**KFRI Research Report No. 220** **ISSN 0970-8103**

# CONSERVATION OF INVERTEBRATES THROUGH CAPTIVE BREEDING - A STUDY WITH REFERENCE TO BUTTERFLIES

**George Mathew**

**Kerala Forest Research Institute**
**Peechi-680 653**
**Kerala, India**

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(Final report of project FRI 294/98; January 1998 - March 2001. Sponsored by the Ministry of Environment and Forests, Govt. of India, New Delhi)

**George Mathew Division of Entomology**

**Kerala Forest Research Institute**
**Peechi-680 653**
**Kerala, India**

**ABSTRACT OF PROJECT PROPOSAL**

1. Project No. : KFRI/294/98
2. Title of the project: Conservation of invertebrates through captive breeding - a study with reference to butterflies
3. Objectives:
   i. To set up a butterfly house and garden to facilitate education of the public on the significance of nature conservation and to prepare a document on butterfly farming.
   ii. To standardise a methodology for mass rearing butterflies in field cages.
   iii. To establish a Centre to assist in the conservation of endangered species, by mass rearing and reintroduction.
4. Date of commencement: January 1998
5. Scheduled date of completion: December 2000 (extended up to March 2001)
6. Funding agency: Ministry of Environment and Forests (Government of India)
7. Project Team:
   Principal Investigator: Dr. George Mathew
   Research Fellow: Smt. Mary Anto
8. Study area: KFRI campus
9. Duration of study: Three years

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**ABSTRACT**

Butterfly gardens and butterfly houses are ideal means by which visitors can observe butterflies in a recreated environment. In this study, attempts were made to standardise methodologies for augmenting local butterfly fauna in order to maintain them in recreated habitats - both indoors and outdoors- which has application in, *in situ* and *ex situ* conservation programmes.

*In situ* propagation of butterflies was achieved by establishing a butterfly garden in a 0.5 ha of moist deciduous forest patch in the KFRI Campus at Peechi, Kerala, India. Based on the habitat preferences of various species, the area was landscaped so as to create different butterfly habitats. As a result of host plant introduction and habitat management, there was a tremendous increase in the butterfly population. During the first half of the project, 4509 sightings of butterflies belonging to 43 species were recorded. In the second half, 5993 sightings of butterflies belonging to 50 species have been recorded. Altogether, 10502 sightings of butterflies belonging to 56 species were recorded during the thirty months study period. These included nine species that are endemic to the Western Ghats and 10 species having protected status under the Indian Wildlife Act.

The relationship between the occurrence of different butterflies and the weather conditions was also studied. For many butterflies, an average temperature ranging between 25-26°C was the most favourable followed by 23-25°C and 27-29°C. Similarly, atmospheric humidity ranging between 80-100 percent was the most preferred range followed by 60-80 percent. With regard to daily rainfall, 50 mm was the most favourable level followed by 50-100 mm rainfall.

Investigations showed that there was a continuous population trend for butterflies belonging to the families Danaidae, Lycaenidae Papilionidae and Pieridae which also developed resident populations in the study area. Attempts to manipulate local populations of certain aggregating danaine butterflies to roost on some alkaloid containing host plants (such as *Crotalaria retusa* and *Heliotropium keralense*) were successful. The multi species aggregation comprising of 30-40 butterflies per plant was a major attraction to visitors.

In order to examine the suitability of various butterflies for captive breeding in *ex situ* conservation and for butterfly exhibitory programmes, biology of 20 species of butterflies was studied and methods for captive breeding standardised. Based on the data generated in this study, 13 species of butterflies, *viz*., C*hilasa clytia*, *Pachliopta aristolochiae*, *Papilio demoleus, P. hector*, *P. polytes, Troides minos* (Papilionidae); *Catopsilia pyranthe*, *Eurema blanda* (Pieridae); *Talicada nyseus* (Lycaenidae); *Danaus chrysippus, Parantica aglea, Tirumala limniace* and *T. septentrionis* (Danaidae) were proposed as good candidates for butterfly gardening / captive breeding programmes in Kerala.

# 1. INTRODUCTION

Conservation of biodiversity is very important for the existence of mankind in this universe. The value of biodiversity has been defined as the difference between the current and future value of a diverse range of genes/species/ecosystems, and the value of a less diverse range, and it is not the gross value of all naturally derived goods and services.

Much of the natural products available today are the result of past conservation of biological diversity. Apart from the value of biodiversity in keeping natural ecosystems functional, it may be seen as having at least three types of values: ethical, socio-economic and eco-systemic.

i. Ethical: All creatures have a right to exist regardless of whether they are beneficial or harmful to the mankind.

ii. Socio-economic: Man depends on biodiversity for food, medicines and a variety of products. The sustainability of the diverse food habits of the different people around the world requires the continued existence of the diverse plants and animals used by them. Biological diversity especially of cultivated and domesticated species is heavily dependent on that cultural diversity which evolved the different biological strains in the first place. Similarly, diverse life styles and customs are often dependent on the availability of diverse types of ecosystems and biological resources.

iii. Ecosystemic: Natural ecosystems and their ingredients support all life on earth. Soils feed us, forests replenish the soils and give us various products, rivers and lakes provide water and air is the basis of life itself. For any one of these systems to survive, there is a need of a host of diverse biological functions and species. Most significant among these are the invertebrates and microorganisms, which biodegrade the wastes of nature, form the soils by breaking down biomass and ensure that agricultural cycles continue. For all these crucial functions to continue the balance of nature has to be maintained and the destruction of species can disrupt this balance (WCMC, 1992).

Invertebrates, which form an overwhelming majority of life on earth in terms of individuals, species and bio-mass are important components in the functioning of natural ecosystems. It has been estimated that invertebrate species constitute over 95% of all recorded living animal species. Approximately 1.4 million species of invertebrates have been described so far, of which 75,000 species are insects. It has been stated that if the vertebrates were to be wiped out, the world's ecosystems would be perturbed for several years but, if invertebrates were to be wiped out, our planet would never recover (Wilson, 1987).

It has been predicted that as much as 25 per cent of the world's species could be lost in the next several decades. Being highly fragile organisms, even minor perturbations in the ecosystem may affect the survival of invertebrates. This is highlighted by the fact that there are more cases of documented endangered invertebrate species than any other group. Invertebrates thus deserve as much consideration as is currently devoted for vertebrate conservation.

Of the 1.7 million species, approximately one quarter are plant feeding insects (Strong *et al.*, 1984) and roughly half of these are species of Lepidoptera (butterflies and moths). With over half of the world's insect species believed to be endemic to tropical forests, a good chunk of which is destined for degradation before the end of the century, the number of extinctions may exceed our 'worst nightmare' (Collins, 1987b).

Most changes to ecosystem are brought about by human activities and therefore public awareness on the need to conserve biodiversity must be increased. This can be achieved in several ways but most effectively by enabling continued development of partnerships between the community, industry and government in the custodian-ship of our biodiversity.

### 1.1 Why conserve butterflies?

Because of their aesthetic value, butterflies form important objects for display in Zoos and Natural History Museums. Butterfly exhibits are major attractions in many museums. Of late, attempts are also being made to maintain natural populations of butterflies in carefully landscaped areas termed variously as ‘butterfly houses, gardens, parks or safaris'.

Besides their aesthetic value, butterflies have great ecological significance as well. Their immature stages or caterpillars are largely herbivorous and form the primary consumers in the ecosystem. Butterflies in turn are fed upon by various higher groups of organisms such as birds, lizards and some mammals and thus form more than one link in the food web. Butterflies visit flowers for nectar and thus help in pollination.

### 1.1.2 Causes for decline

Butterflies are highly diversified in their habits and require specified ecological conditions for survival. Natural forests, grasslands as well as banks of rivers and streams are the major butterfly habitats. An account of the various causes for the decline of butterfly populations is given below.

*i. Habitat loss*

One of the main causes for the decline in butterfly wealth is habitat destruction by deforestation for urbanisation, industrialisation and agriculturisation, which also causes changes in temperature, humidity and rainfall. Though activities like land drainage, application of fertilizers and herbicides and mechanization of farming increase productivity, the survival of butterflies is affected (van der Made, 1987). Pollution caused as a result of industrialisation and urbanisation is also harmful to butterflies.

*ii. Unfavourable weather conditions, natural enemies etc.*

Local extinctions may be caused by periods of unfavourable weather when habitat suitability has also declined (Pollard, 1979; Dempster and Hall, 1980; Elhrich *et al*., 1980; Thomas, 1980). They may also be brought about by parasites or disease, although this is less well documented.

*iii. Commercial collection*

The effect of collection on populations of butterflies is controversial due to lack of data but the impact is largely dependent on the biology of the species. Most authors suggest that collection can only affect already weakened populations (Spooner,1963; Muggleton,1973; Gardiner,1974; Pyle,1976) while others (Sheldon,1925; Mc Leod,1979) suggest that collection on commercial scale can cause extinction.

**1.1.3 Conservation strategies**

Various attempts have been made to conserve butterflies in different parts of the world. Some of the strategies adopted for butterfly conservation are as follows.

*i. Legislation*

The first step in conservation is usually some form of species conservation based on legislative action against hunting or collection of rare and endangered species at international and national levels. The most important is the Convention on International Trade in Threatened and Endangered Species (CITES). However, only a few butterflies are listed in CITES, since not much information is available about most species to fulfill the requirements for listing. CITES recognizes no butterflies in Appendix I and the birdwing butterflies (*Ornithoptera*, *Trogonoptera* and *Troides*) are listed in Appendix II along with *Parnassius apollo*. IUCN lists over 350 species and subspecies of butterflies and moths ranked from indeterminate status to possibly extinct.

The Government of India (GOI), under the Wildlife (Protection) Act (GOI, 1972) has extended legal protection to butterflies. Under the act, nearly 120 species (including subspecies) of butterflies and moths are listed in Schedule I and nearly 292 species and subspecies in schedule II.  The export of butterflies (dead or alive) and decorative articles from them are prohibited. As per Section 40 (92) of the Act, no person can acquire, receive, to keep in control, custody or possession, any of the species included in the above schedule without previous permission in writing of the Chief Wildlife Warden or his authorised officer. Nevertheless, illegal trade in butterflies continues. Recent estimates place the butterfly fauna of India at 1501 species of which the Western Ghats harbours 330 including 37 endemics and another 23 shared only with Sri Lanka (Gaonkar, 1996). A strict evaluation of the survival status of various species would lead to inclusion of many more species under the protected category.

There are diverse opinions with regard to such trade restrictions. Restrictions on trade of endangered species may reduce incentive for commercial rearing of these species and may also reduce pressure on wild stocks. Too often, attempts to enter a species into the market are opposed by protectionists who view such approaches as detrimental to the survival of the species (East, 1974). However, Morton and Collins (1984) are of the opinion that commercial collection can be an important source of income and that if populations are harvested in a sustainable manner, then both conservation and commercial interests can be satisfied.

*ii. Captive breeding and reintroduction*

The principles emerging from scientific research into ecology have led to the view that it is impossible to conserve a species in its wild state without conserving the whole environment. For the reasons just mentioned, current conservation strategy gives priority to protecting entire ecological communities rather than single species. For single species in danger of extinction, the approach is different. In such cases direct, urgent action is required to identify the causes of the threat and modify the conditions that endanger the species (Sbordoni and Forestiero, 1985). Captive breeding and reintroduction of stock in the wild is method adopted in such cases. For sustaining, re-establishing and reproducing organisms, we must have full knowledge of the biology and ecology of the organism. Captive breeding programmes have been successfully adopted for a number species such as the heath fritillary *Melicta athalia*, the large copper butterfly *Lycaena dispar* and the swallow tail *Papilio machaon britanicus*.

*iii. Enhancing public awareness on species conservation*

Active involvement by the community is one of the greatest resources available in managing biodiversity across all landscapes. Educating the community on the need for environmental conservation is very important to achieve the desired goals. In Victoria State in Australia, for instance, there are several 'Friends' groups focusing on various fields of environmental conservation. One such group called 'Friends of Eltham Copper Butterfly' focus on conservation of the rare Eltham Copper Butterfly. The Threatened Species Network in Victoria has liased with over 100 small community groups that focus on a particular threatened species or community. In India, although there are a number of Non Governmental Organizations (NGOs) involved in nature conservation, there are very few agencies that cater to the conservation of invertebrates except for the recent initiatives by the Zoo Outreach Organization in Coimbatore, Tamil Nadu. There is also no institution in the country to co-ordinate the activities on invertebrate conservation. Maintenance of stocks of live cultures is essential for possible reintroduction in conservation programmes and also as exhibits to promote environmental education of the public. It was in this context that the present programme to establish a butterfly farm/garden in the KFRI campus at Peechi was initiated in order to standardise methodologies for maintaining live populations of butterflies.

## 1.2. Role of Butterfly Houses in conservation

Butterfly houses serve two important roles, first as a tourist cum educational institution for promoting public awareness on nature conservation and secondly as a centre for *in situ* conservation. At present, there are no institutions in India for undertaking research on rare or endangered invertebrates, monitor their population status and maintain stock cultures, to involve in activities pertaining to habitat improvement as well as to attempt introduction of extremely rare or threatened species. However, this is going to be a tremendous task with several challenges. An account of the basic requirements for a butterfly breeding facility is given below.

### 1.2.1. Some aspects to be considered while setting up a butterfly breeding facility

Most commercial butterfly houses in temperate countries are walk through heated glass houses that are expensive to construct and maintain. However, such structures are not necessary in tropical conditions. A brief review on the various aspects of butterfly farming are outlined below.

*Environmental conditions*

For most Lepidoptera the environmental requirements of adults and larvae are not similar. Tropical butterflies require day temperatures in excess of $25^{o}$C and relative humidity of around 70-80 per cent. Night temperatures can drop to around $15^{o}$C. Some tropical species require almost 100 per cent humidity before they will mate.

A slight and intermittent air current seems to stimulate flight in many butterflies and thus increases the frequency of feeding, mate locating and courtship behaviour. Butterflies should have access to moist sand and spraying with a mist of water is beneficial.

*Nutrition*

When planning a live butterfly exhibit, it is necessary to ensure the continued supply of both nectar plants for the adults and food plants for the larvae. Both nectar and larval food plants should be established while keeping in mind the landscaping aspects of the garden.

*Larval food plants*

The management of larval food plants plays a crucial role in the success of captive breeding programmes. Larval plants have to be maintained both in the flight area (for enabling oviposition) as well as in the breeding area (to tend the larvae). Among the various factors involved, the growth and regeneration rate of the food plant, larval feeding efficiency, the part of the host plant used and total number of ovipositing butterflies are critical.

The management of important larval food plants should be closely monitored since the plants get quickly consumed. The breeding cage or garden should be planted with sufficient number of the host plants. In addition to this, adequate number of cuttings or seedlings should be kept ready so that sufficient quantity of host plants are always available. When more eggs are needed, the potted plants kept in pots in the green house may be brought into the flight area. These plants may be transferred to the breeding area when enough eggs have been laid. Here, the caterpillars that emerge may be allowed to feed on the plant.

*Nectar plants*

The important factors to be considered when choosing the nectar plants are the feeding preferences of the butterfly species and the length and timing of flowering. Plants such as *Lantana* spp. and *Ixora* spp. which flower almost continually, are the commonly used plants. Since the flowers of these plants have nectaries close to the surface, nectar is very easily accessible to most butterflies. Lycaenids and pierids with short proboscis prefer smaller flowers (eg. Compositae) while for the larger papilionid butterflies, *Hibiscus, Ixora* and *Clerodendrum* are ideal.

When there is scarcity of flowers, artificial feeding may be attempted. Usually, sugar/honey solutions (10 per cent) are presented as soaked pads of cotton wool or in a tube fitted with a colored corolla. Butterflies often have strong species specific colour preferences. Since such colour preferences can change with age, it is important to provide a wide range. When given a choice of abundant floral nectar and abundant artificial nectar, butterflies show a preference for the natural substance (Calvert, 1990). Moreover, for display purposes it would be more appealing to observe the butterflies exhibiting their natural feeding behaviour.

Some butterflies show preferences for other substances like fruit, berries, sap, dung and carrion. Rotting fruits to which about 10 per cent (w/w) honey has been mixed to assist fermentation are ideal for species attracted to fruits. The use of mud or urine for accumulating sodium is also important in certain species. All possible food sources must be provided as appropriate.

*Plant management*

Plant management is absolutely indispensible for creating the right environment for butterflies. A successful butterfly exhibitary is in fact a successful plant management programme (Calvert, 1990). Some important points to be considered in this regard are discussed below.

Since all the stages of butterflies are extremely susceptible to insecticides, use of chemicals for pest control should be avoided. Bio-pesticides like neem cake when applied regularly as a spray on foliage helps to check white flies, aphids and fungal infestations. Heavy watering of plants is necessary as most butterflies require high humidity levels and this leads to deterioration of soil structure. Organic manures may be applied periodically to keep the soil fertile.

Propagation of plants should be undertaken at appropriate seasons either as stem cuttings or from seeds. Seedlings thus obtained may be bagged in plastic covers and maintained as replacement stock.

*Conditions for mating*

Though Lepidoptera are fairly easy to rear, they are difficult and expensive to maintain as viable breeding colonies.The most common cause of failure of Lepidoptera captive breeding programmes is the inability to secure pairings and fertile eggs. Most butterflies require a suitable environment for the display of elaborate courtship behaviour. Suitable dimensions for a flight arena relate to the wingspan of the species (x) as follows: length 20-25 x; height 10-15 x; depth 10-15x (Morton, 1991a).

The presence of the larval host plant appears to stimulate pairing in many butterfly species. However, very large cages are to be avoided because some species tend to disperse to the roof and sides and ignore potential mates (Morton, 1991a).

If the emergence of adults is extended over too long a period, the optimum periods may not synchronize and it may then be difficult to secure pairings. The best way to avoid this problem is to rear larger batches so as to encourage synchronized emergence.

*Oviposition and care of eggs*

Butterflies require ambient temperatures of about 25$^{o}$C and many also need to bask under radiant heat sources in order to bring their body temperatures up to 32-35$^{o}$C in preparation for oviposition. Appropriate larval host plants should be provided and as with mating, a little light may be necessary.

The eggs are surface sterilized by immersion in solutions of sodium hypochlorite (0.1-0.2 per cent for five to ten minutes) or formaldeyde (10 per cent formalin for ten to thirty minutes) or both to kill any latent virus. Depending on quantity, the eggs should be stored either in short lengths of plastic tube, loosely plugged with cotton wool, or in small plastic boxes with perforated lids. Saturated solution of reagent grade sodium chloride may be used to maintain a relative humidity of 75-76 per cent over the temperature range 0-25$^{o}$C.

