SPECIES COMPOSITION, SEX-RATIOS AND MOVEMENT PATTERNS IN DANAINE BUTTERFLY MIGRATIONS IN SOUTHERN INDIA[1]

KRUSHNAMEGH KUNTE[2]

[1]Accepted November 2004
[2]Life Research Foundation, 1000/6-C, Pranav, Navi Peth, Pune 411 030, Maharashtra, India.
Current Address: Section of Integrative Biology, University of Texas at Austin,
1 University Station C0930, Austin, TX 78712, USA. Email: krushnamegh@mail.utexas.edu

Longitudinal migration of danaine butterflies takes place across the plains of southern India to the Western Ghats during October-November, and towards the plains, about April-May. I report here on the butterfly migration through Chinnar Wildlife Sanctuary, Kerala, in October 2001. *Tirumala septentrionis* (Butler) was predominant, constituting 78.5% of the migrating butterflies. *Euploea sylvester* (Fabricius) was twice as numerous as *E. core* (Cramer), the two species making up the remaining 21.5%. The migrants were freshly emerged adults and sex-ratios were equal, except in the slightly male-biased *E. sylvester*. The number of butterflies in this swarm was conservatively estimated at over 175,000 over three days. Reproductive status of migrating danaines and the apparent resident population of *E. core* at Chinnar Wildlife Sanctuary are discussed. I suggest that the migratory tendencies evolved to avoid the torrential southwest monsoon in their larval habitats in evergreen and semi-evergreen forest of the Western Ghats. This hypothesis is consistent with the absence of diapause in early stages of these species, and with the fact that the butterflies breed alternately in the plains and in the Western Ghats.

Key words: *Tirumala, Euploea*, Danainae, butterfly migration, sex ratio, seasonal movements

INTRODUCTION

Annual butterfly migrations in southern India have been documented since the turn of the 19th century (Williams 1927, 1930, 1938) but their nature is still poorly understood. Unlike the small-scale or occasional butterfly migrations that take place in central India and northern Western Ghats (Bharos 2000; Chaturvedi 1993; Chaturvedi and Satheesan 1979; Reuben 1961, 1962; Williams 1938), the southern Indian migrations are both regular and on a very large scale, involving hundreds of thousands of individuals (Fisher 1945; French 1943; Larsen 1978; Williams 1927, 1938). The patterns of the short-distance north-south migrations in the Anamalai-Palni and Nilgiri mountains are relatively well-documented and have been monitored over decades (Evershed 1910; Williams 1938; Briscoe 1952; Larsen 1978, 1987). However, literature pertaining to the long-distance east-west migrations that take place through the plains of southern India is scarce. During this migration butterflies traverse a distance of 300-500 km, from the plains near the eastern coast to the Nilgiri and Anamalai-Palni mountains, near the western coast of southern India. This migration takes place mainly during October or November and towards the plains about April-May (Williams 1930, 1938; Karthikeyan *et al.* unpublished observations. The east-west migrating swarms are composed mainly of *Tirumala septentrionis*, *Euploea sylvester* and *E. core* of Danainae (Nymphalidae), as opposed to the north-south migrations exclusive to the hills, which are composed of *Catopsilia pomona* (Fabricius), *C. pyranthe* (Linnaeus), *Appias albina* (Boisduval), *Papilio demoleus* Linnaeus and smaller proportions of *Tirumala limniace* (Cramer), *Danaus genutia* (Cramer), *Hypolimnas bolina* (Linnaeus), *Cynthia cardui* (Linnaeus), and *Lampides boeticus* (Linnaeus) belonging to families Papilionidae, Pieridae, Nymphaliade and Lycaenidae (Evershed 1910; Larsen 1978; early works reviewed by Williams 1938).

