Host plant based ecobiological attributes of a mimetic set of Nymphalids from Taki, North 24 Parganas, West Bengal: A comparative documentation

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ABSTRACT

Nymphalids, the largest lepidopteran family, is represented by altogether 19 species (37% of the total species abundance) from the present study site Taki, West Bengal, India, with multiple habitat profiles exposed to different anthropogenic interventions. Nymphalidae is reported to be with highest occurrence of mimicry, a naturally selected survival tool for lepidopterans. A nymphalid set, including a model [Plain Tiger: *Danaus chrysippus* (Linnaeus, 1758)] and a mimic component [Danaid Eggfly ♀: *Hypolimnus misippus* (Linnaeus, 1764)] is selected for studying the specific ecological and functional correlation among them in their natural habitat. Their comparative seasonal and habitat wise distribution shows co-existence, the unpalatable model species outnumbering the mimic, the vulnerable target, corresponding to the Batesian mimicry. The wing morphology pattern is significantly shared, though the larval and adult host plants are exclusive and species specific. The year long field observation indicates the existence of considerable degree of similarity with respect to the ecobiological details, like flight pattern, mudpuddling, resting, basking and alternative resource utilisation activities. Species specific unique foraging attributes is observed. Being potential pollinators, they play key role to maintain the wild floral diversity at landscape level. The study bears conservation value towards these nature's artwork, acting as the biotope indicator.

1. INTRODUCTION

In nature, mimicry offers a provision to the vulnerable species to gain an evolutionary advantage by imitating the other one, which have become harmful to their natural predators with their inherent protective properties. Mimicry involves reciprocating signals by the mimic to the receiving organisms, be it predators or other natural enemies, mostly from the arthropods (spiders, ants), reptilians and avian individuals, whose behaviour the mimic aims to alter. Batesian mimicry is the similarity of a palatable, profitable prey (the 'mimic') to an unpalatable, unprofitable species (the 'model'). Generally, the Batesian mimicry becomes operative when a chemically defended species advertises their toxicity and a second species, lacking any form of defence, copies the warning colours of the previous one. The trait of adaptive wing colouration among butterflies includes sexual selection, crypsis (camouflage) and mimicry.

It is common among tropical butterflies that, groups of species sharing a similar colour pattern, often form 'mimicry rings' (Bates 1862; Gilbert 1983; Brower 1964; Joron1998; Mallet and Joron 2000; Srygley 2003). Present study deals with species belonging to orange complex, exhibiting female limited mimicry. Interestingly, there exists a dynamic interplay between ecology and evolution within the components of mimetic sets. For understanding the community structure and interactions of constituent mimics and models co existing in a particular habitat, analysis from both the autecology and the evolutionary point of view is essential (Elias *et al.* 2008). Besides physical similarity, mimicry often extended to behaviourally identical activities, providing enhanced protection against predation. Locomotory response is important for prey to avoid predatory encounter. Generally, palatable species are reported to fly fast and erratically to confuse the predatory scanning of the flight path and ultimately leading to reduced frequency of successful predatory attacks. Contrastingly, unpalatable species or models tend to fly slowly and regularly which mediates predatory recognition and toxicity influenced avoidance. Models' wingbeats with slower angular velocity compared to that of palatable species may enhance the imprinting about the colour signal to the predators. In butterflies, palatability and flight velocity are highly correlated, whereas only weak correlation exists between palatability and flight path (Kitamura and Imafuku, 2015).

In fact, not much is documented about the actual flight patterns of the Batesian mimics. In the present study, horizontal flight range and vertical flight heights are explored to be used as a qualitative estimation of their behavioural correlation. Seasonal as well as spatial co-occurrence of the members of the mimicry-complex is dependent on floral resource availability. As well, survival and uninterrupted distribution of the mimetic groups acting as potent pollinators of native plants play the key role in the conservation of the wild floral distribution (Kearns and Inouye 1997). Thus, butterflies are considered as focal species of conservation in several areas of world (New 2011). A survey was aimed to document the prominent mimicking butterflies found at Taki, North 24 Parganas, West Bengal, as there is no such record till date (Ghosh and Saha 2016a,b). It is comprised of a multiple land usage pattern thus creating fragmentation of the native floral distribution including various nectar and larval host plants nurturing and sheltering the native butterfly populations both in larval and adult life. Nymphalids, the 'brush-footed butterflies' represents the largest lepidopteran family, with

highest number of mimics. In the present study, Batesian mimicry is displayed by a mimetic set, where, the model is Plain Tiger, *Danaus chrysippus* (Linnaeus, 1758) and the mimic is Danaid Eggfly female, *Hypolimnus misippus* (Linnaeus, 1764). The minute field observation throughout a year long study period revealed a dynamic interplay between the ecology and evolution of the constituent species of the mimetic set. The aim of the present study is to document the seasonal abundance, habitat distribution of the model and mimic components, detecting about their host plant range and reporting the ecobiological details like foraging pattern including landing and nectaring details, courtship profile, flight features on a comparative basis. The underlying objective of such detailed ecological study is to find out how intensively and delicately the mimetic partners are inter related with respect to their resource usage pattern. The information may turn out to be helpful also for their conservation as potential pollinators and nutrient recyclers in their native landscape.

