oberthur; Oplar (1968, 1974) discussed the phenomenon of myrmecophily, morphology of the immatures and behavioural aspects of various life history stages of Lycaenid and Pierid butterflies.

A significant contribution in study of biology, ecology and ethology of various butterflies referable to the families Pieridae, Lycaenidae, Nymphalidae, Papilionidae and Danaidae were made by Young (1972 a, b, c; 1973 a, b, c; 1974 a, b, c, d, e; 1976; 1977 a, b; 1978 a, b, c, d; 1979 a, b, c; 1980, 1981, 1982, 1983, 1984 a, b), Young and Moffett (1979a,b), Young and Stein (1976), Young and Thomson (1974, 1975), Scott (1973 a, b, c; 1974 a, b), Scott and Oplar (1975). Arms et al. (1974) observed the mud puddling behaviour in P. glaucans Linn., and reported its attraction towards the sand soaked with dilute aqueous solution of sodium salts. Amladi (1975) made an interesting
observation by recording clustering of Danaid butterflies on the decaying inflorescence of a plant species, *Heliotropium indicum* of the family Boraginaceae.

Brain (1975) made observations on recognition of the Lycaenid larvae by the workers of an ant of the genus *Myrmica*. Chew and co-workers (Chew, 1975, 1977, 1979, 1980; Chew and Robbins, 1984; Chew and Countney, 1991) studied in considerable details the various aspects of co-evolution of Pierid butterflies and their cruciferous larval host plants. Nakamura (1976) stated the function of the female anal hair tuft on an egg-camouflaging source and also discussed its taxonomic significance in *Nordmannia myrtale* Klug, of the family Lycaenidae. The prolonged pupal diapause in *Papilio alexanor* Esper due to irregular blooming of the host plant has been subsequently observed by Nakamura and Shirgru (1977). Arnold and Fischer (1977) described in details the morphology of the skeleto-muscular, copulatory and oviposition mechanism in the Nymphalid butterflies.

Fiedler (1992 a) made remarkable contributions by studying the aspects like life history, biology and myrmecophily in the Lycaenid butterflies, specially on the association of the ants with the pupae (Fiedler, 1988); the proboscis palpation as a way of tactile communication between the Lycaenid butterflies and the ants (Fiedler, 1989); biology of two sibling Lycaenid species i.e., Maculinea nausithous Bergstrasser and M. leteius Bergstrasser (Fiedler, 1990); behavioural ecology and evolution of the Lycaenid ant associations (Fiedler, 1991); biology of Hypolycaena othona Hewitson from west Malaysia (Fiedler, 1992 a); life history of Surendra florimel Doherty from west Malaysia (Fiedler, 1992 b); biology of a Lycaenid Ecoxylydes tharis Geyer (Fiedler, 1994 a); life history of Caleta roxus (Godart) (Fiedler, 1994 b); host plant diversity in myrmecophilous Lycaenids (Fiedler, 1994 c); association of the myrmecophilous Lycaenids with legume host plants (Fiedler, 1995 a); range of the host plants in 1050 phytophagous species of the Lycaenid butterflies in the tropical and temperate environments (Fiedler, 1995 b); range of association of the ants on caterpillars in the Lycaenid butterflies (Fiedler, 1996).

Studies on habits and life cycle of different butterfly species have been conducted in various parts of the world like Larsen (1992) while compiling a general account on eight hundred and seventy one species of butterflies from Kenya, also furnished brief notes on their natural histories; Fiedler and Hagemana (1995) studied the influence of larval age on number of ants in Zizeeria knysna Trimen; Fiedler and Hummel (1995) explained the effect of the larval age in ant association in brown genus butterflies, Aricia agestis (Schiffermuller); Fiedler and Saam (1994) recorded the reaction of the ants on the tentacular organs in the nature Lycaenid larvae; Fiedler and Saam (1995) reported the fungal infection on the dorsal nectary organ in two facultatively myrmecophilous species, Polyommatus icarus and P. (Lysandra) bellargus; Fiedler and Schurian (1994) observed the oviposition behaviour in Lycaena thetis King; Fiedler and Seufert (1995) studied the structure of the mature larva and pupa of Semanga superba (Druce); Fiedler et al., (1992) made observations on seventeen species of butterflies of the family Lycaenidae from Europe to
retain myrmecophilly after emergence of the parasitic Braconid larvae; Fiedler et al., (1994) reported the larval host plants of *Callophyrus rubi* Linnaeus; Fiedler et al., (1995) worked on the life history and myrmecophilly in *Palyommatus candalus* (Herrich-Schaffer) and furnished notes on biology and pupal morphology of various species referable to the genus *Curetis* Hubner from Malaysia.