Estimates of the size of swarms of migrating butterflies based on quantitative data are scarce, although a few subjective estimates are available. Relative proportions of species (Palot 2000) and sex-ratios (Larsen 1986) in largely danaine aggregations have been reported, but not from migrating swarms in southern India. The sex-ratios of migrating butterflies are also of crucial importance, since they would strongly influence sexual displays and mating behaviour at their ultimate destinations. In this paper, I provide quantitative estimates of the size of the swarm, relative proportions of species and the sex-ratios of butterflies in the migration that passed through Chinnar Wildlife Sanctuary, Kerala, in October 2001. Also reported are observations on the breeding and larval parasitization in the local *E. core* population during the migration period. I further suggest a pattern of movements and breeding of migratory danaines of southern India.

METHODOLOGY

Chinnar Wildlife Sanctuary (10° 15'-10° 22' N, 77° 05'-77° 15' E; total area 90.42 sq. km) is situated between Amaravathi Wildlife Sanctuary in Tamil Nadu and Eravikulam National Park in Kerala. It is near Munnar, on the eastern side

of the Western Ghats, in Kerala, at an altitude of 500 m to 2400 m. The mean annual rainfall is 1000 mm, due mainly to the northeast monsoon, from late October to December. The Sanctuary contains dry deciduous and scrub forests. The vegetation is dominated by stunted trees and thorny shrubs, including various species of *Acacia*, *Ziziphus*, *Santalum album*, *Anogeissus latifolia*, and along riverbeds, *Terminalia arjuna* and *Pongamia glabra*. This is similar to the original vegetation of the plains of southern India east of the Western Ghats (Puri *et al.* 1983).

I observed migrating butterflies at Chinnar Wildlife Sanctuary and Eravikulam National Park from October 18-20, 2001, and sampled individuals from the swarm between 0900 hrs and 1430 hrs on October 20. I do not know exactly for how many more days the migration lasted. On October 20, the weather was warm and sunny, but there had been occasional rains the previous week, with clouded evenings. Observations were made from a spot approximately in the middle of the stream of butterflies. The migrating band was at least several hundred metres wide, but for a most conservative estimate I restrict my calculations to 50 m. The general direction, flight behaviour and total number of individuals were quantitatively estimated, without collecting the butterflies. For this purpose, I chose a 10 m wide imaginary belt at the centre of the stream of butterflies, and counted the number of butterflies passing through this belt over a 5-minute duration. Eight such observations were taken between 0930 hrs and 1405 hrs (Table 1). Since the two species of *Euploea* could not be distinguished apart in flight, they have been combined in this count. *T. limniace* did not form a significant proportion of these butterflies, and it was missing completely from the quantitative sampling.

A random sample of 250 migrating butterflies was taken with a butterfly net to confirm species identities and determine sexes of the butterflies caught, after which they were released on the spot.

RESULTS

The butterflies were flying from east to west, with a slight northeast to southwest tilt, over the plains through Amaravathi and Chinnar sanctuaries towards Eravikulam National Park. *Tirumala septentrionis*, *E. sylvester* and *E. core* comprised most of the migrating swarm, with *T. limniace* making up a very small fraction. A few other species, notably *P. demoleus*, *C. pomona* and *Danaus chrysippus* (Linnaeus), were also seen flying along with the swarm, but due to their small numbers, inconsistent direction and manner of flight, it could not be concluded that they were migrating. *Tirumala septentrionis* far outnumbered all other species, in the migrating swarm, making up about 78.5% of all butterflies (Tables 1 and 2). *Euploea sylvester* was twice as numerous as *E. core*, the two species making up the remaining 21.5% of the swarm. All butterflies were flying between 1 and 4 m above the ground. The flight speed and style were usual for the danaines - leisurely but persistent with continuous wing-beats — and during the day they never halted to feed or rest. There was no perceptible wind when the observations were made. More than 95% butterflies captured for close examination were freshly emerged adults, without any wing wear or tear.

Table 1 shows number of butterflies that passed through a 10 m belt in five minutes. Based on these data, of the total number of migrating butterflies was estimated. The migration was in progress for a minimum of three days for at least five hours daily (0900-1400 hrs). Assuming a minimum width of 50 m for the main stream of the migrating swarm, size was calculated as follows:

Butterflies flying in 1 hour in a belt of 10 m (195 in 5 minutes x 12) = 2,340.

Butterflies flying in 5 hours a day in a belt of 50 m (2,340 x 5 x 5) = 58,500.