Study sites

Sampling Site selected is **Taki** (22º59′ N and 88º92′ E), a small semi urban habitat of 13 sq. km, on the border of Bangladesh, situated at the farthest end of the North 24 Pgs. standing on the bank of river Ichhamati, with an average elevation of 5 meters (Ghosh and Saha, 2016a).
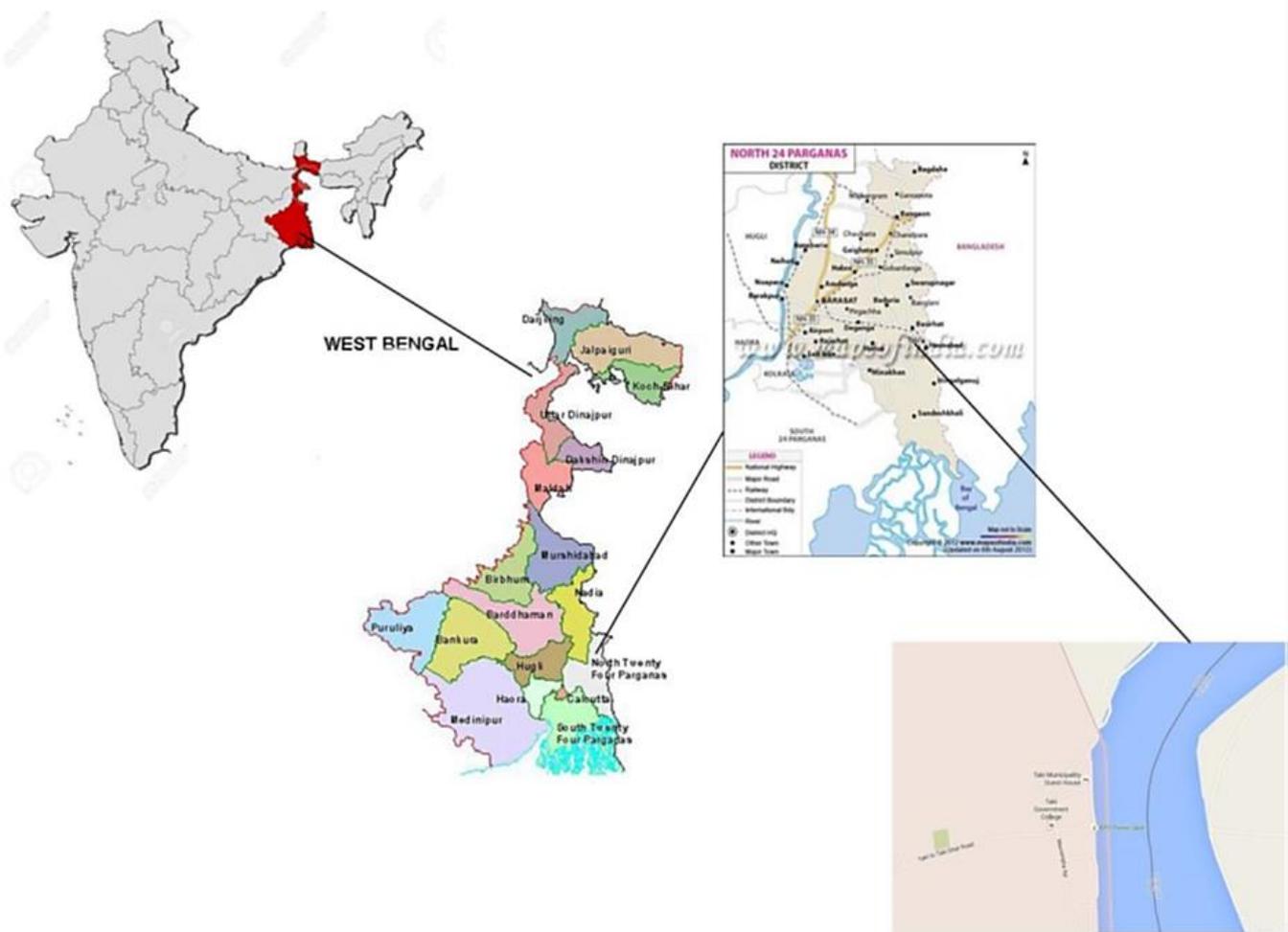

Fig. 1A. Studysites

Fig. 1B. Studysites

Fig. 1C. Studysites

2. EXPERIMENTAL

Duration of Study

March 2015 to February 2016

Sampling Period

Field study is performed for once in a month; thrice in a day: 8-10 am (MOR), 11 am - 1 pm (DAY), 2-4 pm (AFTN). Division of seasons (summer, monsoon, post monsoon and winter) are based on the variation in the rate of precipitation and temperature.

Sampling Techniques

Seasonal availability is documented by presence-absence scoring method. Four randomized transect walks for 12 minutes during each survey period through the study areas following "Pollard Walk" method (Pollard 1977; Pollard and Yates 1993) are performed with necessary modifications. Fixed transect routes (250m long and 5m wide) are followed for a particular habitat patch.

Approximately a uniform pace is maintained at each study site. Prominent host plant trails are selected on the basis of >70% of visiting frequencies of the respective butterflies. Nectar and non-nectar host plants are randomly selected from the same transect. 5-10 numbers of each host plant species, depending on availability are focussed. Stationary observation time is fixed for 15 minutes per survey period at three suitable locations to watch host plant-based activities for assuming the visiting profile by butterfly to host plant. Ten frequently encountered and easily observable landing sites are selected for individual host plants.

The number of butterflies encountering each host plant and their behavioural specificity are temporarily scanned and reported. Microhabitat details are also noted. Duration of specific behaviours is noted with the help of a stopwatch. Encountered butterflies are identified using suitable keys (Wynter-Blyth, 1957; Kunte, 2000; Kehimkar, 2008; Varshney and Smetacek, 2015). Species are noted along with the date, location of encounter. Specific host plants are identified and recorded (Mukherjee, 1981; Kehimkar, 2000).

Minimum distance for minute observation is constantly maintained to be 1.5 metres between the observer and the host plants. Binoculars are occasionally used for observing high and distantly flying individuals. Wing lengths measured with a ruler to the nearest point from the base of the wing, near articulation point with the thorax to the most distal part on the wingtip.

Study Specimen

Batesian members from an orange mimicking complex, common to India and other parts of Asia, south to Himalaya are selected; *Danaus chrysippus* (Fig. 2a) - the model and *Hypolimnas misippus* (Fig. 2b) -the mimic. They commonly occur in open woodland, grassland, wild flowered bushes, gardens, agricultural associated lands and wetlands.

Fig. 2a. Study specimens
Danaus chrysippus (Linnaeus, 1758)

Fig. 2b. Study specimens
Hypolimnas misippus (Linnaeus, 1764)

Host plant selected

Lantana camara, providing the overlapping resource pool to both the mimic and the model; as for both the species visiting frequency to this particular host plant is >70% (Fig. 2c).

Fig. 2c. *Lantana camara* L.

3. RESULTS AND DISCUSSIONS

Mutualistic interactions along different ecological axes lead to the convergence in physical appearances like wing pattern and colouration as well as behavioural attributes including basking, locomotor activities like horizontal and vertical flight, alternative resource utilization patterns and mudpuddling (Tables 1, 5, 6; Figs. 2a & b, 10, 11a & b, 12a & b). Interestingly, the unique species-specific features of courtship flight (Table 4) and foraging (nectar and pollen gathering) profile ensure their survival fitness by acting as the bypass measures for outweighing the competition load and shared resource utilization issues (Table 3; Figs. 7, 8, 9). Microhabitat occupancy details (Figs. 4, 5, 6) also vary for individual species. Polyphagous range of nectar plant coverages and multiple larval host plant dependencies are significantly documented and interestingly certain level of host plant overlapping is reported during the study (Table 2). Thus, such dual pattern of convergence and divergence provides a scope of comparative ecobiological analysis for these two constituents of Batesian mimicry sets.

Our study species come under the Tiger group. Figs. 2a & b and Table 1 detail the morphological relatedness of the model and mimic species in the present study. Significant level of morphological similarity shared by the female of *Hypolimnas misippus,* the mimic and *Danaus chrysippus*, the model. Every exposure of the distasteful model butterflies to the invertebrate and vertebrate predators cumulatively help intensify disliking and avoidance of the predator's mind to the particular colour or pattern of the target species by repeated imprinting. The predatory avoidance is resulted due to their physiological discomfort (like stronger heart beats, retching, vomiting etc.) caused by the cardenolides derived from their host plants during their phytophagous larval stages (Brower 1964; Brown 1984; Seigler 1998; Schulz *et al.* 2004).