Behavioural studies on butterflies have always fascinated various workers like Chapman et al. (1990) reported some changes in the pattern of egg laying and larval feeding with change in patch size in the host plant in soody wing skipper, *Phobisora catullus* (Linn.); Haribal (1990) gave a brief account of the behaviour of Indian tortoiseshell, *Vanessa cashmeiriensis* Kollar from the Himalaya; Ravenscroft (1990) studied the ecology and conservation of silver studded blue butterfly, *Plebejus argus* Linnaeus from East Anglia; Pojode La Paz (1990) reported the occurrence of myremecophily in two lycaenid species viz., *Cigaritis zohra* (Donzel) and *C. allardi* (Oberthus); Suzuki and Matsumoto (1990) made valuable information on interesting phenomenon of the pair clinging behaviour in the male of papilionid, *Atrophaneura alcinous* (Klug); Ritland (1991) reported mullerian mimicry between *Limenitis archippus floridenis* (Streeker) and *Danaus gilippus berenice* (Cramer); Haribal (1992) included brief information on the immature stages and larval host plants of about two hundred species of butterflies from Sikkim.

Various studies pertaining to ecology of butterflies include Ohaski (1995) who discussed the life histories of *Junonia everate* (Linn.) and *Acromyra striatus* (Butler); Castelloni et al. (1995) reported *Palpalanthus polyanthus* (Beng.) as their larval food plant; Mattiacci and Dicke (1995) discussed the discrimination of the host age during host location by *Cotesia glomerata*; Sparks and Parish (1995) made comments on certain factors affecting the aggregation pattern of the butterflies; Tennent (1995) made field observations on the hilling-topping phenomenon in the butterflies from north-west Africa; Anderson and Brower (1996) explored the role of forest vegetation regarding over wintering
of the monarch butterflies in high altitude in Mexico; Burghart and Fiedler (1996) noted the influence of diet on the growth of the caterpillars of *Polyommatus icarus*; Fukuda (1996) worked on the status, habitat and conservation of four species of butterflies viz., *Celastrina sugitani* (Matsumura), *Fixenia album* (Knoch), *Antigius butleri* (Fenton) and *Sasabia charonda* from Kyushu, Japan.

Ecological studies have been conducted on an endangered nymphalid species i.e., *Fabricinae nerippe* (Fielder) in Japan by Fukuda (1997 a, b); Hagen (1996) studied the behaviour of nymphalid butterfly, *Vanessa cardui* (Linn.); Hagen and Eckursler (1998) studied the biology and ecology of the lycaenids *Polymmatus (Aricia) andarponi* (Pfeiffer) and *Palymmatus (Aricia) bassoni* Larsen; Sourakov and Emmel (1996) outlined the life history aspects of *Ahetia jaegeri* from Hisponiola; Clark and Faeth (1997) made an interesting observation on the larval aggregation in the species *Chlosyne lacinia* (Geyer); Lewis *et al.* (1997) explored the habitat for nectar resources of one hundred and five butterflies from Siruvaltakasdu, Komel Palni Hills; Thompson (1998) conducted studies on the evolution of morphology and polyphagy amongst the swallowtail butterflies; Oostermeijer and Swaay (1998) made an assessment about the role of butterflies being played as environmental indicators and a tool of conservation in changing landscape. Singh (2007) made detailed observations on habits, habitat and food plants of 87 species of butterflies recorded in different zones of Shiwalik hills. He observed that 8 butterfly species belonging to family Papilionidae and Pieridae indulge in mud puddling behaviour. Adults were frequently found to drink water contaminated with excreta. In addition to mud puddling, species such as *Prostas nora*, *Tagiades menaka* and *Suastus gremius* and *Charaxes solon* were also found to have an inclination to date palm juice, elephant dung and bird’s dropping respectively. Besides, habits and habitat, he also studied the different flowering plants visited by butterflies, their foraging activity and abundance at different elevations of Shiwalik hills. He found that a total of 51 species of flowering plants were visited by different butterfly species.
SCANNING ELECTRON MICROSCOPE STUDIES

Lepidoptera display vivid iridescent colouration that exists largely independently of pigmented colour. The nature of the structures producing this iridescence has been studied extensively for over a century (Hagen 1882; Mayer 1897; Onslow 1921; Suffert 1924). Some early workers, using only optical microscopy, correctly concluded that multilayer systems were primarily responsible for this iridescence Mason (1927). Later, electron microscopy allowed these systems to be imaged and characterised in such greater details (Anderson and Richards 1942; Lippert and Gentil 1959). Recent work on a wide range of lepidopteran species has elicited a more complete understanding of their iridescent colouration (Ghiradella et al. 1972, 1984, 1991; Huxley 1975).

