J. Biosci., Vol. 22, Number 5, December 1997, pp 593-603. © Printed in India.

Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats

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MS received 10 March 1997; revised 15 September 1997

Abstract. In northern Western Ghats (India), four tropical habitats with different disturbance levels were monitored for diversity and seasonal patterns in butterfly communities. Species richness was highest in late monsoon and early winter. Majority of the butterfly species also showed abundance peaks in these seasons. Fire played a significant role in determining species composition in fire-afflicted areas and affected flight periods of some species but did not affect species richness. Grazing had a major impact on species composition and it favoured only those Lycaenids and Nymphalids whose caterpillars feed on herbs. In case of one of the sites where phenophases of the larval foodplant and population trend of a small Lycaenid was documented, the population showed rapid increase at the time when the plants were in suitable phenophase for growth of the caterpillars. A possible evolutionary interaction between herb-feeding and non-herb-feeding Lycaenids is proposed.

Keywords. Butterfly communities; population dynamics; species richness; grazing.

1. Introduction

Butterflies and moths (order Lepidoptera) offer good opportunities for studies on population and community ecology (Pollard 1991). Many species are strictly seasonal, preferring only a particular set of habitats. In spite of this, butterflies have been generally neglected by community ecologists and there are very few studies available on their community structures, population dynamics and the ecoclimatic factors which affect them. Being good indicators of climatic conditions as well as seasonal and ecological changes, they can serve in formulating strategies for conservation. However, they have largely been ignored by conservation biologists and policy-makers as well. It is hence encouraging that butterflies are now being included in biodiversity studies and biodiversity conservation prioritization programmes (Gadgil 1996).

The present study was started with a view to examine the dynamics of butterfly population across seasons and habitats. With quantitative data on butterfly populations gathered from a variety of habitats, the questions became more apparent. What, for example, drives butterfly populations to fluctuate? What are the mechanisms and escape routes used by these insects to overcome their own inherent limitations or limitations imposed by the ecoclimate? The present analysis is intended to reveal the seasonal patterns in butterfly populations, and interactions among them, the plants on which they depend, and their ecoclimate. Despite its limitations, this study did attempt, perhaps for the first time, short-term butterfly monitoring in India.

2. Study sites

Pune (73° 53′E — 18° 30′N) has tropical dry equable climate. Mean summer temperature is about 40°C. Temperature is highest in April but it rarely exceeds 42°C. In winter the temperature is around 12° — 15°C, but on cool nights it may lower down to 4° — 5°C. January is the coldest month. Annual precipitation is 661 mm. Ninety five per cent of the precipitation takes place in four months, i.e., from June to September. July is the rainiest month.

All the study sites were close to Pune city in Maharashtra state within a radius of 20 km. In all, 4 sites were chosen on the basis of their contrasting vegetation types and levels of disturbance. The sites were as follows:

Sinhagad: Southrwest of Pune, a valley situated in the eastern offshoot of the Western Ghats was chosen. The rainfall and present vegetation indicate that in the past it hosted a good patch of closed forest with predominantly moist deciduous tree species. Now it has turned into a degraded secondary deciduous forest. Planted teak is abundant here and the mouth of the valley is under paddy cultivation. Lopping, *Carvia* collection and cattle grazing are present, though on small scale.

Peacock bay: It shows scrub and disturbed dry deciduous forest species. Nearly half of this area is dominated by *Acacias, Flacourtia,* planted mango, tamarind and teak. The rest of the valley has mixed deciduous forest species. The ground is covered with tall grass, and *Lantana* patches are present at a few places. In early spring, all the ground cover burns in the annual fires. This land is protected against grazing and tree felling.

Pachgaon: It is a scrubby hill with abundant grasses, but small trees like *Acacias, Flacourtia, Boswellia, Capparis, Odina* are common. Grass height varies from about 10-15 cm in a few rocky areas to as high as 120-150 cm on the plateau and the slopes. Herbs are present in the rocky areas and beside the paths. But otherwise the ground cover is dominanted by tall tussock grasses. Annual fires burn the vegetation in early spring. Grazing is absent.