The mimics share the derived benefit by evolving similarities in wing morphology and behavioural patterns like flight or resting characteristics (Mallet and Gilbert 1995).

Table 1. Distinguishing morphological particulars of model and mimic components.

Plain Tiger *(Danaus chrysippus)*	Danaid Eggfly *(Hypolimnas misippus)* female
• 70-80 mm wingspan • upper side reddish brown with black border and black apex • dark brown in the upper half with white spots in the black area • with variable numbers of white spots in the costa and apex • with four small black spots around the cell and a pouch in males • three small black spots are there. Underside of hindwing is dull orange in females • White streaks are lines than points over the wing margins • In the middle portion of the wing three or four black drops comparatively smaller in size • On apical part of forewing chocolate coloured stripes	☐ 70-85 mm wingspan ☐ Body black, thorax with white spots ☐ Wavy wing margin ☐ The upper side of wings are brownish orange ☐ More wavy wing margins marked with prominent and wide white margins on black border ☐ On anterior part of hindwing, a prominent black spot ☐ On apical part of forewing prominent black stripes

Fig:3. Seasonal abundance profile
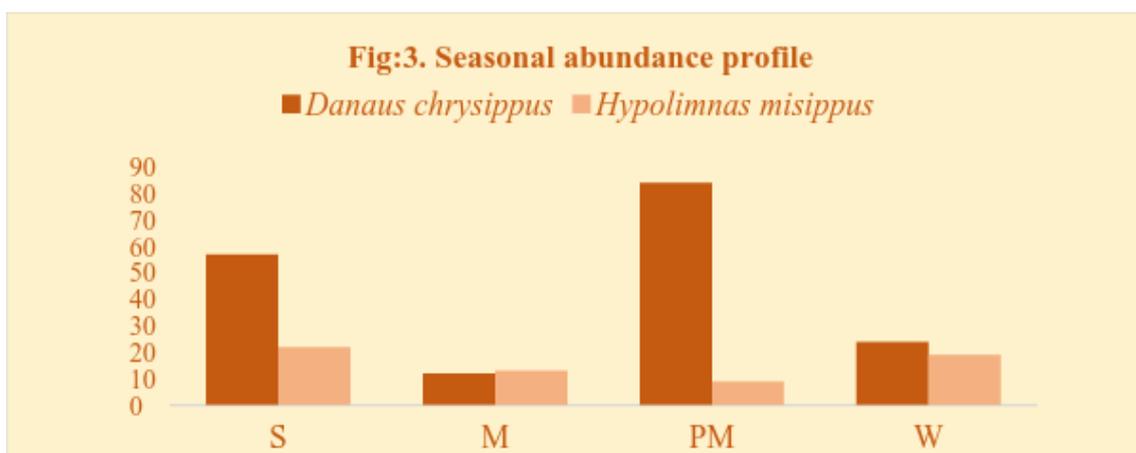
S (Summer) - March, April, May; **M** (Monsoon) - June, July, August; **PM** (Post Monsoon) - September, October, November; **W** (Winter) - December, January, February

Figure 3 depicting the seasonal abundance profile and comparative seasonal distribution, shows the co-existence of models and mimics. Significantly, the model species (the unpalatable one, toxic to predators) found to outnumber the mimic one (the vulnerable target of the predators), throughout the year, following a primary condition for Batesian mimicry. Maximum numbers of model species are reported during post monsoon and the mimics are reported with peak abundance during summer and winter. Lepidopteran abundance seems to be overlapping with their host plant phenology (Yeargan and Colvin 2009).

Tables 2a & b show the range of nectar, non-nectar and larval host plant occupation by both the species. Driving factors behind the choice of food plants by both the components of the mimetic set includes presence of predators, larval gregariousness, egg clustering. Multiple larval host plants are selected by both the species for secured oviposition as dispersing the eggs on different host plants may prevent the attack of parasitoids and predators (Beccaloni 2008). The components of a mimetic set sharing morphological similarities often found to interact diversely when interacting along multiple ecological axes (Elias *et al*. 2008). Such type of mimetic butterflies may become preferable objects for the study of community ecology (Papageorgis 1975; Johnson and Stinchombe 2007). Lepidopteran activities known to be correlated with different interdependent environmental factors like temperature, relative humidity, exposure of the host plants to direct sunlight (De Vries *et al*. 1999). Shape and structure of various parts of the floral units and the flower colour are few of the key factors determining the butterfly visits to the nectar plants (Peterson 1997; Penz and Krenn 2000).

Table 2. Nectar plant preference shown by the members of the mimetic set

Table 2a. Nectar plant preference shown by *Danaus chrysippus*, the model

Host Plants	Serves as	Family	Type	Habit and Habitat	Avg. height from ground level	Blooming period	Description of the floral unit
Asclepias curassavica	Larval Host plant	Asclepiadaceae	sub shrub	moist loving, orchard, damp patches	1.5 m	S, M, PM, W	yellow; 1-1.5cm across
Calotropis gigantea	Larval Host plant, Nectar plant	Asclepiadaceae	Shrub	open, arid region, railway trackside, roadside	1.5-3 m	S, M, PM, W	pale violet; 4cm across
Lantana camara	Nectar Plant	Verbenaceae	invasive evergreen shrub	railway tracks, river bank, uncultivated lands, roadside vegetation patches	2-2.5 m	S, M, PM, W	small white to yellow, orange to red, pink to violet; tubular; 4mm across

Tagetes erecta	Nectar Plant	Asteraceae	annual herb	garden, cultivated land; both wild and plantation variety	1 m	W	yellow, orange flower; clustered, both ray and disc florets
Crotalaria retusa*	Larval host plant and Nectar plant	Papilionaceae	erect, annual herb with more or less woody stems	Riverbank, marshlands, open fields, grassland, waste places and fields	0.6-1.2 m	S, M, PM, W	yellow; 2-3 cm across

*bruised and dried plant parts are very much attractive to milkweed butterflies like tigers in present study as a source of pyrrolizidine alkaloids (Seigler 1998)

**Table 2b.** Nectar plant preference shown by *Hypolimnas misippus,* the mimic.

Host Plant	Serves as	Family	Type	Habit and Habitat	Avg. height from ground level	Blooming period	Description of the floral unit
Abelmoschus manihot ssp. Tetraphyllus	Larval Host plant	Malvaceae	perennial shrub	degraded land, roadside	2.7 m	M, PM	yellow; 5-7.5 m across
Portulacea oleracea	Larval Host plant	Portulacaceae	low growing invasive succulent weed herb	Disturbed areas, agricultural lands, plantations, railway tracks, roadsides	0.15-0.3 m	S, M, PM, W	yellow; 8 mm across
Lantana camara	Nectar plant	Verbenaceae	invasive evergreen shrub;	railway tracks, river bank, uncultivated lands, roadside vegetation patches	2-2.5 m	S, M, PM, W	small white to yellow, orange to red, pink to violet; tubular; 4mm across
Cosmos bipinnatus	Nectar plant	Asteraceae	Annual shrub	Roadside vegetation, nearby waterbodies	0.3-1.2 m	M, PM, W	Pink, purple; 0.05 m across
Crotalaria retusa	Nectar plant;	Fabaceae	erect, annual herb with woody stems	grassland, along rivers, waste places and fields,	0.6-1.2 m	S, M, PM, W	Yellow, 0.01-0.02 m across