Scanning Electron Microscopic investigations on butterfly scales is one of the latest techniques being employed in biosystematics of different species. It started in later half of the nineteenth century. Many workers studied the butterfly scales with application of SEM throughout the world like Mason (1926) who studied the structural color in insects; Yagi (1954) who explained the electron microscope research on pterin pigment in the scales of pierid butterflies. Similarly, Vukusic (1998) studied the iridescence on butterfly wings. Moreover, Tilley and Eliot (2002) investigated the scale microstructure and its phylogenetic implications in lycaenid butterflies (Lepidoptera, Lycaenidae). Stavenga et al. (2006) calculated the reflectance and transmittance of light scattering scales stacked on the wings of pierid butterflies.

In recent years pigmentation in butterflies has been investigated by some workers like Giraldo and Stavenga (2007) who reported sexual dichroism and pigment localization in the wing scales of *Pieris rapae* butterflies; Morehouse et al. (2007) who explained that Pterin pigment granules are responsible for both broadband light scattering and wavelength selective absorption in the wing scales of pierid butterflies. Wijnen et al. (2007) explored the colours and pterin pigmentation of pierid butterfly wings.
LIFE CYCLE STUDIES

Life history studies have been an interesting field of butterfly studies from long time. These studies started in the later half of the nineteenth century and many workers studied the life histories of butterflies throughout the world. Besides, morphology of many immature stages of different species of butterflies have been explained by many workers like Wallace (1865); Scudder (1872); Edwards (1878; 1881 a, b); Moore (1880, 1882, 1903); Forsayeth (1884); Wood-Mason and de Niceville (1887); Hart (1889); Davidson and Atkin (1890, 1891); Davidson et al. (1896); Dyar (1890); Manders (1890); de Niceville (1890); McCinnon and de Niceville (1897), whereas, Poulton (1882, 1887, 1909, 1924 a, b) while preparing general inventories has also made scattered notes on life history of some butterfly species. Similarly, notes on immature stages of certain species of butterflies have been provided by Thomann (1901, 1908); Seitz (1927); Verity (1907); Jordan (1909); Doherty (1886) made an attempt to make use of sculpturing patterns and shape of the egg in classification of different families of butterflies. Similarly, Chapman (1896) discussed the characters of the egg and the pupae in order to trace the phylogeny in butterflies. Bingham (1905, 1907) gave scattered information on the early stages of as many as one hundred and twenty eight species.

Kershaw (1905) investigated the life history of Gerydus chinensis Felder referable to family Lycaenidae. Bell (1909-1914) gave a good account of structure of eggs, larvae and pupae of a number of species of butterflies from the plains of India. Lefroy (1909) published a brief note on life history of sixteen species of butterflies along with some illustrations on their immature stages. Chapman (1922) described the morphology of the last instar larva and pupa of Catochrysops phasma Butler. Chapman and Buxton (1919) reported the life history of another butterfly Tarucus mediterranes. Eltringhan (1922) described the morphology of the larvae and the pupae of family Lycaenidae from Southern Nigeria. Farquharson (1922) discussed the mutualistic relationship between the larvae and the ants. In his taxonomic studies on the subfamily Liphyrinae, Bethune-Baker (1925) described the structure of the
pupa of *Liphyra brassolis* Westwood. Clark (1925, 1927) gathered brief information on the carnivorous habits of the larvae of certain butterflies. Jackson (1937, 1947) observations on the structure of the early stages and life cycle of the African lycaenids, besides working out the protective mimicry in the pupa of *Epilota urania* Butler (Jackson, 1957).