Malwadi: This is a grassland plateau with luxuriant growth of herbs. The area is practically devoid of trees due to excessive cutting. It has very short (10-15 cm), sparse grass. In small gullies hardy, woody species such as *Butea, Diospyros* and *Lantana* occur in a stunted form. Many herbs, dominated by *Triumfetta, Zornia* and small, prostrate Fabaceae members grow along with the grass. This site is intensively grazed by the livestock. Annual fires are absent.

3. Methodology

One permanent transect-line was set up at each site, approximately 500 m in length. Observations were taken in the morning between 8·30 to 11·30 when the butterflies were most active. Pace was; slow but constant, covering the transect-line in about an hour. One to three transects in each season at every site were covered. All individuals seen at all heights and distances from the Une were recorded. Other relevant details such as phenophases of the larval foodplants and weather were also recorded. Major

field-work was done between September 1992 to August 1993, and the remainder in 1995-96. For convenience of data collection and interpretation, the year was divided into six seasons (i) spring-February and March, (ii) summer-April and May, (iii) early monsoon-June and July, (iv) late monsoon-August and September, (v) early winter-October and November and (vi) late winter-December and January. For assessing population fluctuations across seasons and sites, species were arranged in a definite order and then a simple matrix with species in rows and seasons in columns was made for each site.

4. Results and discussion

Butterflies in all habitats showed a highly seasonal trend. A previous study (Wynter Blyth 1956) had identified two seasons as peaks, March-April and October, for butterfly abundance in India. However there was no evidence of a peak in summer in this study (tables 1 to 4). The populations were low in spring and summer. This was certainly because of fires in the case of Peacock Bay and Pachgaon, and probably due to heat, scarcity of water and dry ground cover in the case of Malwadi and Sinhagad.

Table 1. Species abundance across seasons at Sinhagad*.

	Spring	Summer	Early monsoon	Late monsoon	Early winter	Late winter	Total No. of individuals
Family Pieridae							
Common emigrant	0	0	0	24	3	4	31
Mottled emigrant	0	0	4	20	0	3	27
Spotless grass yellow	13	16	16	56	17	21	139
Total for a family	13	16	20	100	20	28	197
Family Lycaenidae							
Common hedge Blue	0	0	0	8	6	0	14
Lineblue	0	0	0	0	9	2	11
Total for a family	0	0	0	8	15	2	25
Family Nymphalidae							
Common evening brown	7	3	4	0	5	3	22
Common fivering	2	1	6	0	10	3	22
Common leopard	0	2	2	8	2	1	15
Lemon pansy	4	6	20	0	9	4	43
Chocolate pansy	0	0	12	6	13	1	32
Blue tiger	2	2	10	6	0	3	23
Common Indian crow	2	3	6	10	1	2	24
Total for a family	17	17	60	30	40	17	181
Total for a season	30	33	80	138	75	47	403

* Abundance of each species in terms of average number of individuals seen in a season are given for a specific site. Species are arranged according to families. In the last column, total number of individuals of a species for the entire year is given. This gives the relative abundance of a species compared to other species in the study site. In the bottom row, total number of individuals, all families and species included, for a given season is given. Only those species which were either consistently seen at a given site, or which were seen in a considerably large number in a season are included. Also, species which have been discussed in the paper are included. Miscellaneous species are not included.

Table 2. Species abundance across seasons at Peacock bay*.

	Spring	Summer	Early monsoon	Late monsoon	Early winter	Late winter	Total No. of individuals
Family Pieridae							
Common emigrant	2	2	2	24	1	0	31
Small grass yellow	0	0	4	0	4	0	8
Spotless grass yellow	0	12	42	24	43	50	171
Total for a family	2	14	48	48	48	50	210
Family Lycaenidae							
Common pierrot	0	0	0	4	7	2	13
Gram blue	0	0	0	0	9	0	9
Plains cupid	0	8	0	1	5	0	14
Common cerulean	0	0	0	0	9	0	9
Lineblue	0	0	0	0	10	0	10
Total for a family	0	8	0	5	40	2	55
Family Nymphalidae							
Common evening brown	0	0	0	4	14	2	20
Common treebrown	0	0	0	0	9	0	9
Common fivering	0	0	0	1	4	16	21
Common leopard	6	0	0	5	5	4	20
Yellow pansy	6	2	0	2	4	2	16
Blue pansy	12	0	2	3	3	0	20
Lemon pansy	2	0	0	1	4	2	9
Chocolate pansy	0	0	0	0	4	0	4
Total for a family	26	2	2	16	47	26	119
Total for a season	28	24	50	69	135	78	384

*Same notation as in table 1,

From early monsoon the populations started building and showed the first peak in late monsoon, followed by a second peak in winter.