From the present study, divergence is reported in case of habitat preference (Fig. 4), phototropic tendencies (Fig. 5), differential occupancy of perching sites *i.e*. landing pads on the host plants. (Fig. 6), host plant preferences, qualitatively estimated by landing quotients (Fig. 7), foraging exclusivity, represented by landing vs. nectaring ratios (Fig. 8), host plant dependence estimated by nectaring duration (Fig. 9), food resource locating behaviours (Table 3) and mate pursuit flight features (Table 4).

This divergent ecobiological trend is helpful in skipping or avoiding the competitive pressure and nutrient sharing hazards (Mallet and Joron 1999). Adaptation to different ecological niches may turn as a leading factor for speciation (Estrada and Jiggins 2002), whereas mutualistic interactions can drive convergence along multiple ecological axes, outweighing both phylogeny and competition in shaping up the community structure (Rowland *et al.* 2007). Adaptation to different sensory environment results in convergence of resource utilization preferences that include a range of behavioural gradient (Vane-Wright 1978) as reported in the present study in case of basking profile (Fig. 10), horizontal (Figs. 11a & b) and vertical (Figs. 12a & b) flight pattern and consumption of alternative nutrients (Table 5), mudpuddling activities (Table 6). Such type of ecobiological convergence tendencies act like adaptive keys promoting the survival fitness by sharing the risk of predatory attack.

Figure 4 represents the habitat preference of both the species. Almost equal proportion of individuals (18%) from each species were found to occupy the wet habitats particularly near the riverside bushes sheltering local host plants.

Danaus chrysippus, the model prefers the dry habitats most (68%), particularly the roadside wild flowered host plants and on the railway trackside vegetation. *Hypolimnas misippus* is most commonly available at the humid region (53%) particularly the agricultural waterbodies and in the aquatic patches interspersed throughout the mangrove plantation. The model and mimic populations are not distributed randomly throughout the habitats like substratum or understorey levels, canopy layer or open lands. Their vertical distribution appears to be controlled by species specific preferences for flight and perch heights. Their horizontal and spatial distribution is sometimes noted to be associated, even within apparently homogenous habitat, e.g.., same host plant bushes, driven by external factors like light intensity and moisture content. Some roles may be played by interspecific pheromones as reported by (Poole 1970). Vegetational composition and environmental characteristics may also act as important factors.


Fig:4. Habitat preference profile (based on percentage of occurence)
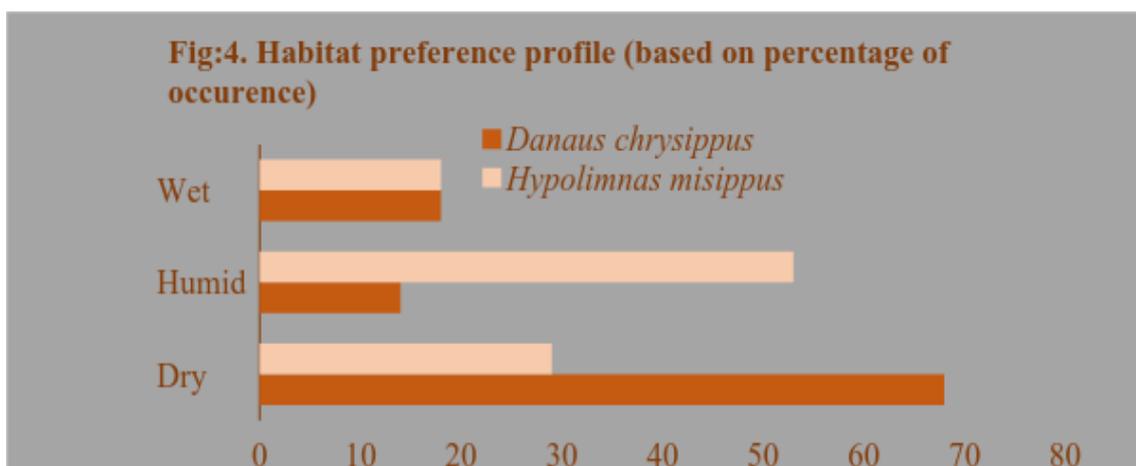
Dry - grassland, open shrub land, roadside, railway trackside

Humid - agricultural waterbodies, marshland, mangrove plantation

Wet - riverside, aquatic bodies

Fig. 5 depicts their phototropic tendencies. *Hypolimnas misippus* shows the scotopic preference (74%) whereas *Danaus chrysippus* are reported to prefer for heliotropic (68%) nature. Shady understorey level is frequently availed by the mimics reached by typical vertical droppings.

Fig:5. Phototropism (on the basis of percentage of occurence)
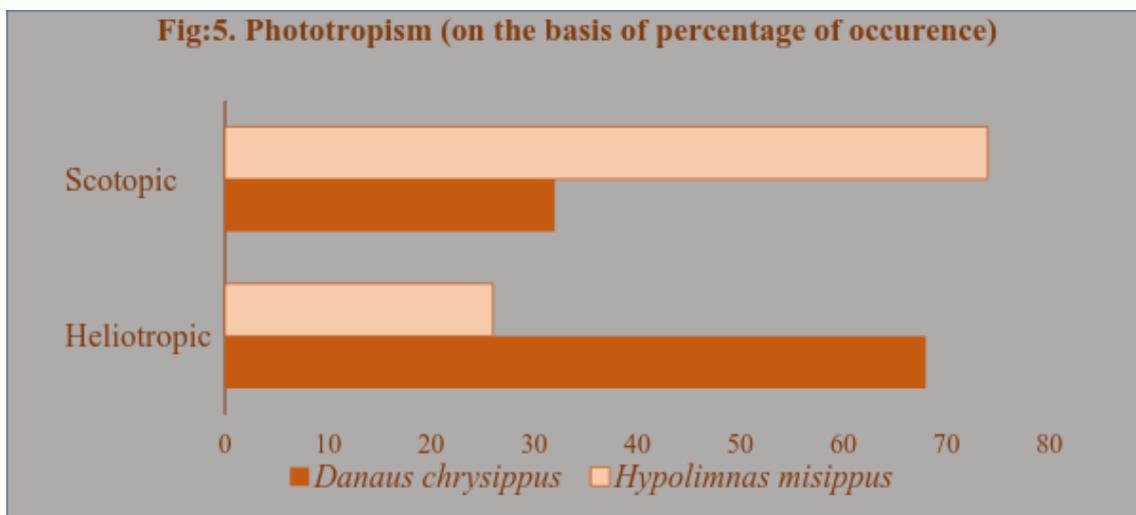
Scotopic: observed at shady habitat patches (substratum level, understorey layer, under surface of leaves, cryptic sites); more commonly during afternoon