Size of the swarm (58,500 x 3 days) = 175,500.

Thus, the most conservative estimate of the size of this migrating swarm was over 175,000 butterflies; *T. septentrionis* constituting almost 137,000 of the total number and *Euploea* spp., the remainder. The number of butterflies involved in this exodus would appear to be small as compared to "millions" of butterflies reported by Larsen (1978) in the Nilgiris. However, it should be noted that Larsen reported the breadth of Nilgiris migrating swarms to be almost 6 km, whereas I have assumed a modest breadth of 50 m for the migration I witnessed. The estimates would rise exponentially if these assumptions are changed and further quantitative observations are made with a more intensive effort.

Table 1: Number of butterflies passing through a 10 m belt in 5-minute duration

Time	0930-0935 hrs	1045-1050 hrs	1140-1145 hrs	1148-1153 hrs	1209-1214 hrs	1239-1244 hrs	1317-1322 hrs	1400-1405 hrs	Average (±SD)
T. septentrionis	175	208	202	80	152	158	102	145	153 (±44.61)
Euploea spp.	42	49	37	50	49	35	36	37	42 (±6.51)
Total	217	257	239	130	201	193	138	182	195 (±41.63)

Table 2 gives sex-ratios calculated from 250 individuals of three migrating species as well as an estimate of relative proportions of two species of *Euploea*, the sample of *Euploea* being random. The sex-ratio in *T. septentrionis* and *E. core* was approximately 1:1, while that in *E. sylvester* was slightly biased towards males.

On the breeding of *E. core* at Chinnar Wildlife Sanctuary: *E. core* from the plains may have both migratory and non-migratory populations, as has been reported for many butterflies with migratory tendencies elsewhere (Williams 1930). In support of this, I report the following observations pertaining to the occurrence and breeding of *E. core* at Chinnar and Bangalore.

Isolated by about 200 m from the main stream of migrating butterflies was a puddling assemblage of about 50 individuals of *E.* core and *Appias libythea* (Fabricius) at the Chinnar forest check-post. These butterflies remained at that spot throughout the day, and showed no indication of joining the migration. Therefore, they were most probably from local breeding populations of these species, rather than the migrating swarm. Of the 25 caterpillars and pupae of *E. core* collected from a *Nerium* plant close by, only two yielded adult butterflies. The rest were destroyed in early stages by parasitoid dipterans except one, which was destroyed by a parasitoid wasp. Fresh eggs were observed on this plant, indicating that breeding was ongoing in the *E. core* population at Chinnar Wildlife Sanctuary. Butterflies from these eggs would have metamorphosed in about 40 days after the migration had passed through, and therefore would probably not have left their place of emergence.

In Bangalore city, which is on the migratory route, mid-way between east and west coasts, *E. core* is active throughout the year (unpublished data). It is not known what proportion of the local population, if any, joins the migrating swarm. However, this area maintains a local, continuously breeding population of *E. core*, feeding mainly on *Ficus* spp. Thus, both migratory and non-migratory individuals are expected to comprise the *E. core* population.