*Larval rearing*

The methods for rearing larvae on growing host plants or on cut leaf material have changed very little from the earliest published accounts. However maintaining supplies of host plants is an important limiting factor affecting captive breeding programmes.

The development of artificial diets for larvae has revolutionized the captive breeding of lepidoptera. Singh (1977) has produced a useful compendium of formulae. The first artificial diet for butterflies was casein, wheat germ diet developed by David and Gardiner (1965) which included dried cabbage leaf as a phagostimulant for *Pieris brassicae*. Morton (1981) obtained better results using germ yeast diet containing 1.5 per cent (w/w) dried host plant.

Diets containing host plant material are very useful for the efficient rearing of butterflies provided adequate supplies of dried leaf can be obtained. The control of relative humidity is a particularly important aspect of rearing larvae on artificial diets. The water content of the diet is often a critical factor affecting palatibility and larval growth rates.

*Pupation and eclosion*

Butterfly larvae reared on artificial diet may be left to pupate on the walls or the lid of the container. The pupae should be removed to an emergence cage once they have hardened. If required, they may be surface sterilized using 2-5 per cent sodium hypochlorite solution. Hanging or girdled pupae should be suitably mounted on strips of cork. The pupae should be kept reasonably moist.

*Conserving genetic variation in captive populations*

All species need a broad genetic base if they are to avoid extinction and continue evolving. Evidence is accumulating that extinction may be a regular feature of the dynamics of butterfly populations (Shapiro, 1979; Ehrlich, 1984). Such extinctions may be due to ecological rather than genetic problems (Berry, 1972). Similar fluctuations have been observed in some populations by Gilbert and Singer (1975), as well as Ehrlich (1984).

Butterfly populations vary in space and through time and this fact holds important implications for conservationists. The fact that butterfly populations are not interchangeable, ecologically or genetically has lead Ehrlich (1984) to advocate a conservation strategy which focuses attention on preserving genetic diversity within species through comprehensive habitat protection. Thus when we try to preserve a species through captive breeding, we may simply produce a generalized gene pool with butterflies that lack close affinity to any individuals remaining in the wild and not adapted to any natural environment. The aim of the insect conservationist must therefore be to conserve the future evolutionary potential of a species, rather than to attempt to preserve any form of *status quo*.

The transfer of a population of organisms from its native habitat into an artificial rearing environment may be viewed as an act of domestication. From a genetic standpoint, such a transfer is in principle the same as any group of organisms colonizing a new and isolated habitat. The long term persistence of even highly colonial butterfly species depends on their ability to colonize new habitats. Natural selection may be thought to have a winnowing effect, which acts by removing unsuitable genotypes and occasionally some suitable genotypes from the population.

*Changes due to inbreeding*

Captive populations will be exposed to a greater degree of inbreeding depression than natural populations. Inbreeding depression manifests itself in deterioration in vigour and health, as a consequence of a rapid loss of heterozygosity and the fixation of homozygous disadvantageous alleles through inbreeding. However, since many natural colonies of butterflies are isolated, small and have persisted in this manner for many generations, Morton (1991b) states that the amount of inbreeding in captive colonies, whose populations may be many times larger than their natural counterparts, is unlikely to be a problem.

If the founding stock is to survive and reproduce under captive breeding conditions, then it must carry existing adaptations permitting it to exploit its new environment The existing adaptations must enable it to survive the transition from natural to captive conditions. Genes that confer fitness in the field may not confer fitness in captivity and the new environment will select for new balanced gene system. The resulting domesticated populations may or may not be adapted to the natural environment.

## 2. REVIEW OF LITERATURE

Many species of invertebrates have long been kept and bred in captivity. The captive breeding of invertebrates for release is not a new concept (Morton, 1983). In recent years, a number of authors have emphasised that invertebrates bred in captivity would help conservation as such stock could help to ensure the continued survival of some species and under certain circumstances, reintroduction might be desirable and possible.

Several groups of invertebrates have been farmed for use as food. Well known examples are those of molluscs which have been farmed and managed in order to improve productivity. Invertebrates may, however, be harvested for purposes other than food. The classical examples of successful domestication are those of the silk worm *Bombyx mori,* the honey bee *Apis mellifera* and the medicinal leech *Hirudo medicinalis* (Wilson, 1971). Captive breeding procedures for invertebrates are simple compared to that of vertebrates. Most invertebrates are relatively small, require little space, reproduce rapidly and frequently produce large numbers of eggs.

### 2.1 Butterfly houses

Butterfly exhibits are now popular not only in Britain, Europe, North America, Japan and Australia but also in some of the tropical countries like Singapore, Malaysia, Hong Kong and Kenya where 'free flight' butterfly houses are rapidly becoming common. Butterfly houses are ideal means to offer an experience in which the visitor can observe the insects in their natural environment. These facilities maintain insect populations in a manner suitable for the provision of entertainment, education, conservation and research services.

The first Insect House or insectarium was opened in 1881 at the London Zoo. Over the next 100 years, other zoos added insects and other invertebrates to their inventories though this often took the form of a few aquaria set up for exhibition. In 1960 a variation on the insect exhibit emerged when the first commercial display of live butterflies was opened in Sherbourne, Dorset in England. In the early 1970's the Guernsey Butterfly Farm on the Isle of Guernsey, established itself as the first true butterfly house. By 1986, there were over 40 butterfly houses on the British mainland (Hughes and Bennett, 1991). In 1988, the development of butterfly houses migrated across the Atlantic. In that year, the first butterfly facilities opened in North America with the 'Day Butterfly Center' in Georgia, 'Butterfly World' in Florida, and 'Butterfly World' in California. Toone (1990) gives an account of various butterfly exhibits around the world. However, in the last 5 years, there has been a resurgence in the popularity of butterfly houses with a number of permanent facilities as well as temporary exhibitions being built. Britain has 50 to 60 butterfly houses attracting five million visitors annually and gate collections exceeded 5 million pounds(Collins, 1987a).

### 2.2 Butterfly gardening

Butterfly gardening has been defined as the art of growing plants to attract butterflies (Booth and Allen, 1990). The concept of having a small area of wild garden where the native vegetation as well as plants introduced especially for butterflies is now popular in many parts of the world (Newman 1967; Heal, 1973). These habitats may be designed to be support colonies of 10 to 25 species, in areas of about 500m$^2$. However, the microclimatic and topographical aspects must be taken into consideration in order to sustain resident butterfly populations in relatively small areas (New, 1991).

A survey was conducted in the U.K. in 1990 in order to document the butterfly species visiting gardens, nectar sources available and other general features (Vickery,1995). The study revealed that larger gardens attracted more species and diversity increased with proximity to natural habitats. Moreover, since the nectar supply may be fostered through watering, rural gardens helped in providing nectar when wild sources are scarce.

### 2.3 Butterfly farming

The management and conservation of flora and fauna by habitat protection is well accepted and the concept of captive breeding and farming of butterflies is a positive step in this direction. Though butterflies have high fecundity, this potential is hardly realised under natural conditions due to parasites, predators and diseases. Butterfly farming is an alternative source not only to replenish the already depleted natural resources, but also to provide material for trade and scientific study and to build up representative collections. It is now well known that populations are endangered by large- scale destruction of habitat and not by harvest of insects for exhibits.

In countries like the UK, USA and Papua New Guinea, butterfly farming and captive breeding is a well established industry. The most effective conservation measures in any part of the world will be those which can show a financial return. In Papua New Guinea, Malaysia, Madagascar and the Philippines, the farming of butterflies has significantly increased the amount of foreign currency traded in these countries. In general, the local butterflies are encouraged through the enhancement of their habitat by the cultivation of host plants. This provides easy access to pupae while having little or no negative impact on the wild population in the area. The pupae can be marked for living collections or emerging adults may be collected to provide undamaged specimens for collectors, museums and research purposes. This non-destructive utilization of a natural resource provides motivation for conservation by making the standing forest an economic asset (Vietmeyer, 1988). In Papua New Guinea, over 700 species of butterflies are traded and it has been demonstrated that farming bird-wing butterflies can produce more income per given area than cultivating coffee (Bloch, 1988).

The Insect Farming and Trading Agency (IFTA) in Bulolo, Papua New Guinea was established in 1978 with the objective of encouraging ranching of native butterfly species. The ranching of butterflies has been proved successful in Papua New Guinea (Anon., 1983; Hutton, 1985).The IFTA is also continuing to improve breeding techniques and to provide new data on the life history and hosts of several butterflies, so that subsequently, any species in the country can be farmed for their benefit.

Captive breeding is possible for many species and butterfly houses can help conservation through scientific research and education of the public. As long as the wild caught material is harvested in a sustainable manner, there will be no threat to the species exhibited. Although a thorough analysis of the potential for butterfly ranches around the world has never been made, there are many opportunities in tropical Africa, S. America and Asia.

### 2.3.1 Prospects for butterfly farming in India

India with its rich butterfly fauna holds great potential for butterfly farming enterprises. Biodiversity 'hot-spots' like North Eastern Himalayas and Western Ghats contain a diverse butterfly fauna and may be considered as ideal areas for butterfly farming enterprises (Khoshoo, 1984).

Butterfly farming will benefit people in rural areas as it will augment their income once they learn to breed butterflies in their homesteads for supply of larvae, pupae or well bred specimens. The methods adopted in Papua New Guinea for the farming of butterflies may be easily followed in our country. In Papua New Guinea, local farmers encourage the wild insects to colonise and breed in their gardens or farms by establishing the appropriate food plants. A certain proportion of the pupae are allowed to remain in the field and the remaining are collected and when the imagines emerge, they are killed and sent away for processing as ornaments or scientific specimens. The project provides income for the villagers and at the same time helps to ensure the continued survival of butterflies. Conservationists are now aware of the conservative potential of such programmes.

Preliminary attempts to maintain butterflies in captivity were initiated at KFRI during 1993-1996 (Mathew, 1998). Under this study, the Common rose (*Pachliopta aristolochiae*) and the southern birdwing (*Troides minos*) were bred on *Aristolochia indica* in field cages. The area surrounding the cage was developed into a butterfly garden. More recently, a Butterfly Garden and a Safari have been established at Calcutta and Hyderabad respectively. In a developing country like India where ecological imbalances due to industrialization, agriculture, pollution and deforestation are inevitable, practical measures to reduce the negative effects should be explored.

## 3. MATERIALS AND METHODS

Being a pilot study, much of the works carried out under this project were of an exploratory nature. Development of strategies for augmenting local fauna mainly by recreating natural habits formed the main component of this project besides testing methods to maintain stocks in captivity. The strategies followed for achieving these objectives are detailed below:

### 3.1 Establishment of a butterfly garden for *in situ* conservation

The butterfly garden was established in a 0.5 ha secondary moist deciduous forest patch in the KFRI campus. The area was along the slope of a hill so that it was possible to create various butterfly habitats such as open sunny areas, shady areas with profuse accumulation of litter, damp areas adjacent to a pond, lianas as well as bushy vegetation through landscaping (Fig.1). Each of these habitats is known to sustain specific groups of butterflies and in order to ensure the formation and survival of local population of these butterflies, a wide range of larval and adult host plants were introduced.

Cuttings / seedlings of the host plants of different butterflies raised in the nursery in polythene bags were planted in the garden in a phased manner. In the open area, nectar sources like Lantana camara, *Ixora* spp., Marigold, *Zinnia* sp. and *Cuphea* spp. were introduced. Certain alkaloid containing plants, which facilitate roosting of danaine butterflies such as *Crotalaria retusa*, *Calotropis gigantea*, and *Heliotropium keralense*, were also introduced in the open area. In the wooded area, the larval host plants such as *Citrus* sp, *Ficus religiosa, Aristolochia indica, Wattakaka volubilis, Tylophora indica*, *Carissa carandus*, *Ruta graveolens* and *Aegle marmelos* and nectar plants such as *Lantana camara* and *Clerodendrum paniculatum* were introduced. Daily watering and frequent application of fertilizers was undertaken to boost growth of plants.

### 3.2 Monitoring

Information on the seasonality of butterflies is very important in captive breeding programmes to ascertain whether it would be possible to sustain the butterfly population in the area throughout the year. For this, the butterfly population in the Butterfly Garden was regularly monitored and data on the relative abundance of butterflies, their seasonality, flight periods, pattern of colonisation etc., were generated by making regular transect counts.

*Transect count*

The transect count was carried out by making observations along a transect route traversing the garden. For daily sampling, two fixed locations were selected along the transect route, of which one was located in the garden area planted with introduced nectar and alkaloid  sources and the other in the area containing wild source of nectar and native tree species.

*Time of monitoring*

As butterflies show daily rhythms of flight activity, two observations were made each day *viz*., a forenoon count between 10.30 hrs and 11.30 hrs and an afternoon count between 02.30 hrs and 03.30 hrs. Counts were not taken during heavy rains or winds. A 10 minute visual census was done during each sampling period.

*Recording of data*

Initially, the butterflies were netted, identified and released while the unfamiliar species were collected for identification. Butterflies were identified by reference to D'Abrera (1982, 1985, 1986); Larsen (1987, 1988); Talbot (1939, 1947) and Wynter-Blyth (1957). The reference insect collection at KFRI was also consulted. As familiarity increased, visual recognition of various species was possible. Date, species, number of individuals and weather parameters like temperature, humidity and rainfall were recorded. Butterflies that could not be identified were not recorded.

## 3.3. Analysis of data

*Seasonal index*

The number of butterflies sighted per day was recorded separately for each family. The total number of butterflies sighted during each month for the period of study (24 months from June 1998 to May 2000) was calculated. For comparing the trends in the butterfly population, the seasonal index for each month was calculated using the following formula:

$$\text{Seasonal index} = \frac{\text{Month-wise mean}}{\text{Overall mean}} \text{ X100}$$

where, month -wise mean is the mean number of butterflies for a given family sighted over two years and overall mean is the mean of all month-wise means. By calculating the seasonal index it was possible to interpret the mean percentage occurrence of butterflies in a given month in relation to the overall mean monthly sightings.

*Correlation with weather conditions*

The total number of butterflies sighted per month belonging to each family and weather parameters such as monthly mean temperature and humidity as well as total rainfall for a period of 30 months commencing from June 1998 were recorded. The correlation coefficient between the number of sightings per month and the various weather parameters was computed.


Fig. 1. Layout of the Butterfly Garden
i. Butterfly forage area
ii. Insectary
iii. Exhibit area

## 3.4 Captive breeding for *ex situ* conservation

*Laboratory studies*

Immature stages collected in the field were brought to the laboratory. Rearing was done in sterlised glass bottles containing foliage of appropriate host plants maintained at room temperature. Leaves were changed daily. Morphological characters and the duration of instars were noted for the larval stages of the species reared. Mortality of egg, larval, and pupal stages due to insect parasites or microbial organisms was also recorded.

*Field- cage trials*

Adults reared in the laboratory were released in the field cages (Fig.2). An existing Insectary where larval host plants like *Citrus* sp, *Ficus religiosa*, *Aristolochia indica*, *Wattakaka volubilis*, *Tylophora indica*, *Carissa carandus*, *Ruta graveolens* and *Aegle marmelos* and nectar sources such as *Clerodendrum paniculatum*, *Lantana camara*, Marigold, Bachelor button, *Zinnia* and *Ixora* sp., were established, was used in the study. Cut flowers of the above plants were also kept in the cage and were changed every two days.

Fig.2.Inside of the Insectary used for captive breeding of butterflies.

The emergence of the adults after the successful completion of larval and pupal stages was noted. The emerged adults were tended in the cages by providing nectar sources.

## 4. RESULTS

### 4.1. Landscaping and introduction of butterfly host plants

Landscaping was carried out depending on the butterfly species present. Based on available information, the preferred larval host plants as well as the nectar sources of various butterflies were introduced in the study area. Some of the host plants were already available in the area prior to the study. Table 1 gives list of some local butterflies and their preferred host plants which were selected for introduction.

In establishing butterfly parks, time is a constraint as the success depends on the establishment of appropriate habitats for the various species. Therefore, in this study a two-pronged strategy aimed at boosting the population of the common butterflies as the immediate and that of the rare ones as a long-term objective was adopted.