Heliotropic: observed at exposed surfaces, ground layer, over leaf or stem parts; more common during morning and day time span.
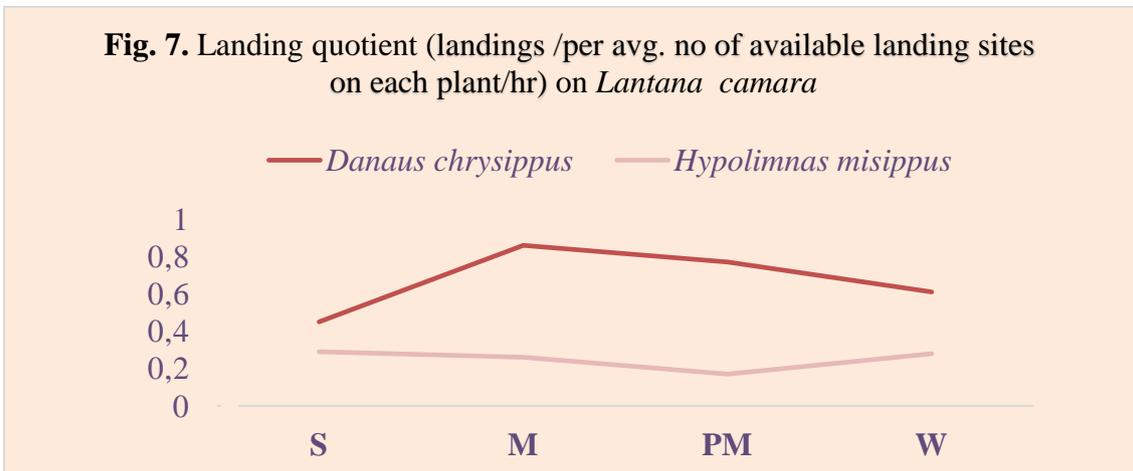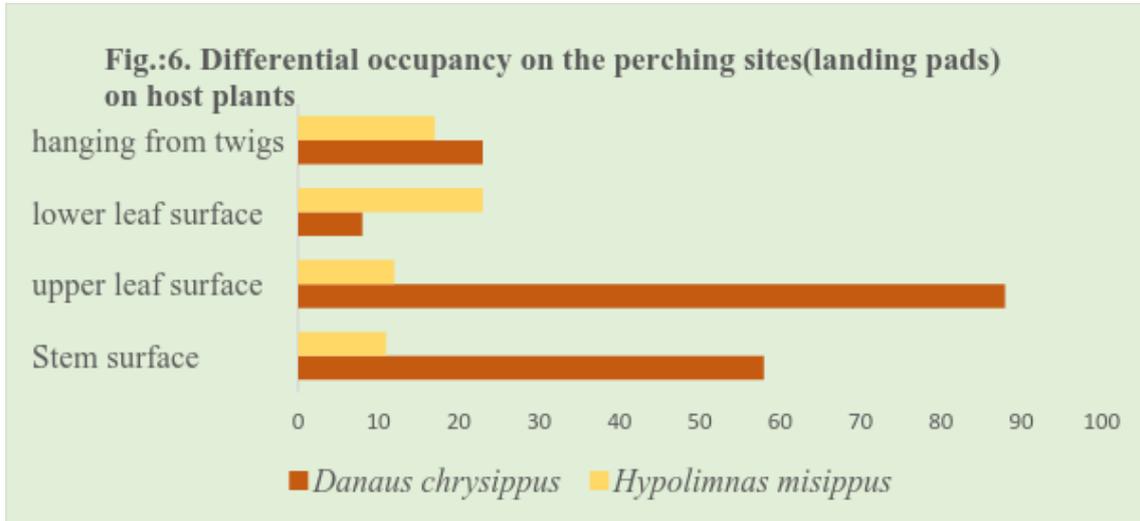(Observation at rest or during short term flights)

Differential occupancy on the perching sites i.e. landing pads on host plants are presented in Fig. 6. Perching is performed by wings folded together over their backs. Proximity between model and mimic is maintained during perching, models avail exposed surfaces whereas mimics tend to occupy somewhat hidden places.

But during diurnal resting, the butterflies are found to spread wings near substratum or ground level both reported to prefer hidden sites and proximity not necessarily maintained always. Perching height and intensity are related to light intensity and humidity (Joron 2005).

They are commonly found with almost similar resting postures during peak afternoon hours holding the wings together over their back when perching on a leaf.

Figure 7 illustrates the comparative profile of the landing quotients as a qualitative assessment indicator for host plant preference. Floral units during blooming seasons and other suitable plant parts like stem, leaves, fruits, hanging ends of plant parts are commonly opted as landing platforms by both the species. Both contacts and stoppages on the hostplants are considered as "landings". For *Danaus chrysippus,* it reaches the peak (0.86) during monsoon

and becomes lowest during summer (0.45). For *Hypolimnas misippus* almost a uniform value (around 0.28) is maintained throughout the year with a slight drop down during post monsoon (0.17).
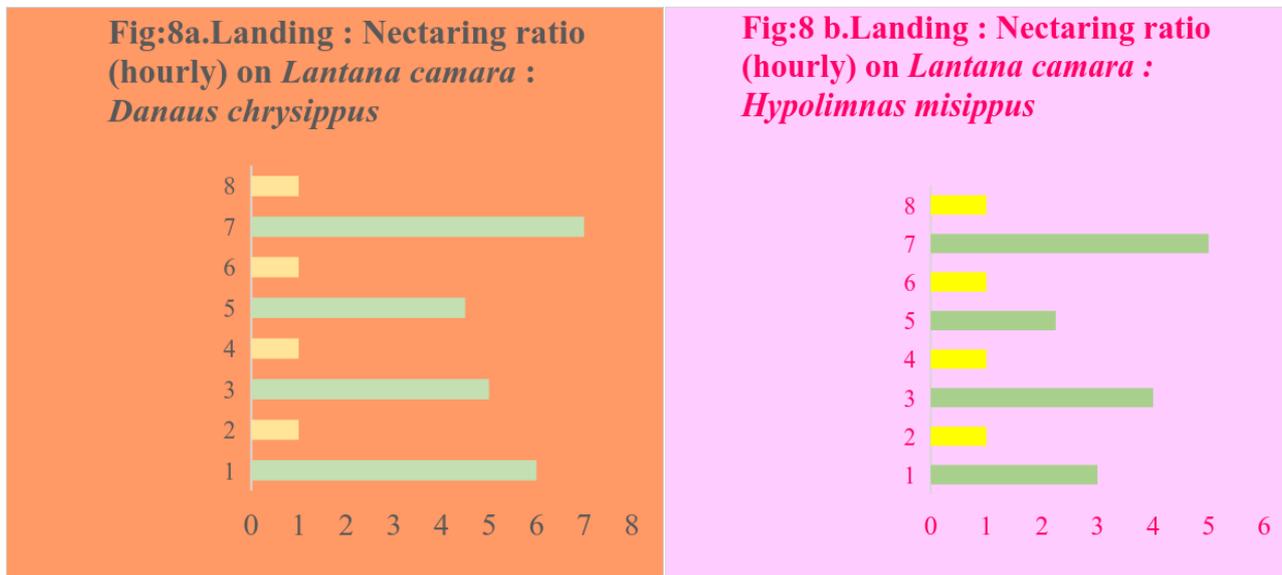