Table 2: Sex-ratios of migrating butterlies

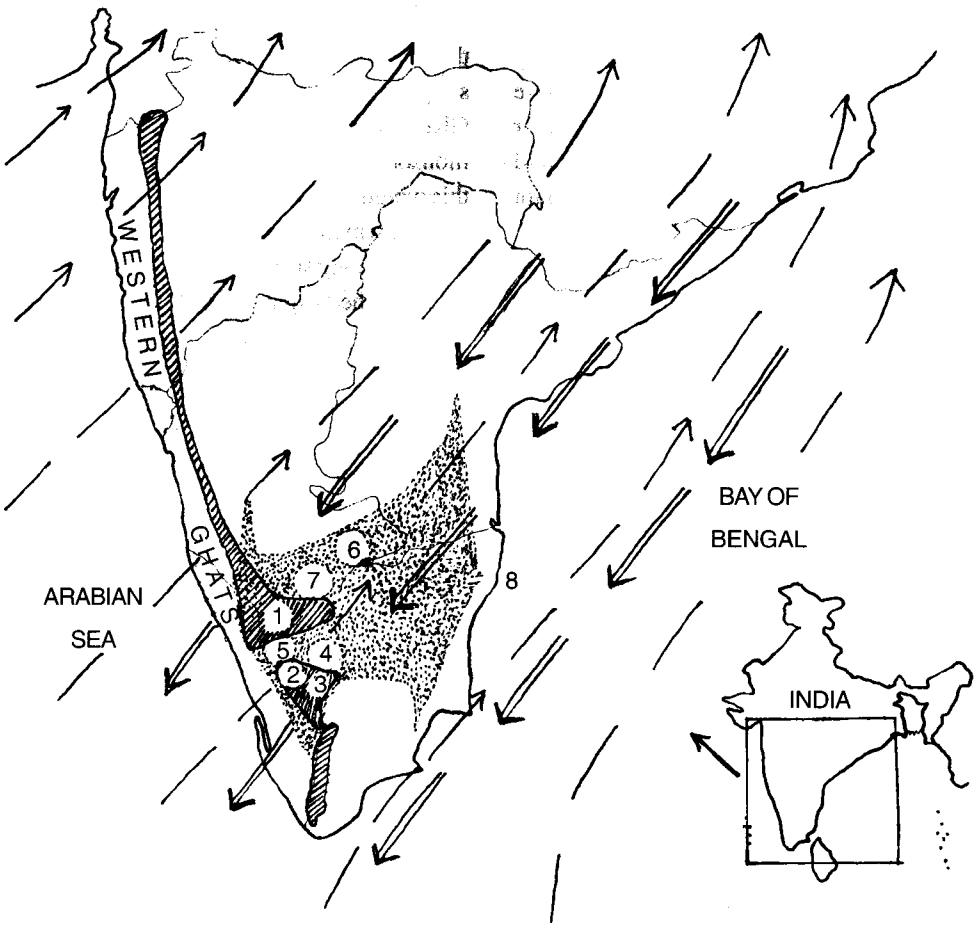
Species	Male	Female	Total	%Males
T. septentrionis	78	80	158	49.5
T. limniace	03	00	03	100
E. sylvester	37	26	63	58.75
E. core	14	12	26	54
Total	132	118	250	

DISCUSSION

The danaine butterfly migration in southern India is interesting for a) its longitudinal extent, and b) the pattern of migrational movements which is influenced by the Indian monsoon. Most of the known seasonal migrations of butterflies in the world are either latitudinal or altitudinal (Johnson 1969; Williams 1958). Both are somewhat similar, in that they are adaptations mainly to escape adverse seasonal temperatures and host plant availability at very high altitudes or latitudes. The southern Indian migration does involve an altitudinal component, but the butterflies do not just descend the hills and settle in the eastern foothills on the plains in the rain shadow, but travel across the plains to disperse close to the eastern coast, travelling a minimum of 300 km. However, the exact area of dispersal is still unknown, and therefore the longest distance travelled, by migrating butterflies is still unknown. Importantly the longitudinal component overwhelms the altitudinal component, and therefore this migration is better viewed as longitudinal.

Southwood (1962) observed that globally most migratory lepidopterans belong to semi-arid areas where habitats are temporary. These migrants are mainly from cold altitudes, extreme latitudes or warm semi-desert areas; for example *Cynthia cardui* (Linnaeus) and *Pieris* spp. in northern Africa and Europe (Johnson 1969; Williams 1958). In Costa Rica, *Danaus plexippus* (Linnaeus) and others apparently migrate from dry forests to evergreen forests of the hills (Scoble 1995). The southern Indian danaine migration superficially seems to fit the pattern that their preferred habitat is dry forests of the plains, from which they migrate to moist and cool evergreen forests of the hills, presumably to escape hot summers. However, in the unique geography of the Western Ghats and the eastern plains, where a combination of torrential southwest monsoon and milder northeast monsoon brings about markedly different seasons on either side of the Western Ghats (see below), an interesting new pattern emerges; i.e., southern Indian danaine butterflies escape from the wettest season in an evergreen forest and migrate to drier habitats. This is exactly opposite to the pattern observed in most migratory insects.