Life history studies have been a field of interest in India from the beginning of butterfly explorations. Major contributions in this field include those of Talbot (1939, 1947) who studied the early stages of one hundred and twenty species belonging to the families Papilionidae, Pieridae, Satyridae, Danaidae, Amathusidae and Acraeidae; Jandu (1942) who gave an account of the biology of six species of butterflies from the families Papilionidae and Pieridae from Delhi; Dickson (1943, 1944) who dealt with the life history of *Phasis chrysaor* (Trim) and *Cupido thespis* Linnaeus; Brar (1959) studied the biology of the lemon butterfly *Papilio demoleus* L. from Punjab; Rataul (1960) and Mukerji (1960) have investigated the biological aspects of a Common pierid, *Pieris brassicae* (Linn.); Ganguli (1961) gave a brief account on the biology and control measures in *Eurema blanda* Boisduval, a serious pest of shady trees in tea gardens; Jayarej et al. (1961) furnished brief account of the biology of a fruit borer, *Rapala varuna* Horsfield of gauva from South India; Atwal and Josan (1962) and Atwal (1963) dealt with the biology of *Papilio demaleus* Linn. and recorded this species as a minor pest of Citrus in Punjab.

Similar studies have been undertaken in different parts of the world by many investigators like Wiltshire (1944) gave an account of the structure of the early stages of butterflies from the Oriental- Palaeartic region. Similar studies on different aspects of early life of butterflies have been conducted in various parts of the world by different workers. Norman (1949, 1950) studied the structure and behaviour of the immature stages butterflies. Similarly, Downey (1962, 1966), Downey Fuller (1961), Downey and Dum (1964) and Downey and Allyn (1973, 1978, 1979, 1980, 1981) made extensive studies on the morphology of the immature stages and biology of various Lycaenid and
Riodinid species; Shirozu (1961) worked on the evolution of feeding habits in the larvae of the subfamily Theclinae from Japan; Straatman and Nieuwenhuis (1961) and Straatman (1971) dealt with the biology of certain Papilionid species from Sumatra; Ross (1964 a, b, 1966) discussed the life history, ecology and behaviour of Lycaenids from Mexico; Ziegler and Escalante (1964) made observations on the life history of a Lycaenid, *Callophrysa xami* Linn., from Mexico; Rutkowski (1971) studied the life history and adult behaviour of *P. aristodemus ponceanus* Schaus; Emmel and Ferris (1972) gave an account of the biology of Lycaenid, *Callophrys folis* from United States; Emmel and Shields (1978) recorded life history stages in *Plebejus (Icaricia) shasta* (Edwards) from Western United States; Vane-Wright and Ackery (1984) made valuable contribution on the biology of the butterflies from Europe.

Largston and Comstock (1966) described the life history of *Philotes euoptes bayensis* Langston, from subfamily Polyommatinae. Grund and Sibatani (1975) described the life history of the family Lycaenidae from Mexico. Later, Kendall (1975, 1976) described briefly the life history and larval food plants of the metal mark, Riodinids from Mexico and Texas. Similarly, biology of *Pieris napi* (Linn.), *Totochila theodice* Butler, *Pontia occidentalis* (Reakirt) and *P. protodice* Boisduval and Le Conte, have been studied by Shapiro (1974, 1991, 1992). Moreover, Van Someren (1974) enlisted the food plants of some butterflies from East Africa. Young and his associates made a significant contribution in studying biology of various butterflies referable to the families Pieridae, Nymphalidae, Papilionidae and Danaidae from Costa Rica (Young, 1972 a, b, c; 1973 a, b, c; 1974 a, b, c, d, e; 1976; 1977 a, b; 1978 a, b, c, d; 1979 a, b, c; 1980, 1981, 1982, 1983, 1984 a, b; Young and Moffett, 1979 a, b; Young and Stein, 1976; Yound and Muyshondt, 1972, 1973, 1985; Young and Thomson, 1975). Similarly, various worthy works dealing with the life history studies are those of Callaghan (1977, 1981, 1985, 1986, 1988, 1991, 1992) who gave an account on the biology of some Neotropical Lycaenid and Riodinid butterflies; Forbes (1977) who described the life history and polymorphism in


aspects like life history, biology and myrmecophily in the Lycaenid butterflies, specially on the association of the ants with the pupae.