Fig.:6. Differential occupancy on the perching sites(landing pads) on host plants

■ *Danaus chrysippus* ■ *Hypolimnas misippus*

Fig. 7. Landing quotient (landings /per avg. no of available landing sites on each plant/hr) on *Lantana camara*

── *Danaus chrysippus* ── *Hypolimnas misippus*

Landing: both contacts and stoppages on host plants are considered

Landing platforms: floral units (blooming seasons) or other suitable parts (stem, leaves, fruits)

Landing quotient: a qualitative assessment indicator for host preference

Figs. 8a & b represent the landing vs. nectaring ratio profile for the particular host plant by the model and the mimic respectively. Host plants were selected almost of similar heights to minimize the variables that may affect the number of landings. This landing vs. nectaring ratios significantly addressthe overall host dependence for nutrients and other resources by these butterflies. For *Danaus chrysippus,* maximum level of host dependence is reported during post monsoon (landing vs nectaring ratio is 4.5:1) and minimum during winter (landing vs nectaring ratio is 7:1). For *Hypolimnas misippus,* almost a similar trend is followed, though the

dependence level varies (in post monsoon landing vs nectaring ratio is 2.25:1 and during winter it turns out to be 5:1).

Fig:8a.Landing : Nectaring ratio (hourly) on *Lantana camara* : *Danaus chrysippus*

Fig:8 b.Landing : Nectaring ratio (hourly) on *Lantana camara* : *Hypolimnas misippus*

For both the species nectaring frequency remains highest during the morning hours throughout all the seasons

Common food source locating behaviours:

Indirect procurement

- Circling (upon passing an attractive food source circling once or twice around the food source)
- hovering (along the food item before alighting)
- landing (without reaching directly the food source lands a few cms away and walks to the food source
- to reach the actual 'food point' after landing

Direct procurement:

- food gathering by direct descent through direct involvement of antennal and proboscis parts (e.g. nectaring)
- during this process, both for the model and mimics the wing flexing patterns remain similar, but the antennal waving is markedly different.

In Table 3 few specific attributes about food resource locating behaviours are mentioned (Estrada and Jiggins 2002). For indirect nutrient item procurement both the model and the mimic appear to show few common behavioural features like circling, hovering, landing, walking etc., though the intensity of executing such measures varies to some extent. For direct procurement, both the species almost act similarly.

Table 3. Food resource locating behaviour: Indirect procurement.

Butterfly species	Common host plant based food source locating behaviours			
	Circling	hovering	landing	Walking
Danaus chrysippus	+++	+++	+++	+++
Hypolimnas misippus	+	+++	++	+

Figure 9 documents the nectaring profile on seasonal basis.Nectaring duration recorded from the moment of dipping butterfly proboscis in the flower corolla till the moment of its withdrawal. It acts as a measure of nutritional dependence over their nectar host plants and also as an indirect assessment value about their pollination efficiency. Average nectaring durations for at a stretch over a single event are recorded. It is maximum for *Danaus chrysippus,* during daytime at winter months (56 secs/single floral unit/single encounter/hr). For *Hypolimnas misippus,* maximum duration is reported during the day time of summer and post monsoon and during the afternoon of summer (25 secs/single floral unit/single encounter/hr). The nectaring span is maintained at an individualistic manner for both the species.

Fig:9.Avg. nectaring duration/single floral unit(sec.s)/single encounter/hr at *Lantana camara*
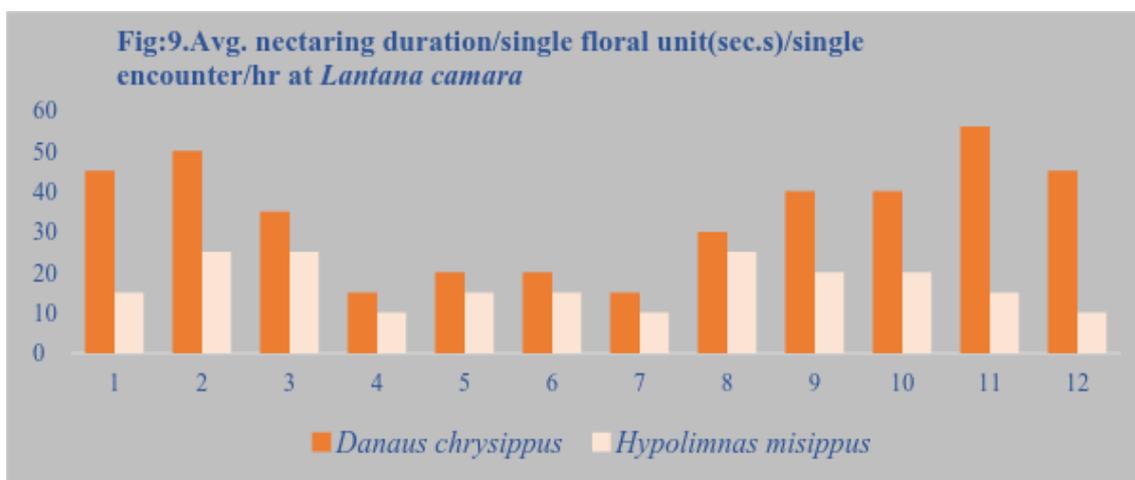
Figures 7, 8a & b, 9 and Table 3 collectively may give a glimpse about their overall foraging pattern over the particular host plant on seasonal basis, which is manifested in an exclusive and species-specific manner. Foraging is continued for both the species intermittently throughout the diurnal phases to the open areas like grassland, railway tracks, near riverbanks. Frequency of floral visits particularly becomes prominent during early morning and late afternoon. General metabolic profile and utilization pattern of flight muscles may be the underlying causes for such type of foraging periodicity.