During unfavourable seasons, that is in spring and summer, a low population was maintained, some species within a family are likely to be more stress-tolerant and therefore are able to survive in these months. For example, lineblues and hedge blues (Family Lycaenidae) appeared only after late monsoon and were not seen after late winter (table 1). (For scientific names of all butterflies mentioned in this paper, see appendix 1). But the plains cupid was seen throughout the year in Malwadi (table 4). This was irrespective of the larval and adult food availability, and therefore was possibly a consequence of temperature changes and other microclimatic changes which follow the former.

Occurrence patterns of a few butterfly species showed interesting trends. The rings (*Ypthima* spp., family Nymphalidae) are grass-feeders in their larval stage. Normally in this region of Western Ghats the monsoon recedes in September. Because of heat the thinlayer of soil loses water very rapidly and the grass turns yellowish at the end of October. Until then the population of rings grew rapidly (tables 3 and 4). In early winter the newly emerged butterflies had to face the problem of availability of suitable foodstufffor their caterpillars. As a result the population sharply reduced, and in case of Pachgaon and Peacock bay it was completely destroyed by the fires. In case of

Table 3. Species abundance across seasons at Pachgaon*.

	Spring	Summer	Early monsoon	Late monsoon	Early winter	Late winter	Total No. of individuals
Family Pieridae							
Common emigrant	3	0	12	7	0	8	30
Mottled emigrant	1	2	0	4	2	12	21
Spotless grass yellow	0	0	34	46	60	22	162
Little orange tip	0	0	1	4	8	0	13
Common gull	0	0	3	16	2	2	23
Pioneer	0	4	13	17	0	0	34
Total for a family	4	6	63	94	72	44	283
Family Lycaenidae							
Common pierrot	0	0	3	4	4	0	11
Babul blue	0	0	0	11	0	0	11
Gram blue	0	0	0	0	10	12	22
Plains cupid	0	0	0	7	4	0	11
Common cerulean	0	0	2	5	4	0	11
Lesser grass blue	0	0	1	0	4	0	5
Grass jewel	0	0	0	0	0	24	24
Total for a family	0	0	6	27	26	36	95
Family Nymphalidae							
Common threering	2	0	6	29	58	2	97
Blue pansy	0	0	0	5	6	8	19
Lemon pansy	0	0	1	13	14	10	38
Painted lady	0	0	0	11	0	12	23
Blue tiger	0	0	7	10	10	4	31
Plain tiger	2	2	2	12	10	2	30
Common Indian crow	0	0	0	13	8	4	25
Total for a family	4	2	16	93	106	42	263
Total for a season	8	8	85	218	244	122	685

*Same notation as in table 1.

Malwadi, there was a peak in early winter, a decline in late winter and another peak in spring. This indicates that most of the ring population was in the larval stage during late winter when the grass was drying. This generation of rings did not find fresh larval foodplant in sufficient quantity in the spring. However, the population did not vanish completely. This is probably due to the remarkable ability of rings to produce dry season forms (Wynter Blyth 1956). As a rule, butterfly caterpillars feed on fresh leaves only. However, the rings are unique in that their caterpillars can also feed on old or drying, less nutritious grass blades. Butterflies which develop from these caterpillars have distinct coloration and are known as dry season forms.

Grass yellows (*Eurema* spp., family Pieridae) had high population in all seasons except in spring or summer, depending on the site. They also show some differentiation in dry and wet season wing patterns. Their occurrence all round the year would perhaps be attributable to their polyphagous nature. However, the fact that their dry season forms were almost as numerous as the wet season forms, is unique. This may be one of their evolutionary advantages which makes them among the commonest butterflies in the world (Larsen 1987). It is evident from tables 2 and 3 that at fire-afflicted sites of

Table 4. Species abundance across seasons at Malwadi*.