Table 1. Host plants of some butterflies selected for introduction in the study area

| Butterfly family / species | Larval host plants |
|---|---|
| **Papilionidae** | |
| *Pachliopta hector* | *Aristolochia indica* |
| *P.aristolochiae* | *Aristolochia indica* |
| *Pachliopta pandiyana* | *Thottea siliquosa* |
| *Troides minos* | *Aristolochia indica, Aristolochia sp.* *Thottea siliquosa* |
| *Graphium doson* | *Michelia champaka* |
| *Graphium agamemnon* | *Michelia champaka, Annona sp.* |
| *Graphium sarpedon* | *Cinnamomum verum* |
| *Chilasa clytia* | *Cinnamomum verum* |
| *Papilio demoleus* | *Citrus limon, Citrus medica, Citrus aurantium, Aegle marmelos, Ruta graveolens, Murrya koenigii* |
| *Papilio polytes* | *Citrus aurantium, Citrus medica, Citrus limon, Aegle marmelos, Murrya koenigii, Murraya exotica, Zanthoxylum rhetsa,* |
| *Papilio polymnestor* | *Citrus aurantium,* |
| *Papilio helenus* | *Zanthoxylum rhetsa* |

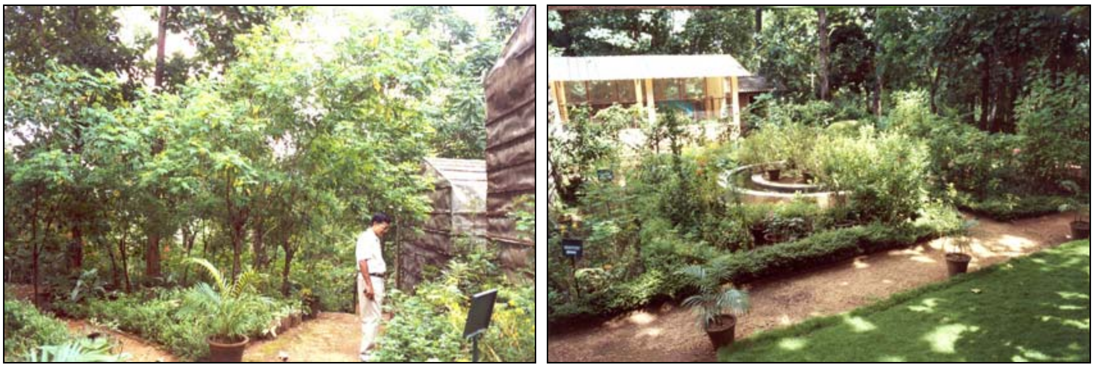
| | |
|---|---|
| **Pieridae** | |
| *Delias eucharis* | *Loranthus sp.* |
| *Eurema hecabe* | *Cassia fistula, Cassia tora, Albizia odoratissima, Caesalpinia pulcherima* |
| *Eurema blanda* | *Cassia fistula, Albizia lebeck, Caesalpinia pulcherima* |
| | *Cassia fistula* |
| *Catopsila pomona* | *Cassia* sp. |
| *Catopsila pyranthe* | *Cassia occidentalis, Cassia biflora* |
| *Appias lyncida* | *Bombax ceiba* |
| **Hesperidae** | |
| *Gangara thyrsis* | *Chrysalidocarpus luitesence* |
| **Danaidae** | |
| *Tirumala limniace* | *Wattakaka volubilis* |
| *Tirumala septentrionis* | *Wattakaka* sp. |
| *Parantica aglea* | *Tylophora indica* |
| *Danaus genutia* | *Holostemma ado-kodien* |
| *Danaus chrysippus* | *Calotropis gigantea* |
| *Euploea core* | *Carissa carandas, Ficus religiosa, Ficus tomentosa, Ficus racemosa, Hemidesmus indicus* |
| **Lycaenidae** | |
| *Talicada nyseus* | *Kalanchoe blossfieldiana,Kalanchoe pinnata,* |
| *Rathinda amor* | *Mangifera indica, Ixora* sp. |
| *Arphopala pseudocentaurus* | *Vateria indica* |
| **Nymphalidae** | |
| *Moduza procris* | *Mussaenda* sp. |
| *Cupha erymanthis* | *Flacourtia* sp. |
| *Cirrochroa thais* | *Hydnocarpus pentandra* |
| *Euthalia aconthea* | *Mangifera indica* |
| **Acraeidae** | |
| *Acraea violae* | *Passiflora edulis* |
| **Satyridae** | |
| *Elymnias caudata* | *Chrysalidocarpus luitesence* |

### 4.1.1. Creation of butterfly habitats

The study area was located of a hill comprising of a ridge and a slope. This area belonged to a degraded moist deciduous forest where a few trees (mostly *Zanthoxylum rhetsa*, *Tectona grandis*, *Bombax malabaricum* and bamboo) were already present. The ground flora consisted mostly of weeds like *Lantana camara, Clerodendrum* spp., and *Chromolaena odorata*.

Fig. 3. A view of the butterfly foraging area

Based on the terrain, the study area was divided into a butterfly foraging area (Fig.3) and an oviposition area. The slope with patches of trees and bushes were already present was selected as the forage area where various nectar plants such as *Clerodendrum* spp. *Lantana camara* and *Cassia* spp. were introduced. In addition to these flowering plants, selected larval host plants such as *Citrus* spp., *Murraya koenigii* and *Cinnamomum verum* were planted in the forage area to offer host plants for ovipostion by specific butterflies that visit the area. The nectar plants remained in bloom for most part of the year except during the summer months when they dried out. Attempts were made in the second year of the project to irrigate the area by setting up sprinklers. Watering the plants during the summer months resulted in more flushing of leaves and flowers which helped to sustain the butterflies which otherwise disappeared from the study area. Bushes, lianas and ground vegetation were maintained as such and new hedges were created by setting up creepers of *Passiflora edulis*, *Aristolochia indica* and *Wattakaka volubilis* in order to attract and sustain selected groups of butterflies. Care was also taken to leave the litter as such since many satyrids prefer to remain among litter.



Figs.4 a,b. A view of the butterfly oviposition cum display area developed on the ridge of the study area.

The ridge of the area that was more or less plain and open was developed into an egg-laying cum display area (Figs.4 a,b). A circular canal of 5m diameter having 60 cm depth was developed in the middle of this area. The area surrounded by the canal was fitted with a sprinkler to maintain adequate humidity throughout the year. This area was also planted with alkaloid containing plants such as *Crotalaria retusa*, *Heliotropium keralense* etc., for demonstrating roosting of milkweed butterflies. *Wattakaka volubilis, Tylophora indica, Hemidesmus indicus, Calotropis gigantea, Holostemma ado-kodien, Bombax sp., Cassia fistula, C. occidentalis, C.tora, Murraya koengii, M. exotica, Aristolochia indica, Citrus* sp., *Carrisa carandas, Ficus* sp., and *Kalanchoe pinnata* were planted in this area to attract butterflies for egg laying. In addition to these larval host plants, 35 species of flowering plants, either propagated from seeds or bought from nurseries were introduced in the forage area (Table 2). Although organic and inorganic fertilizers were applied regularly, no pesticide was applied to the plants, to ward off infestation by undesired pest organisms. Plants that were severely defoliated due to heavy larval feeding were covered with insect proof nets and treated with fertilizers to strengthen them and to induce formation of fresh foliage.

Table 2. List of plants present in the study area

| **Plant species** | **No. of plants in the beginning of the study** | **No. of saplings planted** |
|---|---|---|
| *Acestatia sp.* ∗ | - | 8 |
| *Aegle marmelos*+ | - | 9 |
| *Albizia lebeck*+∗ | - | 525 |
| *Albizia odoratissima* + ∗ | 3 | 5 |
| *Allamanda cathartica* | - | 5 |
| *Angelonia biflora* | - | 2 |
| *Aristolochia indica*+ | 24 | 75 |
| *Aristolochia grandiflora*+ | - | 5 |
| *Bauhinia racemosa* | - | 1 |
| *Begonia spp.* ∗ | - | 30 |
| *Bombax* sp. + | - | 5 |
| *Caesalpinia pulcherima*∗ | - | 20 |
| *Calliandra inequalifolia* | - | 1 |
| *Calotropis gigantea*+ | - | 6 |

| | | |
|---|---|---|
| *Cananga odorata* | - | 3 |
| *Carissa carandus+∗* | - | 17 |
| *Cassia biflora +∗* | 25 | 7 |
| *Cassia fistula +∗* | 2 | 13 |
| *Cassia occidentalis+* | - | 34 |
| *Cassia tora+* | - | 23 |
| *Cassia sp.* | - | 8 |
| *Catheranthus roseus* | - | 2 |
| *Centranthera* sp. | - | 2 |
| *Chrysalidocarpus luitesence∗* | - | 25 |
| *Citrus aurantia +* | - | 10 |
| *Citrus limon+* | 14 | 37 |
| *Citrus medica+* | - | 8 |
| *Clerodendrum paniculatum∗* | 75 | 250 |
| *Clitoria ternatea∗* | - | 4 |
| *Copsia fruiticosa* | - | 1 |
| *Cosmos bipinnatus* | - | 2 |
| *Crotalaria pallida* | - | 5 |
| *Crotalaria retusa* | - | 25 |
| *Cuphea hyssopifolia∗* | - | 25 |
| *Cuphea miniata∗* | - | 300 |
| *Cycas circinalis+* | - | 2 |
| *Doxantha unguis-cati∗* | - | 8 |
| *Durauta plumerii* | - | 1 |
| *Euphorbia* sp. | - | 2 |
| *Ficus racemosa+* | 2 | 3 |
| *Ficus religiosa+* | - | 16 |
| *Evolvulus* sp. | - | 2 |
| *Gardenia sp. ∗* | - | 10 |
| *Gloriosa superba* | - | 4 |
| *Gomphrena globosa∗* | - | 150 |
| *Heliotropium keralense* | - | 5 |
| *Hemidesmus indicus+* | 38 | 55 |
| *Hibiscus rosa-sinensis∗* | - | 12 |
| *Holostemma ado-kodien+* | - | 15 |
| *Hydnocarpus pentandra* | - | 2 |
| *Impatiens* sp. | - | 1 |
| *Ixora chinensis∗* | 2 | 8 |
| *Ixora coccinea∗* | 1 | 35 |
| *Ixora parviflora∗* | 5 | 120 |
| *Ixora macrothyrsa+∗* | 3 | 34 |
| *Jasminum grandiflorum* | - | 5 |
| *Jasminum pubescens∗* | - | 3 |
| *Jatropa podagirica∗* | 1 | 2 |
| *Kalanchoe blossefeldiana+∗* | - | 12 |
| *Kalanchoe pinnata +∗* | - | 57 |
| *Kalanchoe suarezensis+∗* | - | 5 |

| | | |
|---|---|---|
| *Lantana camara*∗ | 25 | 35 |
| *Lantana sellowiana*∗ | - | 4 |
| *Michelia champaka*+ | - | 2 |
| *Mirabilis jalapa* | - | 2 |
| *Murraya exotica*+ | - | 18 |
| *Murrya koenigii*+ | 9 | 15 |
| *Mussaenda erythrophylla*∗+ | - | 2 |
| *Mussaenda incana*+∗ | - | 2 |
| *Mussaenda laxa*+∗ | - | 14 |
| *Mussaenda luteola*∗ | - | 2 |
| *Nyctanthus arbor-tristis* | - | 3 |
| *Nepenthes cassiana* | - | 2 |
| *Ocimum gratissimum* | - | 2 |
| *Ocimum tenuifolium* | - | 2 |
| *Passiflora edulis*+ | - | 8 |
| *Pentas lanceolata*∗ | - | 5 |
| *Plumeria alba* | - | 5 |
| *Plumeria rubra*∗ | - | 10 |
| *Pseudocalyma atata* | - | 2 |
| *Pyrostegia venusta* | - | 2 |
| *Rosa* sp. | - | 2 |
| *Ruellia affinis* | - | 2 |
| *Ruta graveolens*+ | - | 5 |
| *Salvia splendens*∗ | - | 10 |
| *Spilanthes* sp. | - | 4 |
| *Stachytarpheta mutabilis*∗ | - | 15 |
| *Strobilanthus lawsonii* | - | 1 |
| *Tabernaemontana coronaria* | - | 2 |
| *Tacca* sp. | - | 2 |
| *Tagetus erecta* | - | 5 |
| *Thottea barberi*+ | - | 3 |
| *Thottea siliquosa*+ | - | 3 |
| *Thunbergia erecta*∗ | - | 20 |
| *Thunbergia grandiflora* | - | 5 |
| *Tithonia diversifolia*∗ | - | 3 |
| *Turnera ulmifolia*∗ | - | 4 |
| *Tylophora indica*+ | 3 | 27 |
| *Vinca rosea*∗ | - | 15 |
| *Wattakaka* sp. + | - | 24 |
| *Wattakaka volubilis*+ | - | 28 |
| *Zanthoxylum rhetsa*+ | 20 | 15 |
| *Zinnia haageana*∗ | - | 20 |

* Nectar plants
+ Larval host plants

### 4.2. Butterfly fauna

Seventy three species of butterflies belonging to eight families were recorded from the study site as listed in Appendix I. Maximum number of species recorded belonged to the families Papilionidae and Nymphalidae. Of the various species recorded, about a dozen were quite common in the area and the remaining were found only during certain months of the year. The commonly occurring butterflies belonged to the families Papilionidae and Danaidae. Butterflies belonging to the other families were sighted only occasionally. The butterflies recorded in this study included 8 species that are Western Ghats endemics and 10 species having protected status under the Wildlife (Protection) Act (GOI, 1972).

*Butterfly population*

The general trend of the butterfly species visiting the garden was obtained through monitoring, which was initiated in June 1998. Prior to landscaping and introduction of host plants, 46 species of butterflies were present in the study area most of which were represented by a few individuals and spotted at long intervals. Just within two years, following introduction of appropriate larval and adult host plants there was sharp increase in the abundance of butterflies, both of individuals and species. During the first half of this study (after 15 months), there were 4509 sightings of individuals belonging to 43 species. After the study (*i.e.*, after 30 months) 5993 sightings of individuals belonging to 50 species have been recorded (Table 3). This indicates a tremendous increase in the number of individuals and species following introduction of appropriate host plants and creating suitable butterfly habitats.

Table 3. Butterflies sighted from the area during the period of study (Jun.1998 to Nov.2000)

| **Butterfly Family / species** | **No. of sightings** | | |
|---|---|---|---|
| | **Ist half** | **IInd half** | **Total** |
| **Papilionidae** | | | |
| *Chilasa clytia* | 81 | 15 | 96 |
| *Graphium agamemnon* | 5 | 5 | 10 |
| *G. antiphates* | 19 | 13 | 32 |
| *G.sarpedon* | 7 | 5 | 12 |
| *Pachliopta aristolochiae* | 191 | 175 | 366 |
| *P. hector* | 24 | 45 | 69 |
| *P. pandiyana* | 50 | 57 | 107 |
| *Papilio buddha* | 39 | 17 | 56 |
| *P. crino* | 0 | 2 | 2 |
| *P. demoleus* | 2 | 14 | 16 |
| *P. helenus* | 43 | 52 | 95 |
| *P. liomedon* | 1 | 2 | 3 |
| *P. paris* | 4 | 1 | 5 |
| *P. polymnestor* | 141 | 69 | 210 |
| *P. polytes* | 217 | 139 | 356 |

| | | | |
|---|---|---|---|
| *Troides minos* | 226 | 159 | 385 |
| **Pieridae** | | | |
| *Appias sp.* | 1 | 7 | 8 |
| *Catopsilia sp.* | 154 | 93 | 247 |
| *Delias eucharis* | 24 | 10 | 34 |
| *Eurema sp.* | 399 | 288 | 687 |
| *Leptosia nina* | 1 | 3 | 4 |
| **Acraeidae** | | | |
| *Acraea violae* | 0 | 32 | 32 |
| **Satyridae** | | | |
| *Melanitis leda* | 17 | 0 | 17 |
| *Orsotrioena medus* | 1 | 0 | 1 |
| *Ypthima huebneri* | 1 | 4 | 5 |
| **Nymphalidae** | | | |
| *Cupha erymanthis* | 5 | 3 | 8 |
| *Ariadne merione* | 0 | 3 | 3 |
| *Junonia atlites* | 25 | 36 | 61 |
| *J. hierta* | 0 | 3 | 3 |
| *J. iphita* | 36 | 38 | 74 |
| *J. lemonias* | 1 | 112 | 113 |
| *J. orithya* | 0 | 1 | 1 |
| *Hypolimnas bolina* | 0 | 21 | 21 |
| *H. misippus* | 1 | 11 | 12 |
| *Moduza procris* | 0 | 2 | 2 |
| *Neptis hylas* | 14 | 6 | 20 |
| *Phalanta phalantha* | 0 | 2 | 2 |
| **Lycaenidae** | | | |
| *Arhopala pseudocentaurus* | 1 | 0 | 1 |
| *Castalius rosimon* | 5 | 0 | 5 |
| *Jamides* sp. | 202 | 315 | 517 |
| *Rathinda amor* | 0 | 6 | 6 |
| *Spalgis epius* | 0 | 3 | 3 |
| *Talicada nyseus* | 0 | 129 | 129 |
| **Hesperiidae** | | | |
| *Badamia exclamationis* | 0 | 3 | 3 |
| *Celaenorrhinus leucocera* | 2 | 0 | 2 |
| *Pelopidas mathias* | 2 | 1 | 3 |
| *Potanthus sp.* | 0 | 3 | 3 |
| *Tagiades litigiosa* | 1 | 4 | 5 |
| *Taractrocera sp.* | 3 | 0 | 3 |
| *Udaspes folus* | 1 | 1 | 2 |
| **Danaidae** | | | |
| *Danaus genutia* | 484 | 453 | 937 |

| | | | |
|---|---|---|---|
| *D. chrysippus* | 13 | 48 | 61 |
| *Euploea core* | 789 | 1186 | 1975 |
| *Parantica aglea* | 224 | 424 | 648 |
| *Tirumala limniace* | 359 | 382 | 741 |
| *T.septentrionis* | 693 | 1590 | 2283 |
| **Grand total** | 4509 | 5993 | 10502 |

*Population trends of butterflies*

Various factors such as vegetation type, climate, habitat as well as incidence of parasites, predators and pathogens are known to influence the population trends of butterflies. Data generated on the above aspect for the different groups of butterflies are presented below.

Papilionidae

Population was present throughout the year. Maximum number of sightings was observed in August 1998. The population showed a sharp decline during November 1998 when the count was low, probably due to heavy winds characteristic of these months (Figs.5a,b). From December 1998 onwards the population registered an increase and reached its peak in June1999. The months November to February are not very suitable due to heavy winds and prevailing dry conditions. The seasonal index reached a peak during the months June, July and August and showed a sharp decline in November. The population then showed an increase.

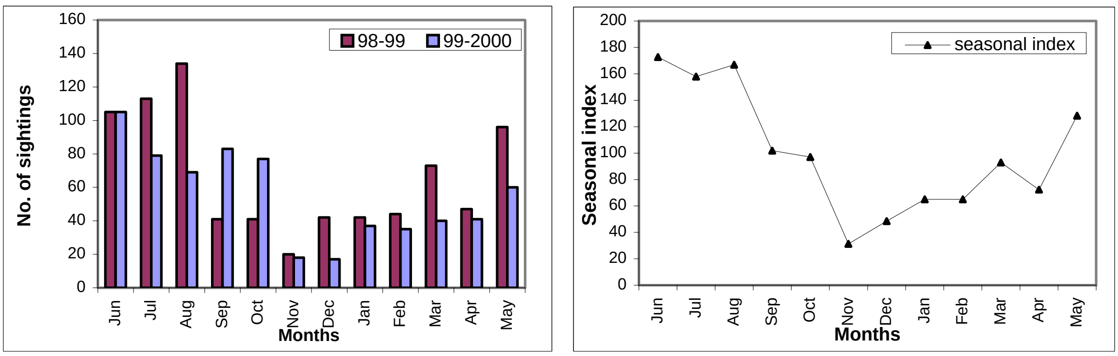



Fig.5. a) Population trends of Papilionidae b) Seasonal Index

Pieridae

Population was present throughout the year. The maximum number of sightings was recorded during November-December 1998 while the rainy months, June, July and August 1998 had low counts. However, in September 1999, the number of sightings was considerably higher than in the previous year and this is attributed mostly to the availability of a wide range of host plants that have been introduced (Figs.6a,b). In the case of the seasonal index, the highest value was in November and the lowest values in the months of July and August.