Feeding aggregation, formed by a temporary clumping of numbers of individuals, include both the model and mimic species visiting and scanning to a single host plant at a time. Most of the times the models outnumber the mimics in such association groups and may lead to

temporary competition due to nectar limitation and often the confrontation is resolved by finding out a newer resource. The conspecific scanning individuals are found to get disturbed at the arrival of newer individuals than those from different species. With respect to the model and mimic species, interspecific cooperative attraction towards food sources is significantly observed. Olfactory signalling may be reinforced by prior visitors from either species. Such behavioural trend might become useful for utilizing patchy resources generated prevalently as an outcome of habitat fragmentation or isolation (Collnette and Talbott, 1928).

In their natural habitats both the species are found basking, sitting open winged on vegetation or substratum level. Figure 10 speaks of assessment about the seasonal variation of their basking duration, which turns out to be maximum both for *Danaus chrysippus* and *Hypolimnas misippus* during the day time of monsoon (65 secs and 55 secs respectively) and lowest (15 secs) during the monsoon afternoon.
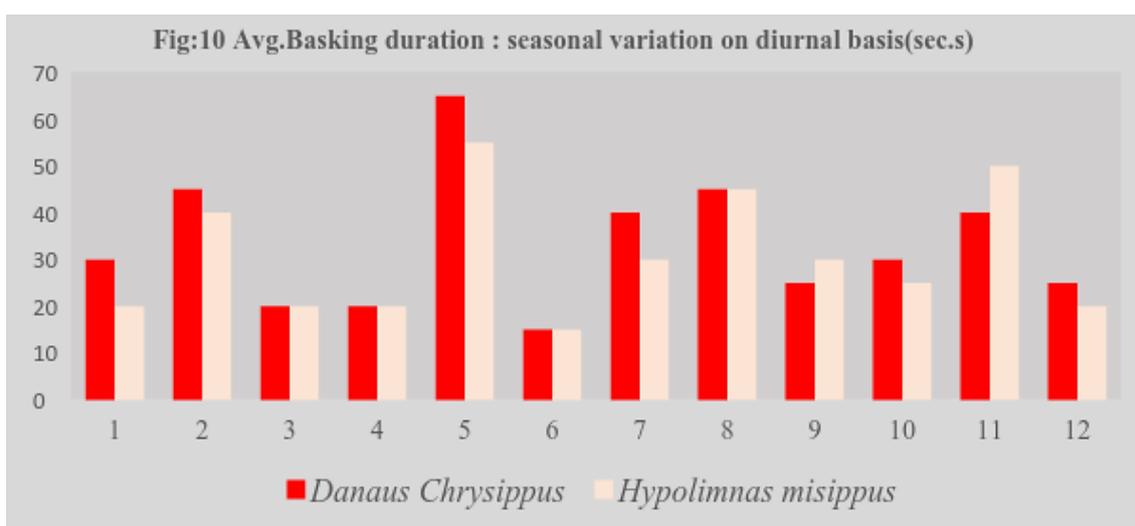
Figures 11a & b and 12a & b attempt to make a qualitative representation about their flight pattern and provide idea about their habitat range maintenance and resource gathering activities in general. Though aerial displays make them highly vulnerable to predation, lepidopteran flight may be categorized according to different functional aspects like searching flight to locate the nutritional resources or appropriate egg laying site, patrolling flights with the scanning purpose, chasing flights, often displayed by males to maintain territory and courtship (including the contesting) and ovipository flight.

The horizontal flight generally encompasses patrolling, chasing and foraging features. Specific vertical flight patterns are observed during foraging, territory maintenance (chasing) etc. Lacking any specific defensive measures against their enemies, flight becomes a selective tool for protection against their natural threats. Our study concentrates on the horizontal and vertical level flight patterns observed during regular foraging on host plants. *Danaus chrysippus* (Figs.10a & b) are significantly found to avail both the 'near' (48%) and moderate (42%) range, when the average horizontal at a stretch flight range is considered. As considered, the average vertical flight height, both for *Danaus chrysippus* and *Hypolimnas misippus* (Fig. 8a), the ground level is found to be most suitable (63% and 62% respectively) followed by that of the bush level (26% and 25% respectively).

Fig:11a. Horizontal flight range(at a stretch)(m) of *Danaus chrysippus*

Fig:11b. Horizontal flight range(at a stretch)(m) of *Hypolimnas misippus*
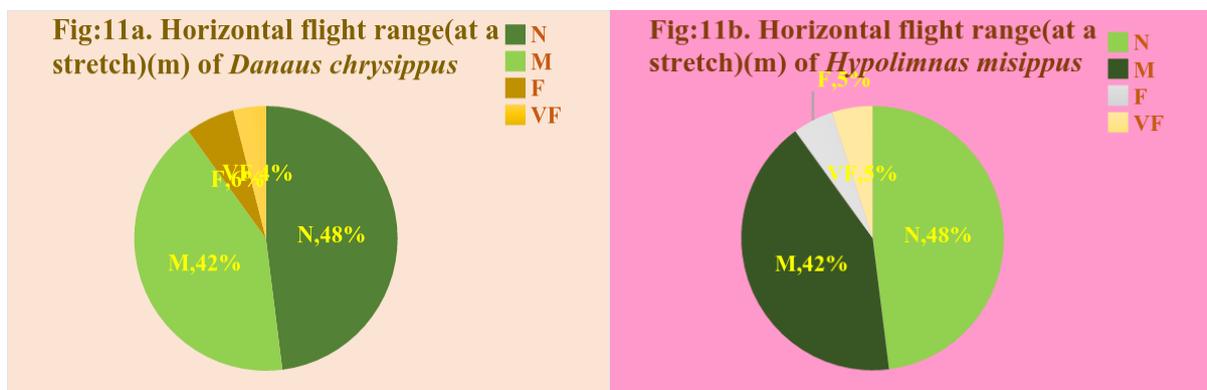
Horizontal Flight range
Near (N) - 1.5 m from observation point; **Medium (M)** - 4.5 m from observation point
Far (F) - 7.5 m from observation point; **Very Far (VF)** - >7.5 m from observation point

Fig:12a. Vertical flight height(m): *Danaus chrysippus*

Fig:12b. Vertical flight height(m): *Hypolimnas misippus*

Vertical Flight - height:
G - Ground level (Ground – 1.5m); **B - Bush level** (Ground-3.5m)
UB - Upper Bush level (Ground – 5m); **C - Canopy level** (Ground to 7.5m);
UC - Upper Canopy level (Ground to >7.5 m)

Aerial hawking of birds are the main predators of flying butterflies. When birds notice a butterfly from long distance, they must make a decision to attack or not within seconds before it flies away. At a distance, birds can differentiate the characteristic flight pattern but not the colour pattern. Thus, characteristic flight pattern becomes the factor that renders the prey 'conspicuous' and becomes a useful cue that signals profitability or unprofitability. When a chromatically mimetic butterfly mimics the flight pattern of its model well, it is difficult to differentiate at a distance. On the other hand, when close to the butterfly, they can be differentiated as mimics or their models by their colour pattern and morphological characteristics.