	Spring	Summer	Early monsoon	Late monsoon	Early winter	Late winter	Total No. of individuals
Family Pieridae							
Mottled emigrant	27	11	42	95	54	23	252
Small grass yellow	38	0	0	0	18	22	78
Spotless grass yellow	17	6	14	2	0	9	48
Total for a family	82	17	56	97	72	54	378
Family Lycaenidae							
Plains cupid	7	17	14	5	5	2	50
Lesser grass blue	2	2	1	9	5	13	32
Grass jewel	6	0	0	0	50	46	102
Total for a family	15	19	15	14	60	61	184
Family Nymphalidae							
Common threering	23	3	1	15	24	1	67
Baronet	11	5	5	4	3	3	31
Blue pansy	7	0	1	10	20	25	63
Lemon pansy	0	0	0	4	11	4	19
Painted lady	1	8	7	8	1	0	25
Joker	5	4	22	39	31	5	106
Total for a family	47	20	36	80	90	38	311
Total for a season	144	56	107	191	222	153	873

*Same notation as in table 1.

Peacock bay and Pachgaon, fires affected grass yellow populations most severely. The most puzzling aspect of small grass yellow was its absence during the monsoon and a peak in spring at Malwadi (table 4).

In most of the landscapes in India, two factors caused by human beings influence the species diversity and composition of flora and fauna. These are grazing by domestic cattle, and fires. Grazing alters grass and herb species composition in grasslands (Rodgers 1986). Cattle uproot grasses while feeding on them (A J T Johnsingh, personal communication). As a result, areas of high grazing intensity show a decrease of tall bunch grasses and increase of small, prostrate annual herbs (Milchunas and Lauenroth 1993). The grazing pressure existed only at Malwadi at a high intensity. This had eliminated tall grass species and had kept the grass density low. As a result, many small herbs such as *Triumfetta, Tragia, Zornia* and a lot of papilionaceous species had grown there. On the other hand, at the fire-afflicted site of Pachgaon the grasses were tall and herbs were rare. Since butterfly species are directly dependent on plant species composition for larval and adult food resources in an area, the dominant butterfly fauna of Malwadi was quite different from that of Pachgaon even though both the sites were grasslands in broad terms. The outcome was the presence of grass blues, grass jewel, joker and blue pansy mainly at the fire-free site of Malwadi. Larval foodplants of all these species are small herbs (Bell 1909 to 1927) which were abundant at Malwadi but relatively rare at Pachgaon. This supported their abundance at Malwadi but resulted in relatively poor representation at Pachgoan. In fact in winter when Malwadi would be crowded with many hundred individuals of these species, at Pachgaon only a few would be seen,

Originally, Pachgaon and Malwadi were probably similar in vegetation types but fire and grazing at the respective sites have converted them into two different habitats as far as butterfly fauna is concerned. They foster two distinct sets of dominant butterfly species. Earlier work (Anderson 1982) suggests that grazing causes replacement of palatable plant species with weedy, nonpalatable invaders. *Triumfetta* is one such herb not preferred by cattle and *Zornia* is probably too small in size. Others such as *Tragia* are stinging. In the study sites, these plants were exclusively or partially restricted to Malwadi, and supported the larval populations of such abundant butterfly species as grass jewel, blue pansy, Joker etc. Since these butterfly species, in their larval as well as imaginal stages, are associated with extremely disturbed vegetation, it is possible that thay have evolved in secondary, naturally or artificially disturbed grasslands.

Fires can occur naturally or be initiated by human beings. It plays a very important role since it affects the vegetation directly. In an area with moderate rainfall and frequent fires, tall grasses dominate the ground vegetation (Evans *et al* 1989). This is evident from present vegetation of Pachgaon and Peacock bay, both severely affected by manmade fires. Due to the presence of tall bunch grasses, herb growth is mostly suppressed in these areas. However fires seemed to affect species composition of butterflies but not species richness, as species richness in fire-afflicted sites was as high as in the fire-free sites (table 5). Most of the differences in comparative relative abundance of butterfly species among sites could be attributed to presence or absence of fires. Butterflies such as common evening brown, plains cupid, spotless grass yellow, blue pansy, lemon pansy, painted lady and leopard were found at fire-free as well as at fire-afflicted sites. These species had more intense peaks at fire-afflicted areas with highly seasonal occurrence. On the other hand, in the fire-free areas occurrence was less seasonal and spread across more seasons (tables 1 to 4).