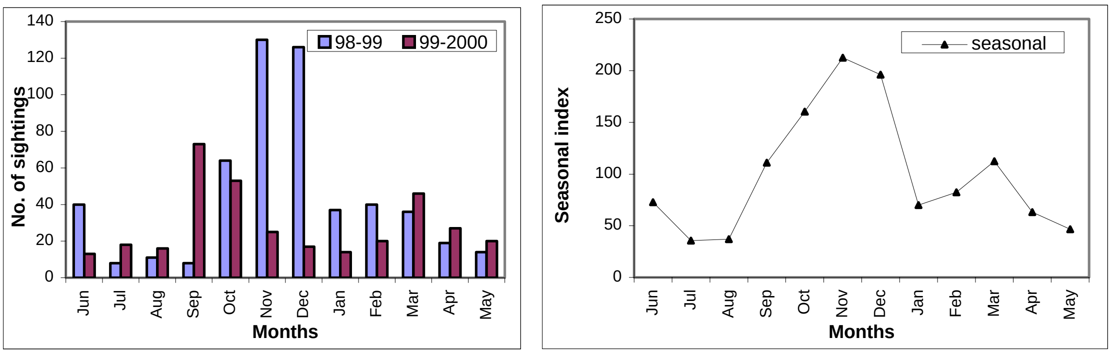



Fig.6. a) Population trends of Pieridae b) Seasonal Index

Acraeidae

Since sightings were obtained only in March to May in second year, clear pattern of the seasonal trends was not available (Figs. 7 a,b).

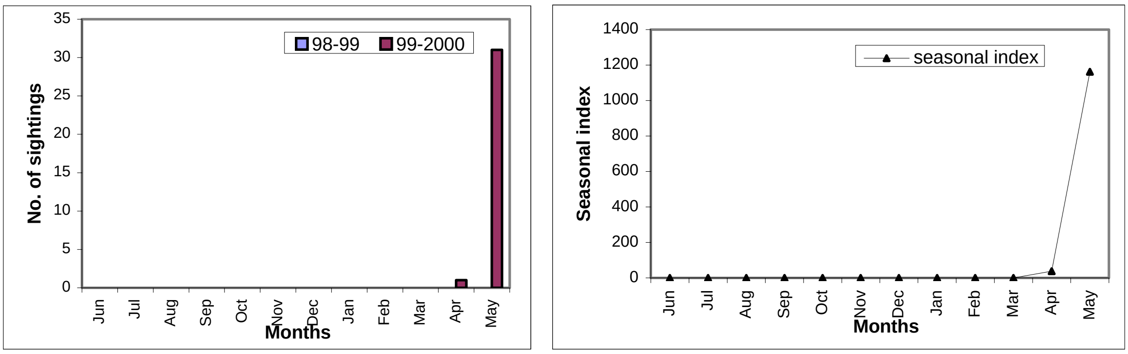



Fig. 7. a) Population trends of Acraeidae b)Seasonal index

Satyridae

For Satyridae, maximum count was obtained in June 1998. Members of this family are mostly crepuscular and shade loving in habits and hence could not be effectively sampled. No consistent pattern was observed for the two years (Figs.8a,b). There were more sightings during 1998-1999 compared to 1999-2000. The seasonal index shows nil values in the months of July, August, September, February and March. The highest value was obtained in June. Since the number of sightings of members of this family was low, this data may not indicate actual population trends.

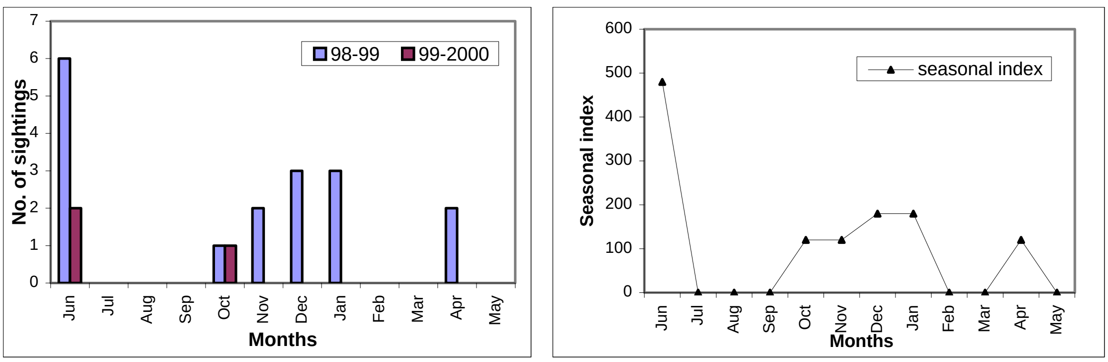
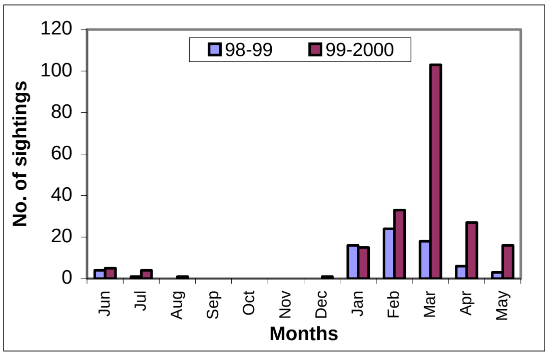



Fig. 8. a) Population trends of Satyridae b) Seasonal index

Nymphalidae

Only a limited number of nymphalid species were observed. During 1999, a few sightings were recorded during January to March which showed a decline till July. The highest count was obtained in March 2000. There were no sightings during September-November in both years (Figs. 9a,b). The drier half of the year from January to May appears to be favourable for this family. The seasonal index shows a steady increase from December reaching a peak in March, then a sudden decline in April and subsequent gradual decrease till August.



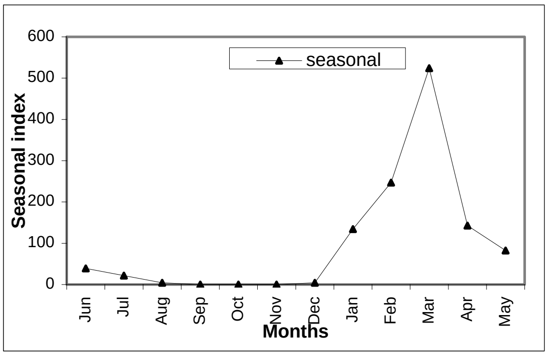
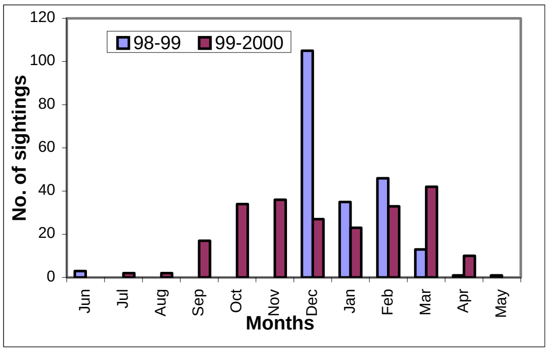




Fig. 9. a) Population trends of Nymphalidae b) Seasonal index

Lycaenidae

In the first year (1998-1999) there was a peak in numbers during December 1998 which decreased in January 1999 and persisted till March 1999, (Figs. 10a,b). In the second year, although the number of butterflies during December was not as high as in the previous year, a moderate population could be sustained for a longer period. This was due to the establishment of specific host plants like *Kalanchoe blossfieldiana* and K. *pinnata*. During the months May to August, very few individuals were recorded. The seasonal index showed a peak in December and a decrease till August after which it gradually increased.



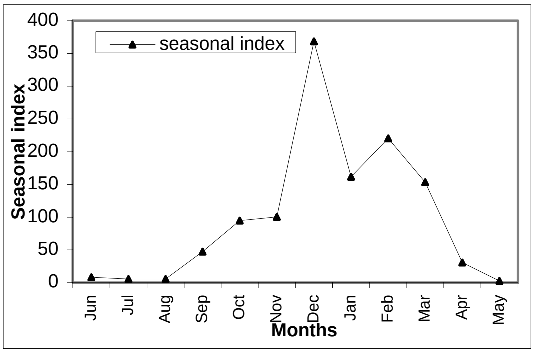
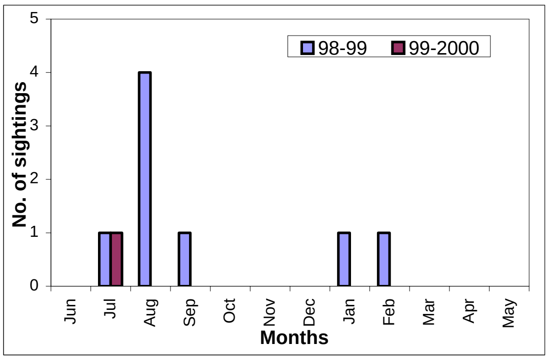




Fig.10. a) Population trends of Lycaenidae b) Seasonal index

Hesperiidae

Since the members of this family are not very conspicuous, sampling was not adequate and the number of individuals sighted was low. Highest numbers were observed during August 1998 (Figs. 11a,b). The seasonal index showed the highest value during August and then a declining trend until October. The population registered an upward trend during January and February and then declined from March to June.



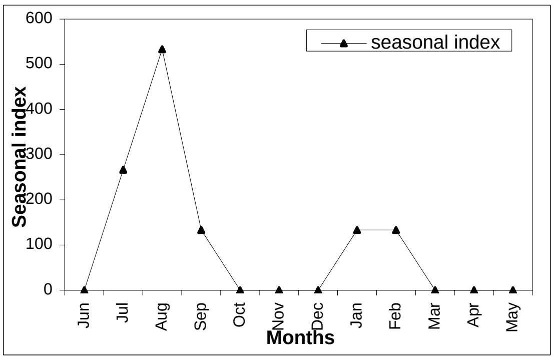
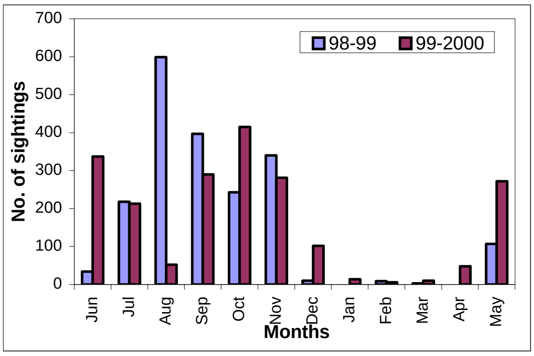




Fig. 11. a) Population trends of Hesperidae b) Seasonal index

Danaidae

The highest count was obtained in 1998 August followed by October 1999 (Figs.12 a,b). The counts in June 1999 was higher than that of June 1998 while the numbers observed in May 2000 exceeded that of May 1999. Similarly, the numbers observed in December 1998 had increased in the second year. In both years, the months January to April had very few individuals. However, in the second year, a moderate population could be sustained from December 1999 to April 2000. The increase in numbers observed in the months June 1999 and October 1999 was possibly due to establishment of larval host plants of the danaids *viz.*, *Holostemma ado-kodien*, *Wattakakka volubilis*, *Calotropis gigantea*, *Ficus* spp., *Carissa carandus* and *Tylophora indica*. Irrigating the area by setting up sprinklers might have also contributed to a spurt in butterfly population in May 2000. The seasonal index remained more or less similar during June to November and thereafter declined sharply during December and remained at a low level until April. The population showed an increase during May.



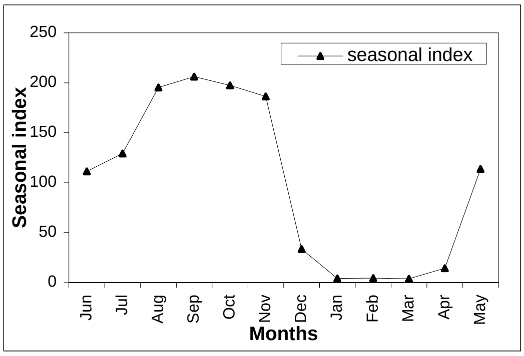




Fig. 12. a) Population trends of Danaidae b) Seasonal index

Data presented here shows that the families Papilionidae, Danaidae, Lycaenidae and Pieridae showed more or less continuous population trends throughout the year while others like Satyridae, Nymphalidae and Hesperiidae showed rather erratic populations.

*Overall population trend*

Data generated by pooling the total number of sighting for all groups of butterflies during the period June 1998 to May 2000, has shown that the families Papilionidae, Pieridae and Danaidae which were able to exploit the available resources showed the highest numbers (Fig. 13).

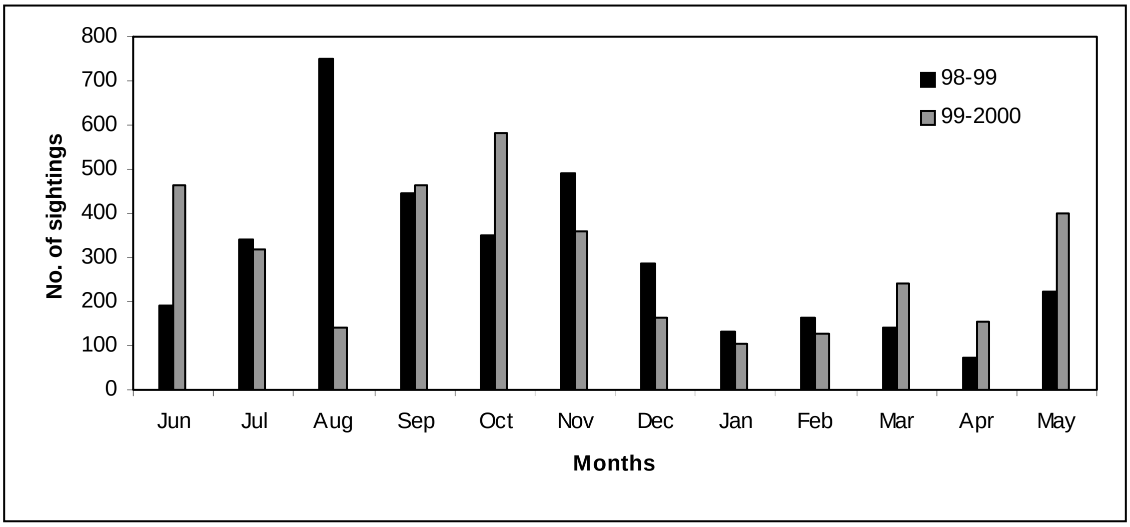
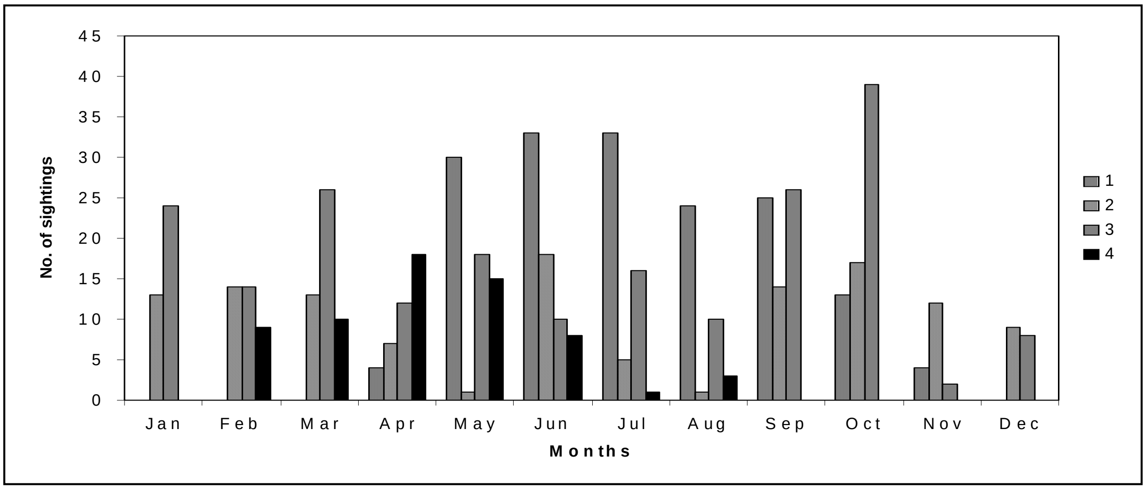



Fig.13. Overall butterfly sightings in various months

*Seasonal trends of butterflies*

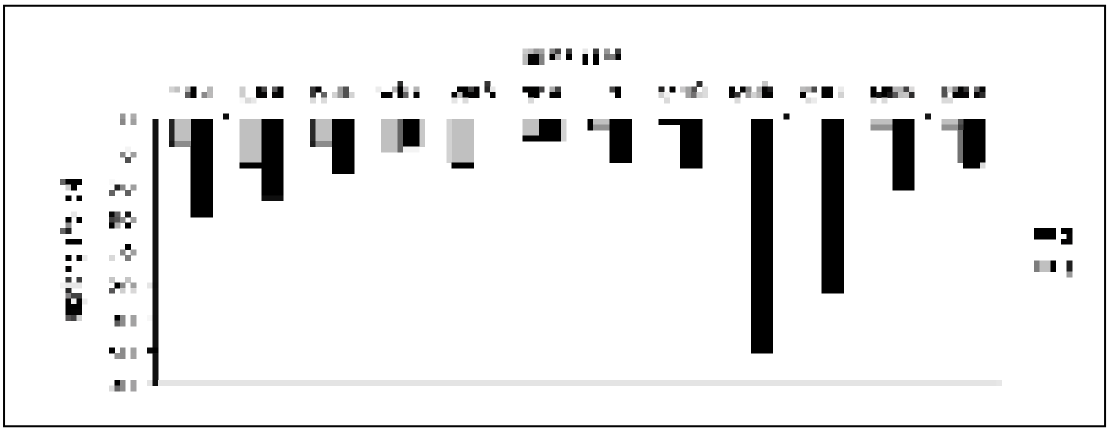
In order to select appropriate species for breeding or gardening programmes, the seasonal trends of butterflies were examined. Among the papilionids, the common rose (*P. aristolochiae*) was observed in all months of the year with the lowest numbers in May and August. June had the highest count and a moderate population could be sustained in the remaining months.