On the pattern of migration and breeding in southern Indian danaine butterflies: Unlike the relatively well-documented, predominantly pierid migrations in southern India (Evershed 1910; Larsen 1978), observations on the exclusively danaine migration have been random and sporadic, because its importance and magnitude was probably not realized. There was no conceptual framework in which observations could be fitted to construct a coherent picture of movements of the danaine butterflies involved in this



→ : southwest monsoon

⇨ : northeast monsoon

▒ : movement of butterflies

1 : Nilgiri Mountains

2 : Anamalai Mountains

3 : Palni Hills

4 : Chinnar Wildlife Sanctuary

5 : Palghat Gap

6 : Bangalore

7 : Mysore

8 : Chennai

Fig. 1: Movement pattern* of migratory danaine butterflies in southern India

*a) Predicted movement pattern is extrapolated from opportunistic observations

b) The Western Ghats are not accurately reproduced, but illustrated only for reference

migration. I attempt to offer such a framework here, based on my observations over the past five years and partly from the data presented here. This needs validation by further observations, especially since 110 years of studies on the migration of *Danaus plexippus* in North America have taken a tortuous path (Brower 1995). I hope that this beginning can generate interest and stimulate further observations and research.

I propose that topography of the Western Ghats in relation to southern Indian plains and its effect on the monsoonal pattern are the decisive factors in shaping the pattern of this migration (Fig. 1). I briefly review these two factors.

Topography of the Western Ghats and southern India: The Western Ghats is a mountain chain parallel to the western coast, about 1600 km long. It can be conveniently divided into three natural zoogeographic zones: a) northern (southern Gujarat up to Kali river in northern Karnataka), b) central (south of Kali river to Palghat Gap) and c) southern (Palghat Gap southward). The migrations of *E. core* reported by Aitken (1898) take place from around Kali river northward.

The danaine migrations under present consideration

occur in the Nilgiri and Anamalai-Palni mountains, lying north and south of the Palghat Gap, respectively. The Palghat Gap is a gap of lowland, about 40 km wide, in the otherwise continuous mountains of the Western Ghats. It forms a major natural barrier between the high hills of the Nilgiris and Anamalais, isolating endemic butterflies of the two mountain ranges.

The Nilgiri and Anamalai mountains rise to an altitude of over 2,500 m, with a spectrum of habitats, from scrub and deciduous forests to mid-elevation evergreen forests and montane *shola* forests and grasslands. The highest peak in southern India: Anaimudi (2,695 m), lies in the Anamalai mountains, and the danaine migration passes at 2,400 m through the surrounding plateau. The Karian and Varagaliar sholas in the Anamalais, on the eastern slope at 600-700 m are known breeding habitats of migrant danaines. They harbour dense tropical evergreen forest, now remaining as tiny habitat islands representing once extensive evergreen forests in the presently vast ocean of secondary deciduous forests, and tea, coffee and teak plantations.

The plains east of southern Western Ghats lie mainly at an altitude less than 200 m. The high mountains of the southern Western Ghats, where southwest monsoon is the main monsoon, cast a rain shadow over the plains.

Monsoonal pattern and seasonality in southern India: The southern part of the Indian peninsula receives two monsoons, the torrential southwest and milder northeast monsoon. The southwest monsoon begins on the Western Ghats with heavy downpours from June to early October. The Nilgiri and Anamalai mountains receive more than 4,000 mm of precipitation mainly in June and July. During this period humidity is maximum and sunshine is virtually absent for two months; therefore adult butterfly activity is suspended. The high ranges more or less drain the clouds. As a result, although the plains receive the southwest monsoon, their main monsoon is the northeast monsoon. This is active from late October to December or early January. In contrast to the Western Ghats, the plains receive very little precipitation, varying from 400 mm to over 1,000 mm. October to January is the ideal breeding season for most butterflies in the plains, the rest of the year being very hot and dry. The northeast monsoon is effective also on the eastern slopes of the Western Ghats, bringing rains mainly in November and December. There is a marked gap in October after the southwest monsoon recedes and the northeast monsoon opens in the hills. Overall butterfly activity peaks in the hills from October to January or early February. Sporadic but heavy pre-monsoon showers break in the hills toward the end of April and continue through May. There is a brief period of butterfly activity in April and May before the onset of the southwest monsoon.