Another effect of fire could be seen in flight periods of some species. Following species had two distinct flight periods—(i) common threering, (ii) lemon pansy, (iii) chocolate pansy, (iv) lesser grass blue and (v) spotless grass yellow. For the (i), (iv) and (v) species see tables 3 and 4, and for remaining species, refer tables 1 and 2. All these species were found at both, fire-afflicted and fire-free sites but at the fire-afflicted sites they had only one major flight period and the second one was lost. What could be the long-term effects of loss of second flight period in these species is not known. But ecologically isolated regions where fires are extensive and the area burning in fires is large, owing to poor dispersal abilities of these species, the effects of fire on their populations could be drastic.

Table 5. Species richness (No. of species)*.

	Spring	Summer	Early monsoon	Late monsoon	Early winter	Late winter
Sinhagad	8	7	17	19	16	14
Peacock bay	6	6	7	14	19	12
Pachgaon	4	3	14	25	18	21
Malwadi	14	8	10	14	18	12

* Species richness at all the localities across seasons is given. All the species are included in this table.

Grazing and annual fires are common to many forests and grasslands in India. This causes serious damage to wildlife, especially the lower vertebrates and all invertebrates. In a majority of cases, all the attempts made to control these pressures have, unfortunately, failed due to demand for grass from the rural populace. Therefore instead of trying to completely ban grazing, it can be used as a tool by wildlife managers, and damage done to the lesser widlife by grazing can at least be minimized. In the United Kingdom grazing by cattle and sheep has been practised as a management tool (Pollard 1991) and there is ample scope for such practices in India.

A potentially interesting phenomenon concerning seasonality of occurrence was observed in Lycaenids at Pachgaon and Malwadi. Many Lycaenid caterpillars, including those of grass blues and gram blue which were among the most common Lycaenid species in this area, feed on low-growing herbs, especially papilionaceous herbs. These herbs grow and die during a period of four months, from July to November. In this period the upper crust of the ground holds enough moisture. At the end of the growing season, plants produce flowers, develop pods and then get dry and die. Many caterpillars, notably those of grass jewel and gram blue feed on flowers and pods of the herbs. So even if the herbs were present right from early monsoon, these butterflies started appearing commonly only from October and reached their peak in late winter, synchronizing with the last stages of their foodplant (tables 3 and 4). In the forested sites of Sinhagad and Peacock bay different Lycaenid species were present when compared to those species present in open habitats. Most of the herb-feeding Lycaenids were absent at Sinhaged due to absence of their foodplants in the low-light conditions of the forested floor. At Peacock bay, heavy growth of grass and *Lantana* suppressed growth of herbs. Interestingly, the Lycaenids here had their peak in early winter, earlier than that of open habitat species (tables 1 and 2).

The question is, why herb-feeding Lycaenids have their peak at the end of the favourable season, that is in late winter when it starts getting very cold, an extremely difficult time for cold-blooded animals. During these months the night temperature may go as low as 4° or 5°C and many times frozen individuals are seen early in the morning, some of which never return to life. A possible explanation for this phenomenon may be as follows:

The wingspan ranges (Wynter Blyth 1956) of herb-feeding and non-herb-feeding Lycaenids are as follows;

Herb-feeders	Non-herb-feeders
Grass blues and grass jewel: 15-26 mm.	Pierrots and plains cupid: 26-32 mm.
Gram blue: 25-30mm.	Flashes: 30-40mm.
	Ceruleans: minimum 30 mm.

(These wingspan measures strictly belong to species found in the concerned study area and do not include other species).