1-Troides minos. 2-Pachliopta aristolochiae
3-Papilio polytes. 4-Chilasa clytia
Fig. 14. Seasonal trends of selected species of Papilionidae (Jan 1999-Dec 1999)

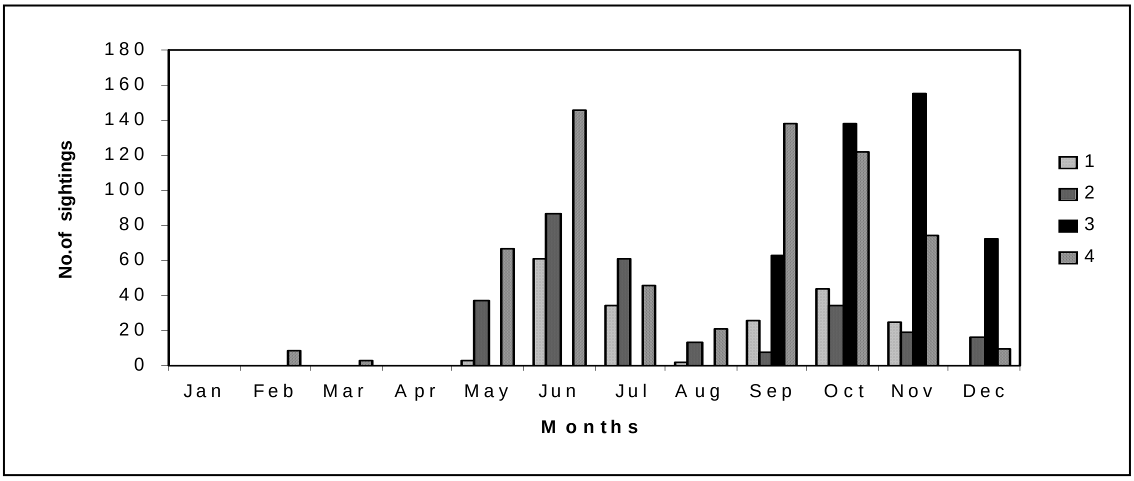
The common mormon (*Papilio polytes*) showed a peak in October and a sudden drop in November. This species was also observed throughout the year. In the case of the southern birdwing (*Troides minos*), population was observed from April to November with highest numbers recorded in June and July. In the case of the common mime (*Chilasa clytia)*, population build up was observed from February to August with highest numbers recorded in April and lowest in July (Fig.14). The sudden decline in the number was attributed to parasitism of larval and pupal stages.

In the Pieridae, *Catopsilia* sp. and *Eurema* sp. were observed in all months of the year except in May (*Eurema* sp.) and September and October (*Catopsilia* sp.). In the case of *Eurema* sp., mass build up was noticed during the months October-November (Fig.15).



1.Catopsilia sp.
2.Eurema sp.
Fig. 15. Seasonal trends of selected species of Pieridae (Jan.1999-Dec.1999)

Most of the danaids could be sustained in the field only from May to December. The blue tiger (*Tirumala limniace)* was observed from May to December with the highest numbers recorded in June. The dark blue tiger (*Tirumala septentrionis)* was recorded fromThe f this species was recorded in). The striped Tiger (*Danaus genutia*) was observed in June-July and September to November. The highest count was recorded in June. The common Crow *(Euploea core)* is the only danaid that was observed in the months of February and March. Highest count was seen in June.




11 - Danaus genuita
22 - Tirumala limniace
33 - Tirumala septentrionis
4 - Euploea core

Fig.16. Seasonal trends of selected species of Danaidae (Jan.1999-Dec.1999)

*Occurrence of butterflies in different climatic regimes*

The effect of climate on the occurrence of various groups of butterflies was examined. Since the tolerance level of various species is expected to be within narrow ranges, the occurrence at different ranges of temperature, humidity and rainfall was studied. For most butterfly groups, an average temperature ranging from 25-26°C was the most favorable followed by a range of 23-25°C and 27-29°C (Table 4).

Table 4. Number of sightings of butterflies at different temperatures

| **Family** | **Temperature (°C)** | | | |
|---|---|---|---|---|
| | 23-25 | 25-27 | 27-29 | >30 |
| Papilionidae | 350 | 937 | 288 | 245 |
| Pieridae | 122 | 551 | 173 | 134 |
| Acraeidae | 0 | 0 | 11 | 21 |
| Satyridae | 3 | 18 | 0 | 2 |
| Nymphalidae | 21 | 58 | 100 | 141 |
| Lycaenidae | 84 | 333 | 171 | 73 |
| Hesperidae | 4 | 14 | 3 | 0 |
| Danaidae | 1314 | 4512 | 658 | 161 |

Similarly, average humidity ranging between 80-100 per cent was the most preferred followed by 60-80 per cent and below 60 per cent was least preferred (Table 5).

Table 5. Number of sightings of butterflies at different levels of humidity

| **Family** | **Humidity (%)** | | |
|---|---|---|---|
| | 40-80 | 60-80 | 80-100 |
| Papilionidae | 18 | 341 | 1461 |
| Pieridae | 18 | 221 | 741 |
| Acraeidae | 0 | 11 | 21 |
| Satyridae | 2 | 3 | 18 |
| Nymphalidae | 15 | 204 | 101 |
| Lycaenidae | 14 | 178 | 469 |
| Hesperidae | 0 | 2 | 19 |
| Danaidae | 4 | 125 | 6516 |

Rainfall up to 50mm per day was the most favourable level followed by 50-100 mm. Heavy rain was not favourable since very few butterflies were observed above a daily rainfall of 100mm (Table 6).

Table 6. Number of sightings of butterflies recorded during different rainfall regimes

| **Family** | **Rainfall (mm)** | | |
|---|---|---|---|
| | <=50 | 50-100 | >100 |
| Papilionidae | 1733 | 69 | 18 |
| Pieridae | 967 | 9 | 4 |
| Acraeidae | 32 | 0 | 0 |
| Satyridae | 21 | 2 | 0 |
| Nymphalidae | 319 | 0 | 1 |
| Lycaenidae | 657 | 4 | 0 |
| Hesperidae | 21 | 0 | 0 |
| Danaidae | 6365 | 221 | 59 |

The correlation coefficient obtained between number of sightings and various weather parameters for different families are reported in Table 7. In the case of Nymphalidae and Danaidae, the number of sightings was significantly correlated with average temperature. For all other families, the correlation coefficient between temperature and the number of sightings was low.

The number of sightings was also significantly correlated with humidity in Nymphalidae (negative), Papilionidae (positive) and Danaidae (positive). Similarly, the total rainfall and the number of sightings was found to be highly correlated (positive) in the case of papilionidae. Low corelation coefficients were obtained in the case of other families.

Table 7. Correlation between the number of sightings of different families of butterflies and average temperature and average humidity

| **Family** | **Correlation** | | |
|---|---|---|---|
| | **Average temperature (°C)** | **Average humidity (%)** | **Total Rainfall (mm)** |
| Papilionidae | -0.3518ns | 0.4072* | 0.7530** |
| Pieridae | -0.0627ns | -0.0091ns | -0.2661ns |
| Acraeidae | 0.2783ns | -0.0099ns | -0.0707ns |
| Satyridae | -0.2914ns | 0.0844ns | 0.2708ns |
| Nymphalidae | 0.5723** | -0.5418* | -0.3090ns |
| Lycaenidae | 0.0633ns | -0.1579ns | -0.3598ns |
| Hesperiidae | -0.3217ns | 0.3535ns | 0.3024ns |
| Danaidae | -0.5297** | 0.6680** | 0.3817* |

**- significant (at 1% level)
* significant (at 5% level)
ns- non-significant

*Habitat preference of butterflies*

Most papilionids like *Papilio buddha, P. polymnestor, P. helenus, P. paris, Troides minos, Pachliopta pandiyana* and *Chilasa clytia* preferred habitats having native trees, visiting flowers in the sunlit patches in the forenoon when nectar concentration is highest. They were observed to fly rapidly amid bushes and tree tops frequently feeding at the flower heads of *Clerodendrum paniculatum*. Certain papilionids like *Troides minos* and *Pachliopta pandiyana* which are more territorial in habits were seen for longer periods in these areas. Most of these butterflies preferred to stay in the forested patch although some species like *Papilio demoleus, P. polytes, Pachliopta hector* were sighted more often in the open garden area devoid of trees.

The pierids and nymphalids were active in bright sunshine particularly during noon feeding at the flowers of *Cassia* spp. The pierids like *Catopsilia sp.* and *Eurema* sp. are usually sighted in the open sunny areas along with the nymphalids like *Junonia hierta, J. altites, J. iphita, J. precis and Hypolimnas* spp.

Satyrids like *Mycalesis* sp., and *Melanitis leda ismene* were seen in the cool shaded areas under trees resting amid dry leaves and litter on the forest floor. Most sightings of satyrids were in the afternoon. The sombre-coloured hesperids as a group were inconspicuous being observed nectaring in the late afternoon hours. With regard to the lycaenids, many species like *Jamides* sp., *Talicada nyseus, Castalius rosimon* and *Everes* sp., were seen in the open sunny areas nectaring mainly on flower of *Cuphea* sp. in the garden area.

The danaids like *Euploea core, Tirumala spp., Danaus spp., Parantica aglea* were observed aggregating in large numbers on alkaloid sources present in open garden area exposed to direct sunlight. However, humidity is also an important factor for the presence of these species in the area. These species prefer flowers of *Lantana* sp. and *Ixora* sp., with males roosting on *Crotalaria retusa* feeding on the sap exuding from the foliage which they lacerate by scratching with the claws of the first pair of legs. Association of caterpillars of the *Argina argus* Koll. was found to be essential to initiate roosting of the danaine butterflies. Probably, feeding by the caterpillars of this insect expose the sap which contain an alkaloid that stimulate the males to roost and start feeding. An alkaloid pyrrolizidine is known to be essential for the development of the male pheromone glands of danaine butterflies (Ackery and Vane-Wright, 1984).

The above phenomena has been taken advantage of and utilised in this study to make danaine butterflies to aggregate in the study area. For this purpose, alkaloid sources like *Crotalaria retusa* and *Heliotropium keralense*, were planted in the garden area and aggregations of *Danaus genutia, D. chrysippus, Tirumala limniace, T. septentrionis, Parantica aglea* and *Euploea core* could be made to roost on these plants during the period June to November. However, in the dry months no aggregation was observed on these plants due to their migration to the cooler habitats in the catchment area of the Peechi dam situated about five km away from our study site. Here, the butterflies were found perched on twigs of understorey bushes about a metre above the ground in clusters of two to six. Obviously, the site determinants for these dry season aggregations are the simultaneous presence of shade and water as well as perhaps nectar sources.

### 4.3. Captive breeding of butterflies

Developing a strategy for breeding butterflies in captivity was one of the objectives of this project. The eggs or early instars of butterflies collected from the garden were reared in the laboratory for studying their morphology and biology. Initially, the larvae were maintained on the foliage of respective host plant in sterilised glass jars with the mouth covered by a cloth to facilitate aeration. Data generated for the various species are presented below.

**1.*Pachliopta aristolochiae* (Common Rose)**
(Plate I, Figs. 4a-d)

Adult tailed, upperside black. Hindwing with five elongate white spots around the lower end of the cell. Marginal series of red crescents (Plate I, Fig. 4a)**.**

The eggs are pale orange in colour and are laid singly (Plate I, Fig. 4b). Incubation period is eight to nine days. The larva is black with fleshy red tubercles. White spot at the base of subdorsal tubercles of segments 11 and 12. Segments 7 and 8 with white markings (Plate I, Fig. 4c). Osmeterium orange. Larval period is thirty two to thirty six days. The pupa is brown in colour with tubercles (Plate I, Fig. 4d). Pupal period is fourteen to sixteen days.

Captive breeding trials

Captive breeding trials using this species were initiated in August 1999. The juveniles found on host plants in the open field and in the garden were collected and released on to potted plants of *Aristolochia indica* maintained in cages. Altogether sixty three juveniles of *Pachliopta aristolochia* collected from the field during 16 August to 22 September 1999 were introduced on to the host plants. Details of immature stages maintained in the field cages are given in Table 8.

Table 8. Data on larvae reared in the laboratory

| **Date** | **1st instar** | **2nd instar** | **3rd instar** | **4th instar** | **Total** |
|---|---|---|---|---|---|
| 15 Aug. 1999 | 3 | - | 1 | - | 4 |
| 20 Aug. 1999 | 1 | 2 | 1 | - | 4 |
| 30 Aug. 1999 | 1 | 3 | 3 | - | 7 |
| 31 Aug. 1999 | - | - | 1 | - | 1 |
| 3 Sept. 1999 | 2 | - | 1 | - | 3 |
| 14 Sept. 1999 | 3 | 2 | - | - | 5 |
| 17 Sept. 1999 | - | 1 | - | - | 1 |
| 22 Sept. 1999 | - | 1 | - | 1 | 2 |
| 27 Sept. 1999 | - | 2 | 8 | - | 10 |
| 28 Sept. 1999 | - | 3 | - | - | 3 |
| 29 Sept. 1999 | 1 | - | 3 | - | 4 |
| 30 Sept. 1999 | 1 | 2 | - | - | 3 |
| 4 Oct. 1999 | - | - | 1 | - | 1 |
| 5 Oct.1999 | - | 2 | - | - | 2 |
| 14 Oct. 1999 | 2 | 1 | - | - | 3 |

| | | | | | |
|---|---|---|---|---|---|
| 15 Oct. 1999 | - | 1 | - | - | 1 |
| 18 Oct. 1999 | - | 4 | - | 1 | 5 |
| 21 Oct. 1999 | 2 | 2 | - | - | 4 |

The adults emerged were maintained on flowers of *Clerodendrum paniculatum*. They were found to be quite active within the cage. Although courtship was not observed, eggs were seen on plants, indicating successful mating among the butterflies released.

Performance of second generation

The eggs laid were reared to get the second-generation larvae which showed signs of loss of vigor and did not attain pupation. This could probably be due to the inadequate nectar sources provided to the parents or due to deterioration of the quality of the larval host plants as a result of defoliation by insects of the previous generation. However, in subsequent trials, these drawbacks were taken into account and large numbers of larval host plants and nectar sources were introduced into the field cages to offer uninterrupted supply of good quality host plants and nectar sources. A summary of breeding trials further undertaken with this species in the next year is given below.

On 16th November 2000, five third instar larvae were released onto the host plants in the field cages. The larvae pupated from 23rd November onwards and adult emergence was observed from 8th December onwards. The adults emerged (three males and two females ) were maintained in the cages for about ten days. The female adults laid viable eggs on the host plants although no mating was observed. The population introduced in November could be maintained in field cages without induction of additional juveniles, for more than six months and this population is still active and viable.

The preferred host plants are *Aristolochia indica* and *Thottea siliquosa*. There are several generations in a year with a maximum larval population during July to September. Larvae were reared in the laboratory and the main problem encountered was mortality possibly due to high humidity particularly during the monsoon. Rearing on potted plants in field cages was found to be a good strategy. However, incidence of a hymenopteran parasite was noticed in field collected larvae. All juveniles found in the field could not be reared in captivity due to the large quantities of leaves required to sustain the larvae until pupation. A large number of host plants are needed for captive breeding of the species. Mating was observed in field cages and the species was found to be quite good for captive breeding and is suited for exhibitory since the species is available throughout the year.

**2. *Pachliopta pandiyana* ( Malabar Rose )**
(Plate I, Figs. 3a-c)

Adults tailed with black upper side. Fore wing with pale brownish streaks between veins. Hind wing with a creamy white patch and sub-marginal series of crimson lunules (Plate I, Fig. 3a).

The eggs are pale orange in colour and are laid singly (Plate I, Fig. 3b). The incubation period is eight days and the larvae that hatch out are deep purplish-black with red tipped tubercles on all segments except those on segments seven and eleven which are white. A transverse white band is present on seventh segment (Plate I, Fig. 3c). The larval period lasts twenty two to twenty five days. The pupa is brown with tubercles; the pupal period lasts for thirteen to fifteen days.

During 21st June to 5th August 2000, five caterpillars were reared on *Thottea siliquosa*, of which one eclosed. Egg parasitism by a scelionid wasp was noticed. Since sufficient number of eggs / larvae were not obtained, this species is not considered to be a good candidate for butterfly farming.

**3. *Pachliopta hector* (Crimson Rose)**

(Plate I, Figs. 2a-d)

Adults are tailed having a bluish black upperside. Fore wing with irregular and discontinuous apical and discal white bands. Hind wing with a discal band of bright crimson spots and a marginal row of crescents (Plate I, Fig 2a, b).

Eggs are pale orange coloured and are laid singly(Plate I, Fig 2c). Incubation period is eight days. The larvae are deep purplish black in colour bearing orange red tubercles and a transverse band on segments six to eight (Plate I, Fig. 2d). The larval period lasts twenty two to twenty five days. The pupa is brown with tubercles. The pupal period lasts for 14 to16 days.

Larval populations were observed in the field from May to September. Altogether, about hundred and thirty five juveniles have been reared in the laboratory in glass jars on the foliage of *Aristolochia indica* but mortality due to build up of humidity was observed. Rearing on potted plants kept in cages was found to be favourable. No instance of parasitism was observed. This is a potential species for captive breeding. Breeding strategy to be adopted is similar to that for the Common Rose.

**4. *Troides minos* (Southern Birdwing)**

(Plate I, Figs. 1a-e)

Upper side of the adult glossy black with white bordered veins. Hind wing golden yellow with black wavy borders and black veins (Plate I, Fig. 1a). Female with discal row of large triangular black spots (Plate I, Fig. 1b).

Eggs are bright orange in colour and are laid singly (Plate I, Fig. 1c). The incubation period is eight to nine days. The larva is deep maroonish black with fleshy orange tipped tubercles. Diagonal rosy white band on segments seven and eight. Osmeterium orange. Head black and body with grey and black markings (Plate I, Fig. 1d). The larval period lasts for thirty three to thirty five days. The pupa is brown in colour with tubercles (Plate I, Fig. 1e). Pupal period lasts for twenty three to twenty five days.

During 16 July to 17 October 1998, 24 June to 14 September 1999 and 16 June to 27 August 2000, 132 juveniles collected from the field were reared on the host plants, *Aristolochia indica* and *Thottea siliquosa*. Mortality due to parasitism by a scelionid parasite was noticed in field collected larvae.

In the laboratory, rearing in glass bottles was found to be not very appropriate especially during the monsoon months due to high humidity. Rearing on potted plants in field cages was a good strategy. However, matings could not be observed in captivity. The large size, beauty and conspicuous flight makes this species ideal for display purposes.

Trials were carried out in July 2000. The adults that were reared out in the laboratory were released into the field cage. The adults could be sustained for about ten days on flowers of *Clerodendrum paniculatum* kept in the cage. Mating and oviposition were not observed.