The southwest monsoon has earlier been implicated as the prime force driving butterfly migrations. Aitken (1898) suggested that *E. core* fly north to the northern Western Ghats to escape the heavy rain with which the southwest monsoon opens in the southern and central hills. However, this would only affect butterflies in areas close to the northern ranges, which do not participate in the migration discussed here. The long stretches of mountains immediately north and south of the Nilgiris, Anamalais and Palni Hills, where the present migration occurs, are equally wet and unfavourable during the southwest monsoon. Williams (1938) in connection with the butterfly migrations from the Palni Hills, alluded to October-November being a shift between southwest and northeast monsoons in southern India. However, neither author developed the theory further to cover exact movement patterns and breeding cycles of the butterflies involved in this migration, as has been done here.

Movement and breeding patterns of the danaine butterflies: *Tirumala septentrionis*, *E. core* and *E. sylvester* are widespread in Asia, and have been reported to be migratory in various parts of their range (Ackery and Vane-Wright 1984; Wang and Emmel 1990). In southern Western Ghats and the plains lying to the east the butterflies have two migratory flights every year: towards the Nilgiris, Anamalais and Palni Hills in October-November, and towards the plains in April-May. Therefore, they spend roughly half the year on the plains and half in the hills, but during most years they take flight by late April or May and mid-October, thus spending more of their time in the hills. This pattern could result from either of two possibilities: a) the preferred habitats of these danaine butterflies are scrub and dry deciduous forests of the plains, and the butterflies take refuge in the cooler, forested hills for part of the year, or b) these species belong to evergreen and semi-evergreen forests of the hills, and are forced to migrate to the plains to avoid the southwest monsoon. The former would resemble the movement pattern of *Danaus plexippus* and others in Costa Rica (Scoble 1995), while the latter would mean a unique pattern of migrational movements in southern India. I favour the latter possibility. The crucial point is that November-December is the wet season for southern plains and therefore October to January is the ideal breeding season there for most butterflies. In spite of this, the danaines emigrate from this region without exploiting the optional breeding season of the plains, and take refuge in the hills. On the other hand, the months the butterflies spend away from the hills are the exact period when the southwest monsoon is at its peak, adversely affecting adult activity, breeding and larval growth. Combining these observations, evergreen and semi-evergreen forests of the Western Ghats could be interpreted as preferred habitats of

the danaines. This migratory tendency has apparently evolved to escape the heavy southwest monsoon. Possible adaptation to escape this monsoon could have been to undergo a long diapause. However, diapause in early stages is apparently absent, and because of the monsoonal climate in the hills is unhealthy for adults, the option of migration was necessary. Since the hills of the Western Ghats immediately south and north of the Nilgiris, Anamalais and Palni Hills are equally inhospitable, the butterflies fly to the eastern plains, rather than north, as *E. core* does in northern Western Ghats (Aitken 1898).

On arrival in the hills in late October-November, the butterflies spend a few weeks in dense congregations (pers. obs) that are reminiscent of the overwintering congregations of danaines elsewhere in Asia (Wang and Emmel 1990). They cling in dense clusters of several thousand individuals to higher branches at about 15 to 20 m of medium-sized trees inside the forest. Mortality seems to be very high in these congregations, and the forest floor is strewn with scores of body-less wings of butterflies. This could be due to avian predation as in overwintering colonies of *D. plexippus* (Brower and Calvert 1985), or to other reasons. Butterflies from these congregations, however, do not usually visit wet soil patches for puddling or feed regularly from flowers, although they occasionally fly around the congregations. They disperse by December-end or early January, with the males soon engaging in feeding at the edges of forests on damaged plant parts of *Crotalaria* spp. (Fabaceae), the sap of which contains pyrrolizidine alkaloids.