DeVries et al. (1986) described the ultrastructure of the setae and epidermal organs in the larva of Curetis Hubner butterflies. Ballmer and Pratt (1988) in their much celebrated work on the immature stages of the family Lycaenidae, have described the biology and morphology of the last instar larvae of about, sixty nine species. Similarly, Ballmer and Pratt (1989) have inferred that the number of instars is fixed at the time of oviposition in a lycaenid butterfly, Lycaena phlaeas hypophaeas (Boisduval). Subsequently, Ballmer and Pratt (1991) studied the myrmecophily aspects in fifty eight species of the family Lycaenidae. Baylis and Kitching (1988) described the myrmecophilous organs in the larvae of Cupido minimus Fuessly, besides exploring the effect of the host plant quality on survival of the larvae and oviposition in another lycaenid i.e., Jalmenus evagoras (Donovon) (Baylis and Pierce, 1991). Braby and New (1988 a, b) discussed the population biology, sex ratio and longevity in the Satyrid species i.e. Geitoneura klugii (Guerin-Menevill) and G. acuntha acrea (Guest). Braby (1990) made observations on the life history of a Lycaenid, Paralucia pyrodiscus lucida Crosby and also gave notes on the biology of Pierid, Delia hyrpalyce (Donovan) from Australia. Braby (1995) described the early stages and life cycle of Zetone delospila (Waterhouse) from Australia.

Various aspects of the biology of some species of butterflies belonging to the families Lycaenidae, Nymphalidae and Satyridae have been studied extensively by Jutzeler (1988 a, b, c, 1989 a, b, c, d, e, f, 1990 a, b, 1992, 1993). Likewise, Larson (1988) recorded the differences in oviposition in two species i.e., Colotis amata (Fab.) and Colotis vestalis (Butler) of the family Pieridae. An account of the life history stages of Agraulis vanillae Linnaeus and Phoebis sennae (Linn.) has been given by May (1988). Munguira and Martin (1988) made observations on the biology of Lycaenid Aricia morronesis (Ribbe). Murphy and Weiss (1988) studied the ecology of Euphydryas editha bayensis
(Boisduval) from United States. Miller and Feeny (1989) discussed the interspecific differences amongst larvae of the swallowtails, feeding on a plant species referable to the genus Aristolochia. Urich and Emmel (1990 a, b, 1991 a, b, c) published an account on the life history of certain nymphaulids from Trinidad. Balint (1991) reported the host plants and immature stages of the species belonging to genus Plebejides Sauter of the family Lycaenidae. Khatari (1991) furnished information on the introduced artificial method of egg laying in three species i.e., Pachliopta (Atrophaneura) rhodifer (Klug), Eurema hecabe (Linn.) and Danaus plexippus (Linn.). In an experiment involving forty nine species of the family Lycaenidae, Pratt and Ballmer (1991) tried to feed their larvae on Lotus scoparius, in which twenty seven species grew normally while the remaining failed to grow properly.


Wiltshine (1997) worked on the life cycle, migration and behaviour of *Vanessa atlanta* (Linn.), and he also made observations on the biology of *V. atlanta* (Linn.) and *Cynthia cardui* (Linn.) besides, reporting the predation of these butterflies by a Gray cat. Singh (2007) studied the life cycle of *Papilio polytes romulus* and *Pieris brassicae nepalensis* in Shiwalik hills.

It is ample clear from the above mentioned account that life history and behaviour studies on different species of the butterflies have been undertaken by a number of workers throughout the world. These studies in India except for Bell (1909-1914), Sevastopulo (1933, 1935, 1940, 1941, 1946, 1959, 1973, 1975), Pant and Chatterjee (1950), Wynter- Blyth (1982), Brar (1959), Bean (1961, 1988), Atwal (1963), Saxsena and Goyal (1978), Singh and Mavi (1984), Radke and Kandalker (1989), Haribal (1990, 1992), Jana and Ghosh (1994), Rose *et al.* (1994), Chandel *et al.* (1995), Reddy and Reddie (1996), Smetacek (1997), have not been extensively undertaken so far as their ecology and biology is concerned.

Hence, the review of literature cited above shows that butterflies of the world have been studied by a number of workers. Morphological characters (colour pattern/scale-winged) which, now universally accepted as the most reliable and stable characters for the separation of different biological species, have not been studied for almost all the species. Moreover, with the accumulation of fast growing knowledge and rapid industrial growth almost all old taxonomic work require a thorough revision and butterfly group is not an exception. Besides, the recording of new/additional distributional limits of different species is all the more necessary to rectify the old surveys. Keeping in view the above account, present studies were undertaken in order to update the account of maximum number of species in a short span of time with the aid of latest techniques like scanning electron microscope studies.