**5.*Chilasa clytia* (Common Mime)**
(Plate II, Figs. 13a-d)

Two forms of this butterfly are found in Peechi. The form *clytia* mimics the common crow, *Euploea core*. Its upper side is dark brown and fore wing bears a series of white spots in the marginal and terminal areas. Hind wing with a series of arrow-shaped and crescent markings and white/yellow terminal spots between the veins and a yellow tornal spot (Plate II, Fig. 13a).

The form *dissimilis* mimics the blue tiger, *Tirumala limniace*. Its upper side is black. Fore wing with cream stripes and sub marginal crescent- shaped cream markings. Long, white discal streaks and yellow a tornal spot are present on the hind wing (Plate II, Fig. 13b).

The eggs that are yellowish white in colour are laid singly on tender foliage. Eggs hatch within four to five days. The larvae are black with crimson coloured dorso-lateral spots. Cream coloured bands present on segments three to seven and eleven to thirteen. Segments one to four bear two lateral rows of spines and the remaining segments bear a single row (Plate II, Fig. 13c). The larval period lasts for twelve to fifteen days. The pupa is brown coloured and resembles a broken twig (Plate II, Fig. 13d). The pupal period lasts for eleven to fourteen days. Details of larvae reared are given below (Table 9).

Table 9. Data on larvae reared in the laboratory

| Dates | No. of larvae reared |
|---|---|
| 14 Dec. 1998 to 1 Jan. 1999 | 11 |
| 3 to 28 Feb. 1999; 3 Apr. to 7 May 1999 and 25 Nov. to 31 Dec. 1999 | 24 |
| 8 Feb. to 13 Mar. 2000 and 5 Apr. to 3 May 2000 | 25 |
| 13 Nov. 2000 to 3 Jan.2001 | 8 |

Both forms of this species were reared successfully. Larvae fed on the foliage of *Cinnamomum verum*. Out of sixty eight individuals reared, fifty two emerged successfully, five were found to be parasitised by unidentified Hymenoptera and eleven dead due other causes.

This species was easy to rear and incidence of parasitism was low. Release of adults during December to April will ensure butterfly population when other species are scarce.

**6. *Papilio demoleus* (Lime Butterfly)**
(Plate I, Figs. 8a-c)

In the adult, the upper side of the fore wing is black with yellow spots. Hind wing with a red oval spot with a blue lunule at the inner margin and a blue spot near costal margin. Yellow wavy markings are present at the base of both wings (Plate I, Fig. 8a).

The creamy white eggs are laid singly on tender foliage (Plate I, Fig. 8b). Eggs hatch in three to four days. The early instars of larvae are dark greenish brown with white markings, resembling bird droppings. Later instars are pale green with pale yellowish brown head and with white, brown and grey markings laterally. Osmeterium pink (Plate I, Fig. 8c). Larval period lasts for twenty one to twenty three days. Two types of pupae were observed - mottled brown and green. The pupal period lasts for eight to nine days.

This species can be easily reared on *Aegle marmelos, Ruta graveolens, Murraya exotica* or *Citrus* spp. which are the preferred larval host plants. Larval mortality was found to be fairly low in this species. The extent of parasitism was also found to be low. Of the thirty two individuals reared, twenty eight emerged and three were dead due to parasitism by Diptera. Details of insects reared are given below (Table 10).

Table 10. Data on larvae reared in the laboratory

| Dates | No. of larvae reared |
|---|---|
| 17 Oct. to 15 Dec.1998 | 5 |
| 16 Feb. to 3 Mar. 1999 | 5 |
| 3 to 18 Apr. 1999 | 4 |
| 9 Oct. to 10 Nov.1999 | 3 |
| 21 Feb. to 3 Mar. 2000 | 5 |
| 12 to 26 Apr. 2000 | 4 |
| 15 Oct. to 19 Nov. 2000 | 6 |

**7. *Papilio helenus* (Red Helen)**
(Plate I, Figs. 9a,b)

This is a large, black bodied butterfly having a prominent tail. The upper side is black. Hind wing with a large creamy white discal patch and a series of crimson coloured crescent markings along the margin (Plate I, Fig. 9a).

The eggs are yellow in colour and are laid singly on tender foliage. Incubation period is four to five days. The larva has a bright green body with mottled markings of white, grey and black. Ocelli black and white dotted, situated laterally on third segment and joined by a double band of black rings. Osmeterium dark crimson in colour. Larval period lasts for seventeen to eighteen days. Pupa is brown in colour (Plate I, Fig. 9b). Pupal period lasts fourteen to sixteen days. Parasitism not observed. Z*anthoxylum rhetsa* is a preferred host plant of this butterfly.

The early stages are difficult to obtain from the field. Of the four individuals reared during 21st July to 6th November 2000, only one had emerged.

***8.Papilio polymnestor*** **(Blue Mormon)**
(Plate II, Figs. 11a-c)

In the adult, the upperside is black. Fore wing with a pale blue discal band and with an elongate red spot at the base. Hind wing black at base with the remaining area pale blue and having discal, marginal and terminal series of black spots (Plate II, Fig. 11a).

The eggs are bluish white in colour and are laid singly (Plate II, Fig. 11b). Incubation period is five days. The larva is bright green with segments three and four slightly bulged with lateral green eye-spots and with white and black transverse rings. The lateral white line extends from the middle to the posterior portion of the body. Osmeterium orange (Plate II, Fig. 11c). Larval period lasts for twenty four to twenty six days. Two types of pupae are seen - mottled green as well as brown and green. Pupal period lasts for fourteen to sixteen days.

Only a few eggs and juveniles were obtained in the field. The preferred larval host plant is *Citrus* sp. Of the seven larvae reared during eight July to third August 1998, from 12 October to 21 December 1999 and from 15 June to 31 July 2000, four individuals emerged. Parasitism was not observed.

**9. *Papilio polytes*** **(Common Mormon)**
(Plate II, Figs. 10a-f)

Tailed butterfly with the upper side black. Fore wing with terminal series of creamy spots and hind wing with a discal band of elongate, cream spots (Plate II, Fig. 10a). The female has three polymorphic forms, one resembling the male (*cyrus* form ) and the others mimicking the Common Rose (*stichius* form, Plate II, Fig. 10c) and Crimson Rose (*romulus* form, Plate II, Fig. 10b).

The eggs are pale yellow in colour and are laid singly, usually on tender foliage (Plate II, Fig. 10d). Incubation period lasts for four to five days. The larva is bright green in colour. Its head is dull yellow, ocellus black and osmeterium scarlet in colour. Segments four and five with yellow crest and segments two and thirteen bearing tubercles. Blotched, white and reddish brown markings are present on segments seven and ten (Plate II, Fig. 10e). Larval period lasts for twenty one to twenty four days. Both green and brown coloured pupae were observed (Plate II, Fig. 10f). Pupal period lasts ten to twelve days. Altogether eighty seven larvae collected from the field were reared in this study (Table 11).

Table 11. Data on larvae reared in the laboratory

| Dates | No. of larvae reared |
|---|---|
| 21 Aug. 12 Sept. 1998 | 7 |
| 18 Oct. to 15 Dec. 1998 | 8 |
| 16 Feb. to 3 Mar. 1999 | 9 |
| 27 Jul. to 3 Sept. 1999 | 6 |
| 13 to 27 Oct. 1999 | 4 |
| 5 Feb. to 12 Mar. 2000 | 11 |
| 5 Apr. to 2 May 2000 | 8 |
| 4 to 6 Aug. 2000 | 16 |
| 3 to 23 Oct. 2000 | 18 |

The preferred host plants are *Citrus* spp., *Murraya koenigii*, *M.exotica*, *Ruta graveolens* and *Aegle marmelos*. Since the larval mortality rate is low and since a variety of host plants can be used for oviposition, a steady population can be maintained throughout the year. Larvae were present during most part of the year. Incidence of parasites was not observed. Hence it is a good species for captive rearing.

### 10. *Eurema blanda* (Three - Spot Grass Yellow)

(Plate III, Figs. 25a,b)

Bright yellow on the upper side. Fore wing with an outer black border which is broader in the apical area. Hind wing with a narrow marginal black line. Under side of wings pale yellow with an apical brown patch and three black spots in the cell of fore wing (Plate III, Fig. 25a).

Eggs are white and conical in shape, laid in clusters of sixty to seveny (Plate III, Fig. 25b). Incubation period is from three to four days. Larva is dark green with black head and pale yellowish green lateral line. Feeding is gregarious causing severe defoliation. Larval period lasts for fourteen to sixteen days. The pupa is black in colour. Pupal period is from five to seven days. Altogether seven hundred and twenty four caterpillars were reared in the laboratory (Table 12). *Albizia lebbeck*, *Albizia odoratissima*, *Acrocarpus fraxinifolius*, *Cassia fistula*, *Cassia sp.* and *Caesalpinia pulcherrima* are the preferred host plants. Parasitism by a dipteran was observed in larvae collected from the field.

Large numbers of larvae (batches of sixty five to seventy) could be reared in captivity (Table 12) but the viability and life span of adults in field cages was limited to one to three days. Large scale predation by lizards observed.

Table 12. Data on larvae reared in the laboratory

| Dates | No. of larvae reared |
|---|---|
| 2 to 14 December 1998 | 35 |
| 4 Jan. to 24 Feb. 1999 | 186 |
| 13 Sept. to 14 Dec. 1999 | 320 |
| 6 Jan. to 27 Dec. 2000 | 120 |
| 25 Sept. to 10 Dec. 2000 | 63 |

Since large numbers of field collected eggs and caterpillars may be reared simultaneously, this species is highly suited for display in enclosures where they can be sustained on artificial and natural nectar sources. However, incidence of parasitism in field collected larvae was found to be high which may be avoided by collection at the egg stage. Since the adults can be sustained for only five to six days in field cages, continuous populations should be maintained.

**11. *Eurema hecabe* (Common grass yellow)**
(Plate III, Figs. 24a,b)

In the adult, the upper side is bright yellow. Fore wing with an outer black border which is broader in the apical area. Hind wing with a narrow marginal black line. Under side of wings pale yellow with an apical brown patch and two black spots in the cell of fore wing (Plate III, Fig. 24a).

Eggs, which are white and conical in shape are laid singly (Plate III, Fig. 24b). Incubation period is three to four days. The larva is dark green with a faint yellowish - white lateral line. Unlike *E. blanda*, larvae are not gregarious. Larval period lasts for thirteen to fifteen days. Pupa is yellowish green in colour and sometimes mottled with brown and black spots. Pupal period is seven to eight days. Fifty four larvae were reared during 23 to 26 December 1998 (5 Nos.); 18 August to 13 October 1999 (37 Nos.) and 30 August 6 October 1999 (12 Nos.).

Incidence of a dipteran parasite was noticed in field collected larvae. The incidence of parasitism was found to be lower than that in *E. blanda.* Larval host plants include *Cassia tora* and *Cassia fistula*. This species is seasonal and hence not considered very suited for captive breeding.

**12. *Catopsilia pomona* (Lemon emigrant)**
(Plate III, Figs. 23a,b)

Upper side of the adult is pale yellow with the outer area remaining bright lemon yellowish. Fore wing with the costal margin black at apex and with an outer dark-spotted border. Under side of wings greenish white. Both wings with a disco-cellular, brown- ringed silvery spot. Antenna reddish (Plate III, Fig. 23a).

The eggs are creamy whitish in colour and are laid singly.Eggs hatch out in three to four days. Larva is green with a dark green head. Lateral white spiracular line bordered with a black line above and pale olive green line below (Plate III, Fig. 23b). Larval period lasts for ten to twelve days. Pupa is pale green in colour. Pupal period is six to seven days.

Larvae were reared on *Cassia fistula*. Parasitism was not observed. Of the 12 larve reared during 13 to 28 October 1999 (9 nos.); 5 to 14 May 2000 (1no.) and 5 to 18 October 2000 (2 nos.), eight adults emerged. This species is seasonal and hence not suited for continuous breeding.

**13.** ***Catopsilia pyranthe*** **(Mottled Emigrant)**
**(**Plate III, Figs. 22a-c)

Adult with the upperside greenish white. Fore wing with a black border at the apex and termen and with a cell spot. Hind wing without markings. Under side of wings mottled with fine lines (Plate III, Fig. 22a).

Eggs are white and conical in shape and are laid singly (Plate III, Fig. 22b). Incubation period is three to four days. Larva is dark green with raised black dots. A lateral white band bordered above with black dotted line present (Plate III, Fig. 22c). Larval period lasts for fourteen to sixteen days. Pupa is green in colour. Pupal period is twelve to fourteen days.

All individuals reared during 28 June to 25 July 2000 (7 nos.) and 3 August to 17 Nov. 2000 (31 nos.) have eclosed. No instance of parasitism was recorded. *Cassia occidentalis* and *Cassia biflora* are the recorded host plants of this species. Since rearing is easy and larval mortality rate is low, this insect is considered to be suitable for farming programmes.

**14.** ***Talicada nyseus*** **(Red Pierrot)**
(Plate IV, Figs. 51a-d)

Upperside of the adult blackish brown. Hindwing with a delicate tail and having a scarlet band in the outer area. Under side of the wings white; fore wing with the outer black border bearing white spots. Hind wing with an orange-red border, white spotted black apex and black spotted discal area (Plate IV, Fig. 51a).

Eggs which are pale blue in colour are laid singly (Plate IV, Fig. 51b). Incubation period is three to four days. The larva is pale greenish with a ring of spots in the anterior segments and body profusely covered with hairs. A dorsal, green line and lateral black dots present (Plate IV, Fig. 51c). Larval period lasts for fifteen to sixteen days. Pupa creamy-white in colour (Plate IV fig. 51d). Pupal period is nine to ten days.

About eighty individuals were reared during 24 August 2000 to 26 March 2001 on and *Kalanchoe blossfeldiana* and *K. pinnata*. No instance of parasitism was observed and rearing was easy. Adults, though small, are usually found in the vicinity of host plants and are conspicuous due to weak flight. Considered good for farming programmes.

15. ***Danaus genutia*** **(Striped Tiger)**
(Plate V, Figs. 66a-d)

Upper side of the adult is orange-brown with black veins and white apical and marginal bands (Plate V, Fig. 66a). Eggs are creamy white in colour and are laid singly and hatch in three to four days (Plate V, Fig. 66b). Larva is black with paired fleshy filaments on segments two, five and eleven. Each segment has a pattern of white dorsal streaks and spots and an elongated yellow spot (Plate V, Fig. 66c). Larval stage lasts for ten to twelve days. Pupa is pale green with silver lining and golden spots (Plate V, Fig. 66d). The pupal stage lasts for seven to nine days.

Twelve larvae were reared during 19 September to 13 October 2000 on *Holostemma ado-kodien*. No instance of parasitism was observed. Since only a few individuals were obtained, suitability of this species for captive breeding purposes could not be assessed.

16. ***Danaus chrysippus*** **(Plain Tiger)**
(Plate V, Figs. 67a,b)

Upper side of both wings rust-brown with black borders. Fore wings with black apical region and having white spots in costa and apex. Hind wings with black spots around the cell (Plate V, Fig. 67a).

Eggs are white in colour and are laid singly. Incubation period is three to four days. Larva is pale- bluish grey with transverse black and yellow bands in each segment. Lateral yellow bands present. Paired fleshy maroon-black filaments present on segments two, five and eleven (Plate V, Fig. 67b). Larval period lasts for nine to ten days. Pupa is pale green coloured and hanging type. Pupal period is six to eight days.

*Calotropis gigantea* is the preferred larval host plant of this butterfly. Of the forty individuals reared during 20 April to 18 May 1999 (8 nos.); 25 November 1999 to 6 January 2000 (12 nos.); 15 March to 29 May 2000 (13 nos.) and 30 November 2000 to 14 January 2001 (7 nos.), 27 eclosed, 3 were parasitised and 10 dead due other causes. Incidence of a dipteran parasite was observed in the field. It was easy to rear this species under laboratory conditions as leaves stay fresh for two to three days and hence is considered as a good candidate for farming programmes.

17. ***Parantica aglea*** **(Glassy Tiger)**
(Plate VI , Figs. 70a-d)

Upper side of the adult is dark brown with extensive transparent, bluish white streaks and spots. Fore wings with the cell streak divided into three parts longitudinally. Hind wings with streaks and spots (Plate VI, Fig. 70a).

Eggs are creamy-white in colour and are laid singly (Plate VI, Fig. 70b). Incubation period is three to four days. Larva is dark blue with two sub dorsal series of yellow spots, lateral row of white spots and sub lateral row of yellow spots. Paired fleshy black filaments present on segments two and eleven (Plate VI, Fig. 70c). Larval period lasts for eight to nine days. Pupa is pale green with white and black spots and a black dotted line rimmed by white (Plate VI, Fig. 70d). Pupal period is seven to eight days.

All individuals reared on *Tylophora indica* during 19 April to 16 May 2000 (18 nos.) have emerged. No instance of prasitism was observed. More saplings of the host plant are required to induce egg laying by the females in the field. Rearing was rather easy and mortality was low under laboratory conditions and hence considered as a good species for farming purposes.

**18. *Tirumala septentrionis* (Dark Blue Tiger)**
(Plate VI, Figs. 69a-d)

Upperside of adult black with irregular streaks and marginal spots. Markings are darker and narrower than *Tirumala limniace.* Hind wings with characteristic wish-bone shaped marking in the cell. Underside dark brown (Plate VI, Fig. 69a).

Eggs bluish-white in colour and laid singly (Plate VI, Fig. 69b). Incubation period is three to five days. Larva is pale bluish white with black rings. Fleshy tentacles present on segments two and eleven (Plate VI, Fig. 69c). Larval period lasts for ten to thirteen days. Pupa is bright green with golden lining and three golden spots (Plate VI, Fig. 69d). Pupal period is eight to ten days.

Of the fifty one individuals reared during 4 August to 21 October 2000 on *Wattakaka volubilis*, forty five emerged and six were parasitised by a dipteran. To prevent the incidence of parasites, eggs may be collected for rearing. Breeding of this species is rather easy and hence considered as a good species for farming.

19. ***Tirumala limniace* (Blue Tiger)**
(Plate V, Figs. 68a-d)

Upperside of the adult black with irregular streaks and marginal spots. Underside golden brown (Plate V, Fig. 68a).

Eggs are bluish-white in colour and are laid singly (Plate V, Fig. 68b). Incubation period is three to five days. Larva is pale yellowish white with black rings. Lateral yellow band present. Paired fleshy filaments present on segments two and eleven (Plate V, Fig. 68c). Larval period lasts for nine to eleven days. Pupa is bright green with golden lining and four golden spots (Plate V, Fig. 68d). Pupal period is seven to nine days.