The movement and breeding patterns of these butterflies after they disperse are unknown. However, at least a portion of butterflies breed in the hills by April, before leaving for the plains. I have reared caterpillars of *T. septentrionis* on *Tylophora* sp. in Karian shola, Anamalais, adults from which emerged by May, before the migration towards plains. We do not know whether all adult butterflies breed and perish in the hills and only their offspring undertake the migration towards the plains. Observations on adult butterflies migrating towards the plains will elucidate this. However, it is apparent that the butterflies breed both in the plains and the hills before the respective migrations; and it is predominantly freshly emerged and unmated individuals that participate in the migrations. Thus, seasonal sexual diapause and overwintering behaviour as seen in other migratory danaines (Brower 1995; Wang and Emmel 1990) seem to be replaced in southern India by alternate but continuous breeding in two ecologically very different and spatially distant habitats. Observations on the post-migration behaviour of the danaines in the plains are lacking.

The almost equal sex-ratio of the migrating butterflies reported in here is also significant. Assuming that all freshly emerged butterflies migrate, without sex related bias in migratory tendency, it may be concluded that sex ratio at eclosion in these danaines is 1:1. The fact that freshly emerged males fly along with freshly emerged females further supports the idea that *T. septentrionis* and *Euploea* spp. have pre-reproductive migratory flights. Similar pre-reproductive migration also occurs in *Danaus plexippus* (Brower 1985). The information on sex ratio and physical and reproductive status of butterflies taking a migratory flight towards the plains in April-May is crucial to further understanding.

The unique longitudinal extent and the yearly breeding cycles in different habitats in two distant areas in the hills and in the plains make this butterfly migration in southern India a very interesting study. Some crucial questions remain unanswered. For example, we do not know the exact location(s) of the beginning of the exodus from the plains, and whether it is a single swarm of butterflies starting from the plains which later splits to reach the Nilgiri and Anamalai mountains, or if there are many arms to this migration. It is puzzling that if the butterflies migrate to the plains merely to escape the heavy southwest monsoon, they should travel as far as close to the eastern coast of India, rather than stopping at the eastern foothills. Also unknown is whether *T. septentrionis* and *E. sylvester* have permanent resident, breeding populations, apart from migratory ones, in the plains as suggested here for *E. core*. Most importantly, the exact patterns of breeding phenology, voltinism, relative breeding success and occurrence of danaines in the plains and the hills remain obscure. Large-scale captures and examination of butterflies prior to, during, and following migration would elucidate the reproductive status of the migrating species. I hope that a directional effort may advance our understanding of the causes and working of this migration in the light of the new framework proposed, which may help to formulate and test specific hypotheses about migrational movements and breeding in these danaines.

ACKNOWLEDGEMENTS

I thank James Zachariah (IFS, Wildlife Warden, Eravikulam National Park and Chinnar Wildlife Sanctuary) for his timely permission to conduct this study and for providing facilities. I appreciate Shivakumar and Sumit Dhole's field assistance at Chinnar. I am indebted to Shonil Bhagwat, Lincoln Brower, Thomas Emmel, Harish Gaonkar, Utkarsh Ghate, Kumar Ghorpade and Barrett Klein for offering prompt help with literature and for providing useful criticism of an earlier draft of this paper.

REFERENCES

ACKERY, P.R. & R.I. VANE-WRIGHT (1984): Milkweed Butterflies. British Museum (Natural History), London. 425 pp.

AITKEN, E.H. (1898): Migration of *Euploea core*. *J. Bombay Nat. Hist. Soc. 12*: 229-230.

BHAROS, A.K.M. (2000): Large scale emergence and migration of the Common Emigrant butterflies *Catopsilia pomona* (Family Pieridae). *J. Bombay Nat. Hist. Soc. 97*: 301.

BRISCOE, M.V. (1952): Butterfly migration in the Nilgiris. *J. Bombay Nat. Hist. Soc. 50*: 417-418.