It can easily be seen that the herb-feeders have smaller wingspan ranges than the non-herb-feeders. As stated earlier, non-herb-feeders were mainly from forested habitats and herb-feeders were from open habitats. However, at Pachgaon both these groups were found to occur. At Pachgaon there was a constant peak of Lycaenids from late monsoon to late winter (table 3). However, the non-herb-feeders

dominated the population in late monsoon while herb-feeders dominated in late winter, early winter being the transition period. It is possible that this pattern is a result of resource-based interspecific competition for nectar-sources in the adult butterflies. Being larger in size, wherever both occur, non-herb-feeders are capable of dominating the smaller herb-feeders and push them to survive only towards the end of favourable season where they are held on presently. But why then at Malwadi also these Lycaenids have a peak in late winter? Here larger non-herb-feeders are absent. But in forested habitats butterflies can choose the nectar-source from a variety of big and small plants and from different storeys. This choice is denied to butterflies in open habitats like Malwadi as there is no stratification in vegetation and butterflies from all size classes compete for the ground layer. As a result, much larger Pierids, Nymphalids and tiny Lycaenids, all compete for the same flowers. In general, when a butterfly finds a good-source already occupied by another butterfly, it flutters and hovers over the feeder and drives it away. Small Lycaenids are hence ill-adapted for this type of competition. Similar resource-based competition has been recorded in flour beetles by Crombie (Begon and Mortimer 1986). The above seasonal pattern may hence be interpreted as an example of competitive exclusion among butterfly species which use same nectar sources, where the realized niches of herb-feeders and non-herb-feeders might have been separated by the season, in accordance with wingspan or body size.

It is difficult to test this hypothesis due to lack of basic natural history and ecological data. It is not known what nectar-sources these butterflies use; the yearly pattern of the nectar plants and their comparative importance from butterflies' point of view; degree of searching efficiency and time required for feeding etc. Research on this is under way.

Acknowledgements

I am grateful to Dr Milind Waive who has encouraged and directed this work from the beginning. I thank Dr Anil Gore, Dr Sharayu Paranjape, Department of Statistics, Pune University, Pune, Dr Qamar Qureshi, Wildlife Institute of India, Dehra Dun, and Mr Manoj Nayar for their comments and helpful suggestions. I also thank the two anonymous referees for important suggestions. My thanks are due to Miss Radhika Godbole for assistance in the field.

Appendix 1. Scientific names of the butterflies.

Common name	Scientific name*
Family Pieridae	
Common emigrant	*Catopsilia pomona* Fabricius
Mottled emigrant	*Catopsilia pyranthe* Linnaeus
Small grass yellow	*Eurema brigitta* Wallace
Spotless grass yellow	*Eurema laeta* Boisduval
Little orange tip	*Colotis etrida* Boisduval
Common gull	*Cepora nerissa* Fabricius
Pioneer	*Anaphaeis aurota* Fabricius

Family Lycaenidae	
Common pierrot	*Castalius rosimon* Fabricius
Common hedge blue	*Acytolepis puspa* Toxopeus
Lineblue	*Nacaduba* and *Prosotas* spp.
Babul blue	*Azanus* spp.
Gram Blue	*Euchrysops cnejus* Fabricius
Plains cupid	*Chilades pandava* Horsfield
Common cerulean	*Jamides celeno* Fabricius
Lesser grass blue	*Zizina otis* Butler
Grass jewel	*Freyeria trochylus* Kollar
Family Nymphalidae	
Common evening brown	*Melanitis leda* Drury
Common tree brown	*Lethe rohria* Guerin-Meneville
Common fivering	*Ypthima baldus* Evans
Common threering	*Ypthima asterope* Moore
Baronet	*Symphaedra nais* Forster
Common leopard	*Phalanta phalantha* Drury
Yellow pansy	*Junonia hierta* Fabricius
Blue pansy	*Junonia orithya* Butler
Lemon pansy	*Junonia lemonias* Linnaeus
Chocolate pansy	*Junonia iphita* Fruhstorfer
Painted lady	*Cynthia cardui* Linnaeus
Joker	*Byblia ilithyia* Drury
Blue tiger	*Tirumala limniace* Gmelin
Plain tiger	*Danaus chrysippus* Linnaeus
Common Indian crow	*Euploea core* Cramer

*All the scientific names follow Larsen 1987.

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