The larvae collected from the field were maintained on *Wattakaka volubilis*. Of the individuals reared during 4 August to 8 December 1999 (40 nos.); 15 March to 5 April 2000 (16 nos.) and 31 August to 11 November 2000 (86 nos.), eighty five emerged, thirty nine parasitised (by a dipteran ) and eighteen dead due to other causes. Since high level of parasitism was observed in the field, collection of egg stage for rearing purposes is recommended for lowering rate of mortality due to parasites.

20. ***Euploea core* (Common Crow)**
(Plate VI, Figs. 71a-d)

Upper side of the adult glossy brown with marginal and terminal white spots. Fore wing having a band. Marginal spot of hind wings more prominent. Under side, light brown (Plate VI, Fig. 71a).

Eggs are pale yellowish-white in colour and are laid singly (Plate VI, Fig. 71b). Incubation period is four to seven days. Larva is dark brown with white and red segmental rings. Lateral yellow and white stripes present. Paired fleshy filaments on segments 2, 3, 5 and 11 (Plate VI, Fig. 71c). Larval period lasts for seven to ten days. Pupa is golden coloured (Plate VI fig. 71d). Pupal period is seven to ten days.

*Hemidesmus indicus, Ficus religiosa, Ficus racemosa, Ficus* sp. and *Carissa carandas* are the preferred larval hosts of this butterfly. Of the 56 individuals reared during 15 October to 16 November 1998 (3 nos.); 6 August 1999 to 10 January 2000 (14 nos.) and 26 June to 19 October 2000 (39 nos.), thirty seven emerged, five parasitised (by hymenopteran and dipteran parasites) and fourteen dead due to other causes. Eggs were found eaten by ants in the field. Mortality was high under laboratory conditions and hence this species is not considered to be very suitable for farming programmes.

**PLATE I. Butterflies sighted from the Butterfly Garden**

*Troides minos* Cramer (Papilionidae) Plate I, Figs. 1a-e)
*Pachliopta hector* Linnaeus (Papilionidae) (Plate I, Figs. 2a-d)
*Pachliopta pandiyana* Moore (Papilionidae) (Plate I, Figs. 3a-c)
*Pachliopta aristolochiae* Fabricius (Papilionidae) (Plate I, Figs. 4a-d)
*Papilio paris* Linnaeus (Papilionidae) (Plate I, Fig. 5)
*Papilio buddha* Westwood (Papilionidae) (Plate I, Fig. 6)
*Papilio crino* Fabricius (Papilionidae) (Plate I, Fig. 7)
*Papilio demoleus* Linnaeus (Papilionidae) (Plate I, Figs. 8a-c)
*Papilio helenus* Linnaeus (Papilionidae) (Plate I, Figs. 9a,b)

**PLATE II. Butterflies sighted from the Butterfly Garden**

*Papilio polytes* Linnaeus (Papilionidae) (Plate II, Figs. 10a-f)
*Papilio polymnestor* Cramer (Papilionidae) (Plate II, Figs. 11a-c)
*Papilio liomedon* Moore (Papilionidae) (Plate II, Fig. 12)
*Chilasa clytia* Linnaeus (Papilionidae) (Plate II, Figs. 13a-d)
*Graphium sarpedon* Linnaeus (Papilionidae) (Plate II, Fig. 14)
*Graphium agamemnon* Linnaeus (Papilionidae) (Plate II, Figs. 15a-c)
*Graphium antiphates* Cramer (Papilionidae) (Plate II, Fig. 16)
*Graphium doson* C&R Felder (Papilionidae) (Plate II, Fig. 17)
*Leptosia nina* Fabricius (Pieridae) (Plate II, Fig. 18)
*Delias eucharis* Drury (Pieridae) (Plate II, Fig. 19)
*Appias lyncida* Cramer (Pieridae) (Plate II, Fig. 20)
*Appias libythea* Fabricius (Pieridae) (Plate II, Fig. 21)

**PLATE III. Butterflies sighted from the Butterfly Garden**

*Catopsilia pyranthe* Linnaeus (Pieridae) (Plate III, Figs. 22a-c)
*Catopsilia pomona* Fabricius (Pieridae) (Plate III, Figs. 23a,b)
*Eurema hecabe* Linnaeus (Pieridae) Plate III, Figs. 24a,b)
*Eurema blanda* Boisduval (Pieridae) (Plate III, Figs. 25a,b)
*Acraea violae* Fabricius (Acraeidae) (Plate III, Figs. 26a-c)
*Melanitis leda* Linnaeus (Satyridae) (Plate III, Fig. 27)
*Orsotrioena medus* Fabricius (Satyridae) (Plate III, Fig. 28)
*Ypthima huebneri* Kirby (Satyridae) (Plate III, Fig. 29)
*Mycalesis anaxias* Hewitson (Satyridae)Plate III, Fig. 30)
*Elyminas caudata* Butler (Satyridae) (Plate III, Figs. 31a-d)
*Cupha erymanthis* Drury (Nymphalidae) (Plate III, Figs. 32a-c)
*Phalanta phalantha* Drury (Nymphalidae) (Plate III, Fig. 33)

**PLATE IV. Butterflies sighted from the Butterfly Garden**

*Vindula erota* Fabricius (Nymphalidae) (Plate IV, Fig. 34)
*Cirrochroa thais* Fabricius (Nymphalidae) (Plate IV, Fig. 35)
*Junonia lemonias* Linnaeus (Nymphalidae) (Plate IV, Fig. 36)
*Junonia orithya* Linnaeus (Nymphalidae) (Plate IV, Fig. 37)
*Junonia hierta* Fabricius (Nymphalidae) (Plate IV, Fig. 38)
*Junonia atlites* Linnaeus (Nymphalidae) (Plate IV, Fig. 39)
*Junonia iphita* Cramer (Nymphalidae) (Plate IV, Fig. 40)
*Junonia almana* Linnaeus (Nymphalidae) (Plate IV, Fig. 41)
*Neptis hylas* Moore (Nymphalidae) (Plate IV, Fig. 42)
*Hypolimnas bolina* Linnaeus (Nymphalidae) (Plate IV, Fig. 43)
*Hypolimnas misippus* Linnaeus (Nymphalidae)Plate IV, Fig. 44)
*Moduza procris* Cramer (Nymphalidae) (Plate IV, Figs. 45a,b)
*Euthalia aconthea* Cramer (Nymphalidae) (Plate IV, Fig. 46)
*Ariadne merione* Cramer (Nymphalidae) (Plate IV, Fig. 47)
*Jamides celeno* Cramer (Lycaenidae) (Plate IV, Fig. 48)
*Jamides alecto* Felder (Lycaenidae) (Plate IV, Fig. 49)
*Castalius rosimon* Fabricius (Lycaenidae) (Plate IV, Fig. 50)
*Talicada nyseus* Guerin-Meneville (Lycaenidae) (Plate IV, Figs. 51a-d)
*Loxura atymnus* Cramer (Lycaenidae) (Plate IV, Fig. 52)
*Rathinda amor* Fabricius (Lycaenidae) (Plate IV, Fig. 53a)

**PLATE V. Butterflies sighted from the Butterfly Garden**

*Rathinda amor* Fabricius (Lycaenidae) (Plate V, Figs 53b,c )
*Arhopala pseudocentaurus* Doubleday (Lycaenidae) (Plate V, Fig. 54)
*Cheritra freja* Fabricius (Lycaenidae) (Plate V, Fig. 55)
*Udara akasa* Horsfield (Lycaenidae) (Plate V, Fig. 56)
*Spalgis epius* Westwood (Lycaenidae) (Plate V, Fig. 57)
*Tagiades litigiosa* Moschler (Hesperiidae) (Plate V, Fig. 58)
*Celaenorrhinus leucocera* Kollar (Hesperiidae) (Plate V, Fig. 59)
*Badamia exclamationis* Fabricius (Hesperiidae) (Plate V, Fig. 60)
*Potanthus sp.* (Hesperiidae)Plate V, Fig. 61)
*Taractrocera sp.* (Hesperiidae) (Plate V, Fig. 62)
*Telicota ancilla* Mabille (Hesperiidae) (Plate V, Fig. 63)
*Gangara thyrsis* Fabricius (Hesperiidae) (Plate V, Fig. 64)
*Udaspes folus* Cramer (Hesperiidae) (Plate V, Fig. 65)
*Danaus genutia* Cramer (Danaidae) (Plate V, Figs. 66a-d)
*Danaus chrysippus* Linnaeus (Danaidae) (Plate V, Figs. 67a, b)
*Tirumala limniace* Cramer (Danaidae) (Plate V, Figs. 68a-d)

**PLATE VI. Butterflies sighted from the Butterfly Garden**

*Tirumala septentrionis* Butler (Danaidae) (Plate VI, Figs. 69a-d)
*Parantica aglea* Stoll (Danaidae) (Plate VI, Figs. 70a-d)
*Euploea core* Cramer (Danaidae) (Plate VI, Figs. 71a-d)

### 4.4. Campaign to promote public awareness

During the course of the project as part of the objective of creating public awareness, a one week programme was organised to impart a basic knowledge of butterfly ecology and life habits to school children. This campaign has aroused the curiosity of children and adults alike and the butterfly garden now draws many visitors (Fig.17).


Fig. 17. View of a batch of students observing butterflies in the Butterfly Garden set up at KFRI Campus

# 5.DISCUSSION

## 5.1. Butterfly gardening

*Suitability of different species for gardening programmes for* in situ *conservation*

Butterfly gardening is a unique activity that helps in maintaining natural populations of various butterflies within narrow strips of lands that might become available for such activities. Since the success of this programme is dependent on a number of factors involving selection of host plants for introduction and maintaining appropriate environmental conditions (humidity / sunshine / temperature) utmost care should be taken while designing the garden. The extent of area required for setting up of butterfly gardens varies with the species diversity of that area. Usually, locations near natural forests are likely to result in the re-colonisation of more number of species compared to locations in urban areas. In the present study, although very good results were obtained even with a minimum area of land (0.5 ha), a larger area is definitely a better option considering the diversified habitat requirements of a wide spectrum of butterfly fauna. The outcome of activities undertaken during this study are discussed below.

*Landscaping*

Landscaping and introduction of appropriate host plants are very important to sustain populations of different species of butterflies. An initial survey carried out in the study area revealed the occurrence of forty six species of butterflies in the area (with most species represented by a few individuals and with no resident population for any species). Based on data generated on the butterfly fauna of this region, thirty two species of larval and thirty five species of adult, host plants were introduced and the area landscaped creating various butterfly habitats such as open garden, bushes, lianas, ponds and so on. Following habitat manipulation, there has been an increased butterfly activity in the area involving formation of resident population by several butterflies.

*Seasonal population trends*

Initially, most butterflies were sighted very rarely and as the habitats were improved, there was an increase in the population. Each year, there was a steady increase in the number of individuals and species. In the first half of the project (after fifteen months), 4509 butterflies belonging to 43 species were recorded. In the second half (after 30 months), 5993 butterflies belonging to 50 species were recorded. After implementation of the study, 73 species have been spotted. Of these, 50 species has colonised the area setting up local populations. Recreation of butterfly habitats have definitely effected better survival chances for various species as indicated by the increase in the butterfly population in the study area. A list of butterflies which formed resident populations is given below.

*Pachliopta hector*
*Papilio polymnestor*
*Catopsilia pomona*
*Catopsilia pyranthe*
*Moduza procris*
*Elymnias caudata*
*Talicada nyseus*
*Rathinda amor*
*Danaus genutia*
*Danaus chrysippus*
*Tirumala septentrionis*
*Tirumala limniace*
*Paramntica aglea*
*Euploea core*

The seasonal population trends for various groups of butterflies is given under results (4.2). Papilionidae and Pieridae had more or less continuous generations throughout the year. In the former, there was a decline in population during November-December coinciding with the prevailing dry and windy conditions during this season. Lycaenidae population also had picked up by the third year showing more or less continuous population trends. The families Satyridae, Hesperiidae and Nymphalidae showed up only during certain months. In the case of Danaidae, there was very good population during May-November.

Among Papilionidae, *Troides minos, Pachliopta aristolochiae, Papilio polymnestor, P. polytes* (Papilionidae*);* among Pieridae, *Catopsilia* spp., *Eurema* spp., and among Danaidae, *Danaus chrysippus, Tirumala limniace, T.septentrionis, Parantica aglea* and *Euploea core* showed good population build up for most part of the year (Figs. 14,15 and 16). It may be noted here that due to habitat improvement and conservation, more and more rare species got established in the study area. These included *Papilio crino* (Papilionidae); *Appias* sp. (Pieridae); *Junonia orithya*, *Moduza procris* (Nymphalidae); *Talicada nyseus* (Lycaenidae); *Spalgis epius, Badamia exclamationis* and *Potanthus* sp. (Hesperiidae). Of these, *T. nyseus* has developed very high population in the study area.

*Occurrence of butterflies in relation to weather conditions*

The occurrence of the different butterflies was found to be correlated with weather conditions like temperature, humidity and rainfall. The families Nymphalidae and Danaidae showed a significant correlation to temperature. The former increased with increasing temperature while in the latter, number of occurrences decreased at higher temperatures. These butterflies are relatively hardy species fond of sunshine.

Significant correlation to humidity was seen in the families Papilionidae and Danaidae (positive) whereby number of occurrences increased at higher humidity levels. The former generally prefer to fly through the shades of lofty trees. In the case of Nymphalidae a significant (negative) correlation was observed. The families Papilionidae and Danaidae showed a significant (positive) correlation with rainfall.

*Aggregation*

Danaid butterflies are well known for their need to frequent sources of pyrrolizidine alkaloids which are essential for the males to prime the pheromones necessary for successful courtship. Ackery and Vane-Wright (1984) have given a detailed review of this phenomenon.

Assemblages of *Tirumala septentrionis, T. limniace, Danaus genutia, D.chrysippus, Parantica aglea* and *Euploea core* have been reported on alkaloid sources by several workers. Larsen (1986) reported a dry season aggregation of approximately 1300-2000 individuals consisting of *E.core, D. genutia, D. chrysippus* and *T. liminace* in Uttar Pradesh in the dry season of the year. Individuals were observed drinking from seepage in the ground. Since ingestion of pyrrolizidine alkaloids takes place as a social activity (almost exclusively male), large numbers may be attracted to alkaloid sources.

Fig. 18. Agggregation of butterflies on *Crotalaria retusa* in the Butterfly Garden established in the KFRI Campus

Aggregations of *Danaus genutia, D. chrysippus, Tirumala limniace, T. septentrionis, Parantica aglea* and *Euploea core* could be made to roost on alkaloid sources like *Crotalaria retusa* and *Heliotropium keralense* planted in the garden during June to November (Fig.18). Maintaining a high humidity regime was found to be helpful in maintaining the population during the summer months as well. Obviously, the site determinants for these dry season aggregations are the simultaneous presence of shade and water as well as nectar sources.

## 5.2. Captive breeding and *ex situ* conservation

The success in maintaining various butterfly species under captivity is very important in breeding programmes and is dependent on a number of factors such as the choice of food plants, seasonality, flight / forage pattern, predation by natural enemies and sensitivity of the organism to handling. In this study, attempts were made to breed 20 species in captivity and their suitability in sustained breeding programmes assessed.

*Choice of food plants*

The polyphagous species are the best suited for butterfly gardening or farming programmes due to their adaptability to a variety of host plants. However, certain monophagous species like *Talicada nyseus, Troides minos* and *Pachliopta arristolochiae* were also found to be equally good for captive breeding because of their high survival rates on the preferred host plants during routine rearing programmes. These species were locally very common and less specialised as indicated by their having continuous generations. On the other hand, certain rare species such as *Pachliopta pandiyana, Papilio polymnestor* and *Pachliopta hector* which were more specialised, were rather difficult to be maintained under captivity. These butterflies are seasonal and establishment of the right environmental conditions is very essential to achieve success in maintaining them particularly during "off seasons". Being swift flying species they also require continuous, unobstructed flight area. The insectary used in this study (5m x 10m x 5m) was evidently not suited for such species although it was found to be suitable for species that are feeble fliers. In the case of *Troides minos* which is one of the largest butterflies, although a few individuals could be maintained over a short period,  a viable population could not be maintained due to lack of larger flight arenas. Certain slow flying butterflies such as *Talicada nyseus* and *Pachliopta aristolochiae* could easily be maintained even in small cages of 1m x m x 1m.

The management of important larval food plants particularly *Aristolochia indica* and *Citrus* spp., should be closely monitored as larval use of these plants is somewhat inefficient and the plant is quickly damaged. Under such circumstances the plants are kept in pots and brought into the flight area only when more eggs are needed. When enough eggs have been laid the whole plant is removed to the breeding area for feeding the caterpillars. In contrast, *Passiflora edulis*, *Tylophora indica* and *Wattakkaka volubilis* grow rapidly and the larvae are more efficient. The nectar and larval food plants should be established while keeping in mind the landscaping aspects of the garden.

*Incidence of natural enemies*

Since the original stock for captive breeding is invariably taken from field samples and also since the culture has to be occasionally replenished with material collected from the field to check in-breeding depression, the rate of incidence of parasites is an important aspect to be considered during captive breeding programmes. In this study, incidence of parasites was noticed with many species such as *Pachliopta pandiyana* (Scelionidae),*Troides minos* (Scelionidae), *Eurema* spp. (Diptera), *Parantica aglea* (Hymenoptera), *Tirumala sepentrionis* (Diptera) and *Euploea core* (Hymenoptera) as indicated in parenthesis. However, the rate of incidence was not very high to be of a problem in breeding.

In addition to the parasitic insects, various predatory animals such as the garden geckos and birds were also found to build up in large numbers in the garden, which at times affected the butterfly population. Usually the palatable species (mostly belonging to Papilionidae) were found to suffer maximum attack since the unpalatable ones (especially the Danaidae) were avoided by the predators. Incidently, the latter formed roosts on alkaloid plants that remained practically unaffected by predators thus forming beautiful exhibits for the garden.