BROWER, L.P. (1985): New perspectives on the migration biology of the Monarch butterfly, *Danaus plexippus* L. Pp. 748-785. *In*: Migration: Mechanisms and Adaptive Significance. Contributions in Marine Science, 27, Suppl. (Ed.: Rankin, M.A.). Port Aransas, Texas: Marine Science Inst., The Univ. of Texas at Austin.

BROWER, L.P. (1995): Understanding and misunderstanding the migration of the Monarch butterfly (Nymphalidae) in North America: 1857-1995. *J. Lep. Soc. 49*: 304-385.

BROWER, L.P. & W.H. CALVERT (1985): Foraging dynamics of bird predators on overwintering Monarch butterflies in Mexico. *Evolution 39*: 852-868.

CHATURVEDI, N. & S.M. SATHEESAN (1979): Southward migration of *Euploea core core* Cr. at Khandala, Western Ghats. *J. Bombay Nat. Hist. Soc. 76*: 534.

CHATURVEDI, N. (1993): Northward migration of the Common Indian Crow butterfly *Euploea core* (Cramer) in and around Bombay. *J. Bombay Nat. Hist. Soc. 90*: 115-116.

EVERSHED, J. (1910): Note on migrations. *J. Bombay Nat. Hist. Soc. 20*: 390-391.

FISHER, K.J. (1945): Four butterfly migrations in India and Ceylon. *Proc. Royal Ent. Soc. London (A) 20*: 110-116.

FRENCH, W.L. (1943): Butterfly migration (*Danais melissa dravidarum* and *Euploea core core*). *J. Bombay Nat. Hist. Soc. 44*: 310.

JOHNSON, C.G. (1969): Migration and dispersal of insects by flight. Methuen and Co. Ltd., London. 763 pp.

LARSEN, T.B. (1978): Butterfly migrations in the Nilgiri Hills of South India. *J. Bombay Nat. Hist. Soc. 74*: 546-549.

LARSEN, T.B. (1987): The butterflies of the Nilgiri Mountains of Southern India (Lepidoptera: Rhopalocera). *J. Bombay Nat. Hist. Soc. 84*: 291-316.

LARSEN, T.B. (1986): A dry season aggregation of danaine butterflies in Corbett National Park (Lepidoptera: Nymphalidae: Danainae). *J. Bombay Nat. Hist. Soc. 83*: 456-458.

PALOT, M.J. (2000): An aggregation of butterflies at Hyderabad, Andhra Pradesh. *J. Bombay Nat. Hist. Soc. 97*: 450-452.

PURI, G.S., V.M. MEHER-HOMJI, R.K. GUPTA & S. PURI (1983): Forest ecology: Vol. 1: Phytogeography and forest conservation. Oxford and IBH, New Delhi. 583 pp.

REUBEN, D.E. (1961): Migrational flights of the Common Indian Crow butterfly *Euploea core* (Cramer). *J. Bombay Nat. Hist. Soc. 57*: 673-679.

REUBEN, D.E. (1962): Migration of butterflies. *J. Bombay Nat. Hist. Soc. 58*: 815-816.

SCOBLE, M.J. (1995): The Lepidoptera: form, function and diversity. Natural History Museum and Oxford University Press, London.

SOUTHWOOD, T.R.E. (1962): Migration of terrestrial arthropods in relation to habitat. *Biol. Rev. 37*: 171-214.

WANG, H.Y. & T.C. EMMEL (1990): Migration and overwintering aggregations of nine danaine butterfly species in Taiwan (Nymphalidae). *J. Lep. Soc. 44*: 216-228.

WILLIAMS, C.B. (1927): A study of butterfly migration in south India and Ceylon, based largely on records by Mssrs. G. Evershed, E.E. Green, J.C.F. Fryer and W. Ormiston. *Trans. Ent. Soc. London 75*: 1-33.

WILLIAMS, C.B. (1930): The migration of butterflies. Oliver and Boyd, Edinburgh and London. 473 pp.

WILLIAMS, C.B. (1938): The migration of butterflies in India. *J. Bombay Nat. Hist. Soc. 40*: 439-457.

WILLIAMS, C.B. (1958): Insect migration. Collins, London. 235 pp.

■ ■ ■