### 5.3.Choice of species for gardening / breeding programmes

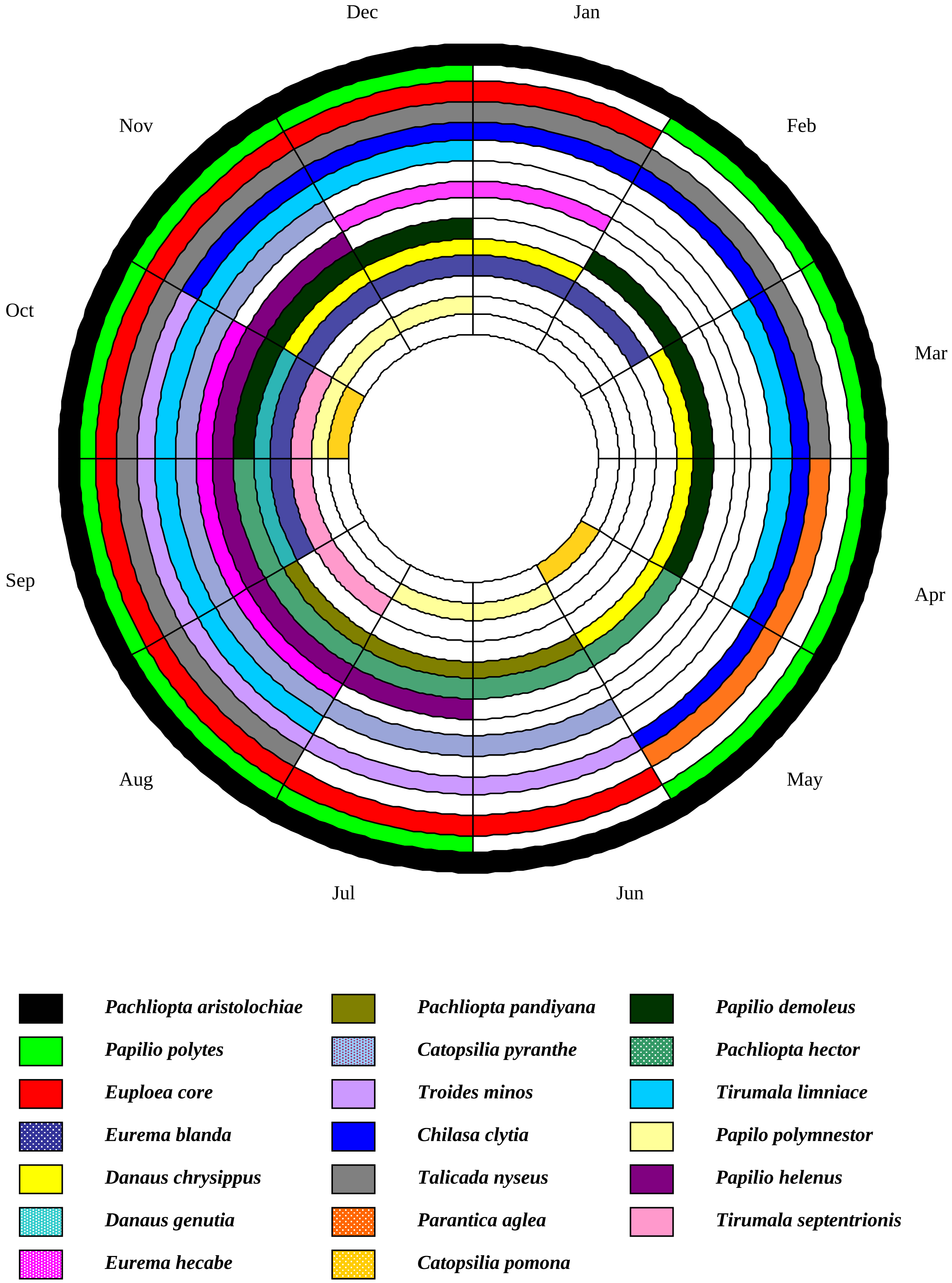
Based on various criteria as discussed above, an attempt was made to select appropriate species for butterfly gardening / farming programmes. Of the various criteria, seasonality of the insect is very important. Availability of host plants and appropriate environmental conditions determine the seasonal abundance of an organism.

The 73 species sighted in this study can be classified into three categories *viz*., very common (occurring throughout the year); seasonal (present only during certain seasons) and rare (present occasionally during certain months). Some Papilionidae, Danaidae, Lycaenidae, and Pieridae have continuous populations spread throughout the year. About half a dozen species belonging to these families such as *Pachliopta aristolochiae, Papilio polytes, P.hector* (Papilionidae) and *Talicada nyseus* (Lycaenidae) have more or less continuous generation throughout the year. Some of these species (*Papilio polytes, Euploea core* and *Eurema* spp.) utilize four or more host plants in the field. Such species can be considered as suitable for maintaining under captivity for prolonged periods. The population trends of other families *viz.*, Satyridae, Hesperidae and Nymphalidae are rather erratic and are confined to a few months. Since many of these butterflies are attracted to rotting fruit, toddy or sap (rarely flowers), baits using the above materials are likely to attract these butterflies to gardens.

Observations have shown that the overall population of butterflies showed drastic reduction during the monsoon (June-July) and dry/windy season (November - December) and in summer months (February - April). During such seasons, butterflies of certain families could be observed. For instance, during monsoon, butterflies of the families Papilionidae, Satyridae, Hesperidae and Danaidae, during windy season Pieridae, Satyridae, Lycaenidae and Danaidae and during summer months certain Papilionidae, Nymphalidae, Pieridae, Lycaenidae and Hesperidae have been observed. Certain species (*Papilio demoleus*, *Troides minos*, *Eurema blanda*, *E. hecabe*, *Catopsilia pyranthe, Danaus chrysippus, Parantica aglea and Tirumala septentrionis*) were present only during certain months and these insects can be maintained only for short periods.

*Pachliopta aristolochia*, *Pachliopta hector* and *Troides minos,* though monophagous species, have prodigious egg production during the breeding season. Of these, the birdwing, *Troides minos* which is a magnificent species to observe in its natural setting is territorial in habits. Maintaining a proper habitat for territory establishment will ensure its presence during June to October. Availability of adequate flight area is essential to keep it in captivity. Propagation of adequate numbers of host plants is also very important in butterfly gardening/ captive breeding programmes. Diseases and pest infestations of plants should be checked in time so that freshly flushed foliage is available for oviposition by butterflies. Artificial diets could not be developed for any of the species although preliminary attempts to use artificial diet formula used for moths (with the larval host plant substituted) was not successful. Diets specific for butterflies need to be standardised for the various species. A breeding strategy which incorporates rearing on potted plants in large field cages and an artificial diet for rearing under laboratory conditions will ensure an adequate population of these beautiful butterflies for release in the exhibit area.

**Fig. 19. Chart showing occurrence of butterflies during various months**



## 6.SUMMARY

Butterflies are ecologically very important because of their role in the functioning of natural ecosystems. They also have great aesthetic value and hence form important exhibits in Zoos and Natural History Museums. However, due to large-scale destruction of natural habitats, many species are on the verge of extinction and urgent measures are required for conserving them from extinction. Captive breeding of endangered species for possible reintroduction as well as recreation of degraded habitats, are accepted methods of animal conservation.

*In situ* propagation of butterflies was achieved by establishing a butterfly garden in a 0.5 ha of moist deciduous forest patch in KFRI Campus at Peechi, Kerala, India. Initially, a survey was made on the butterfly fauna and their host plants in the study area. Based on the habitat preferences of various species, the area was landscaped so as to create different butterfly habitats such as clearings, dense vegetation with lianas, damp areas and bushes. In order to sustain viable butterfly populations, appropriate host plants were introduced in the garden, which included 32 species of larval and 35 species of adult host plants.

Prior to the study, about 47 species of butterflies were recorded from the study area. With the planting of nectar plants, larval host plants and alkaloid containing plants in conjunction with the landscaping and creation of butterfly habitats, there was a sharp increase in the number of species and up to 73 species of butterflies were recorded. This included 9 species that are Western Ghats endemics and ten species having protected status under the Indian Wildlife Act.

Besides increase in the number of species, there was also an increase in the overall population of butterflies. During the first half (after fifteen months) of the project, 4509 sightings of butterflies belonging to 43 species were recorded. In the second half, 5993 sightings of butterflies belonging to 50 species have been recorded. Altogether, 10502 sightings of butterflies belonging to 56 species were specifically recorded during the 30 months study period. Butterflies belonging to the families Danaidae, Lycaenidae Papilionidae and Pieridae showed continuous population trends with resident population in the study area while the families Hesperiidae, Nymphalidae and Satyridae showed erratic population trends.

Different species of butterflies showed characteristic habitat preferences. Most papilionids like *Chilasa clytia*, *Pachliopta pandiyana*, *Papilio budha*, *P.helenus*, *P.paris*, *P.polymnestor*, and *Troides minos* preferred habitats with bushy vegetation interspersed with tall trees although some like *Pachliopta hector*, *Papilio demoleus and P.polytes* were sighted more often in the open areas of the garden. The pierids like *Catopsilia* spp. and *Eurema* spp. and the nymphalids *Ariadne merione*, *Hypolimnas* spp., *Junonia lemonias* and *Moduza procris* were active in bright sunshine; the satyrids *Elymnias caudata* and *Mycalesis anaxias* in the evening and the danaids *Euploea core*, *Danaus genutia*, *Parantica aglea and Tirumala limniace* and the lycaenids *Jamides celeno* and *Talicada nyseus* both in the morning and evening.

The occurrence of different butterfly groups was found to be dependant on climatic / environmental conditions. For many butterflies, an average temperature ranging between 25-26°C was the most favourable followed by 23-25°C and 27-29°C. Similarly, atmospheric humidity ranging between 80-100 percent was the most preferred range followed by 60-80 percent. With regard to daily rainfall, 50 mm was the most favourable level followed by 50-100 mm rainfall. Heavy rainfall was found to be unfavourable since very few butterflies were observed above 100 mm of daily rainfall.

The aggregation of danaid butterflies at alkaloid sources was utilised to boost their population in the garden. The aggregating species like *Danaus chrysippus, Euploea core Parantica aglea, Tirumala limniace and T.septentrionis,* could be established in large numbers on the alkaloid containing plants such *Crotalaria retusa*. The multi species aggregation comprising of thirty to forty butterflies per plant was a major attraction to visitors.

In order to examine the suitability of various butterflies for captive breeding in *ex situ* conservation and butterfly exhibitory programmes, biology of twenty species of butterflies was studied and methods for captive breeding standardised. The study has shown that only a few butterflies have continuous generations and most species are seasonal. By combining the life history specialties of all such groups of butterflies, it will be possible to present a much varied butterfly fauna in the garden round the year. *Pachliopta aristolochiae* and P*apilio polytes,* which have more or less continuous generations throughout the year, were found to be promising in butterfly exhibitory programmes. The former species develop on *Aristolochia indica* and the latter on *Citrus* spp. and *Murraya koenigii.* By establishing sufficient patches of the host plants, it will be possible to maintain their population throughout the year. Similarly, species like *Chilasa clytia, Papilio demoleus, Tirumala limniace, Danaus chrysippus, Eurema blanda, Catopsilia pyranthe* and *Talicada nyseus* may be exhibited for about 6 to 8 months of the year while species like *Troides minos, Pachliopta hector, Parantica aglea* and *Tirumala septentrionis* may be exhibited for about 3 to 5 months.

Based on data generated in this study, *Chilasa clytia, Pachliopta aristolochiae, Papilio demoleus, P.hector, P.polytes* and *Troides minos* (Papilionidae); *Catopsilia pyranthe, Eurema blanda* (Pieridae); *Talicada nyseus* (Lycaenidae) as well as *Danaus chrysippus, Parantica aglea, Tirumala limniace* and *T. septentrionis* (Danaidae) were proposed as good candidates for butterfly gardening / captive breeding programmes in Kerala.

## 7. ACKNOWLEDGEMENTS

I am grateful to Smt. Mary Anto (Senior Research Fellow) and Smt. M.S. Rajalakshmi, (Field Assistant) attached to this project for their whole hearted cooperation and hard work during the course of this study. I thank Shri. C.M. Brijesh (Research Fellow, KFD Project) for help in preparation of Plates, Tables and Graphs included in this report. Smt. P. Rugmini (Stastistician) and Smt. C. Sunanda (Research Fellow) kindly assisted in the statistical analysis of data and interpretation of the results. My colleagues Drs. R.V.Varma, R. Gnanaharan, N.Sasidharan and E.A. Jayson kindly went through the manuscript and made several valuable suggestions. Dr. M.S. Muktesh Kumar and Shri. M. Remesh of the Botany Division checked the identity of plants maintained in the garden and updated the nomenclature. I thank Shri. Subhash kuriakose for photography and Shri. V.Asokan for type setting and layout. I wish to place on record my gratitude to Dr. K.S.S. Nair (former Director) and Dr. J.K. Sharma (Director) for their encouragement and for the keen interest in this study. This project was funded by the Ministry of Environment and Forests, New Delhi and my special thanks are also due to Dr. Chhanda Chowdhury (Additional Director, MoEF) for her kind cooperation throughout this study.

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## Appendix I. List of butterflies sighted in study area.

### PAPILIONIDAE

*Troides minos* Cramer* (Plate I, Figs. 1a-e)
*Pachliopta hector* Linnaeus *+ (Plate I, Figs. 2a-d)
*Pachliopta pandiyana* Moore (Plate I, Figs. 3a-c)
*Pachliopta aristolochiae* Fabricius (Plate I, Figs. 4a-d)
*Papilio paris* Linnaeus (Plate I, Fig. 5)
*Papilio buddha* Westwood*+ (Plate I, Fig. 6)
*Papilio crino* Fabricius (Plate I, Fig. 7)
*Papilio demoleus* Linnaeus (Plate I, Figs. 8a-c)
*Papilio helenus* Linnaeus (Plate I, Figs. 9a,b)
*Papilio polytes* Linnaeus (Plate II, Figs. 10a-f)
*Papilio polymnestor* Cramer* (Plate II, Figs. 11a-c)
*Papilio liomedon* Moore*+ (Plate II, Fig. 12)
*Chilasa clytia* Linnaeus + (Plate II, Figs. 13a-d)
*Graphium sarpedon* Linnaeus (Plate II, Fig. 14)
*Graphium agamemnon* Linnaeus (Plate II, Figs. 15a-c)
*Graphium antiphates* Cramer (Plate II, Fig. 16)
*Graphium doson* C&R Felder (Plate II, Fig. 17)

### PIERIDAE

*Leptosia nina* Fabricius (Plate II, Fig. 18)
*Delias eucharis* Drury* (Plate II, Fig. 19)
*Appias lyncida* Cramer+ (Plate II, Fig. 20)
*Appias libythea* Fabricius+ (Plate II, Fig. 21)
*Catopsilia pyranthe* Linnaeus (Plate III, Figs. 22a-c)
*Catopsilia pomona* Fabricius (Plate III, Figs. 23a,b)
*Eurema hecabe* Linnaeus (Plate III, Figs. 24a,b)
*Eurema blanda* Boisduval (Plate III, Figs. 25a,b)

### ACRAEIDAE

*Acraea violae* Fabricius (Plate III, Figs. 26a-c)

### SATYRIDAE

*Melanitis leda* Linnaeus (Plate III, Fig. 27)
*Orsotrioena medus* Fabricius (Plate III, Fig. 28)
*Ypthima huebneri* Kirby (Plate III, Fig. 29)
*Mycalesis anaxias* Hewitson + (Plate III, Fig. 30)
*Elyminas caudata* Butler (Plate III, Figs. 31a-d)

### NYMPHALIDAE

*Cupha erymanthis* Drury (Plate III, Figs. 32a-c)
*Phalanta phalantha* Drury (Plate III, Fig. 33)
*Vindula erota* Fabricius (Plate IV, Fig. 34)
*Cirrochroa thais* Fabricius* (Plate IV, Fig. 35)

*Junonia lemonias* Linnaeus (Plate IV, Fig. 36)
*Junonia orithya* Linnaeus (Plate IV, Fig. 37)
*Junonia hierta* Fabricius (Plate IV, Fig. 38)
*Junonia atlites* Linnaeus (Plate IV, Fig. 39)
*Junonia iphita* Cramer (Plate IV, Fig. 40)
*Junonia almana* Linnaeus (Plate IV, Fig. 41)
*Neptis hylas* Moore (Plate IV, Fig. 42)
*Hypolimnas bolina* Linnaeus (Plate IV, Fig. 43)
*Hypolimnas misippus* Linnaeus + (Plate IV, Fig. 44)
*Moduza procris* Cramer (Plate IV, Figs. 45a,b)
*Euthalia aconthea* Cramer (Plate IV, Fig. 46)
*Ariadne merione* Cramer (Plate IV, Fig. 47)

**LYCAENIDAE**

*Jamides celeno* Cramer (Plate IV, Fig. 48)
*Jamides alecto* Felder (Plate IV, Fig. 49)
*Castalius rosimon* Fabricius+ (Plate IV, Fig. 50)
*Talicada nyseus* Guerin-Meneville (Plate IV, Figs. 51a-d)
*Loxura atymnus* Cramer (Plate IV, Fig. 52)
*Rathinda amor* Fabricius (Plate IV, Fig. 53a; Plate V, Figs 53b,c )
*Arhopala pseudocentaurus* Doubleday (Plate V, Fig. 54)
*Cheritra freja* Fabricius (Plate V, Fig. 55)
*Udara akasa* Horsfield* (Plate V, Fig. 56)
*Spalgis epius* Westwood (Plate V, Fig. 57)

**HESPERIDAE**

*Tagiades litigiosa* Moschler (Plate V, Fig. 58)
*Celaenorrhinus leucocera* Kollar (Plate V, Fig. 59)
*Pelopidas mathias* Fabricius
*Badamia exclamationis* Fabricius (Plate V, Fig. 60)
*Potanthus sp.* (Plate V, Fig. 61)
*Taractrocera sp.* (Plate V, Fig. 62)
*Telicota ancilla* Mabille (Plate V, Fig. 63)
*Borbo cinnara* Wallace
*Gangara thyrsis* Fabricius (Plate V, Fig. 64)
*Udaspes folus* Cramer (Plate V, Fig. 65)

**DANAIDAE**

*Danaus genutia* Cramer (Plate V, Figs. 66a-d)
*Danaus chrysippus* Linnaeus (Plate V, Figs. 67a, b)
*Tirumala limniace* Cramer (Plate V, Figs. 68a-d)
*Tirumala septentrionis* Butler (Plate VI, Figs. 69a-d)
*Parantica aglea* Stoll (Plate VI, Figs. 70a-d)
*Euploea core* Cramer+ (Plate VI, Figs. 71a-d)
-----------------------------------------------------
* Species endemic to Western Ghats
\+ Species included in Wildlife (Protection) Act, 1972.