Thus, at a distance from predators, unpalatable and mimic species may gain protection against aerial predation by their conspicuous flight pattern rather than by their coloration. Flight pattern may thus function as a primary defence, like aposematic coloration, for unpalatable

species. Nonlinear and irregular flight is reported as one of the defence strategies of butterflies against aerial predation, as it functions like a warning signal indicating difficulty of capture and associated prey unprofitability.

In contrast, the linear and regular lepidopteran flight remain characteristic for unpalatable butterflies and their mimics increasing the prominence of effect of their warning colouration to enhance learning and avoid confusion with palatable butterflies and decreases the chance of mistaken attacks by potential predators (Kitamura and Imafaku 2015). A sluggish behaviour may be associated with the model's warning coloration signalling for the prey's defensive qualities to potential predators (Srygley 1999; Hatle *et al.* 2002; Sherratt and Beatty 2003).

Another explanation is also there stating that the flight pattern functions as an avoiding strategy, rather than as a warning signal. Avian attacks generally take the motion of prey into consideration, so a lepidopteran flight pattern makes the flight path unpredictable at least to some extent and make it difficult for the birds to catch them. On the predatory encroachment, distasteful model butterflies get defended by toxic or nauseous chemicals. On the other hand, the Batesian mimics depend on escape flight to safeguard the predatory attack. Existence of behavioural mimicry in flight paths has been evidenced in earlier studies where the flight paths of mimetic females and non-mimetic females of a Batesian intraspecific polymorphic butterflies were different from each other and that of mimetic females was not significantly different from that of their models (Chai and Srygley 1990; Srygley 1994; Srygley 2004).

The avian attacks are proven not to be the primary selective force leading to evolution of mimicry and aposematism in butterflies, because birds are able to recognize the profitability of prey by their flight pattern as well as their colour pattern. Birds always do not attack only the flying butterflies but also those landing on plants, especially in the early morning. They come into action earlier than butterflies, which enables them to approach butterflies closely with time enough to differentiate them by the colour pattern.

It may be that aposematic coloration evolves for protection against predation in the early morning, whereas a characteristic flight pattern evolves for protection against predation in the daytime. Insectivorous birds tend to attack from a position level with the prey, and thus vertical movements of the potential prey would be easily recognized by the attacker. The predator attacking frequency increases with lesser mobile phase and often act as a stronger driving force (Kunte 2009).

The ultimate factors leading the lepidopteran flight patterns include the energetic cost, wing and body morphologies. Flight in warning-coloured mimetic butterflies and their distasteful models is costlier than in closely related non-mimetic butterflies. Slow flight acting like a signal of distastefulness, may serve as a handicap, still making the signal reliable to the predators (Zahavi 1993). Alternatively, slow flight may be beneficial by reducing the energetic cost of flight relative to that of palatable species. In this instance, slow flight appears to be a conventional signal (Guilford and Dawkins 1993).

The increased cost is the result of differences in both wing shape and kinematics. As per the handicap principle, the models are efficient of meeting the aerodynamic power requirements for flight, and the Batesian mimics or 'signal cheaters' possess neither a higher energetic cost nor the sufficient reserves (in form of abdominal lipid storage) utilizable to meet that cost. Batesian mimics and their models slow the angular velocity of their wings to enhance the colour signal but at an aerodynamic cost. Moreover, the design for flight in Batesian mimics has an additional energetic cost over that of its models.

The added cost may cause Batesian mimics to be rare, explaining a general pattern that Bates first observed. In nature, undisturbed Batesian mimics are reported to fly slowly imitating their models but on attack, they typically adopt the more rapid and erratic flight behaviours like other palatable species. This strategy may act as a jack-of-all trades in escape design that results in less-than-optimal design and greater aerodynamic costs for flight. Ultimately, an energetic cost to aposematic signals may be imposed on the palatable Batesian mimics channelizing a selection force against the evolution of the signal. The added cost for cheating may be a factor responsible for the uncommonness of the Batesian mimicry (Srygley 2003). The existence of behavioural similarity in horizontal and vertical flight pattern of a Batesian mimetic butterfly set is evidenced by this study. Specific and unique escape flights are observed for model and mimics. The models fly away at same level of the disturbance or suddenly direct upward to reach canopy levels, whereas mimics tend to fly downwards to hide inside thick vegetation. Both exhibit a similar patterned navigation flight during crepuscular, particularly during the nesting period.

The information gathered on the basis of yearlong field based observations is represented in Table 4, from which it is quite evident that the mate locating behaviour are unique as well as specific for the model and the mimic species. Pre-pursuit active and passive mate locating behavioural features are driven by mostly visual and secondarily olfactory stimuliin these diurnal pollinators. Passive mate locating behaviour includes simply perching and waiting for appropriate mate to fly by; display perching exhibited with wing opening and typical movement of wing and antennae during waiting for mate and typical androconial display and wing folding at certain typical angles (120-180°) and patrol perching for territory maintenance at the same time when awaiting for mate. Awaiting at a fixed position for mates with minimum or no movements of body parts and short-term inter perch flights tending to concentrate the male's aphrodisiac hormones in a broad disc that presumably lures females into male's sphere of vision, at which point the pursuit is initiated are also in the list. Active Mate Locating Behaviour encompasses patrolling i.e. active search for suitable mating resource, including mate and habitat with a stereotyped flight pattern, seeking i.e. direct searching for attachment with the mate through active attempts. Selection should favour males which perch at a level where conspecific females are most likely to be flying (Costanzo and Monteiro 2007; Takeuchi 2017).

Table 4. Pre-pursuit mating flight features of model and mimic species

	Passive mate locating behaviour				Active Mate Locating Behaviour	
	Perching		Inter perch flight	Waiting	Patrolling	Seeking
	Display perching	Patrol perching				
Danaus chrysippus	+++	+++	+++	+	++	+++
Hypolimnas misippus	+	+++	++ , +	+++	+	++ , +

Passive mate locating behaviour:

Simple perching and waiting behaviour for appropriate females to fly by
Patrol perching may be considered as a special case of waiting behaviour
Display perching is represented by assembling of the wings held apart of males providing androconial display to disseminate male scent and assembling more females. During this time, wings held at 120-180° angle

Perching
+++ - frequent (>6 times/single encounter); ++ - moderately frequent (3-6 times /encounter); + - rare (<3times/encounter)

Waiting
+++ - >60 secs/encounter; ++ - 30-60 secs/encounter; + - up to 30 secs /encounter
Inter perch flight: short inter perch flights between perches tending to concentrate male's aphrodisiac hormones in a broad disc luring female into male's sphere of vision, at which point the pursuit is initiated
+++ - Long term>60 secs/encounter; ++ - medium 30-60 secs/encounter; + - short term <30 secs/encounter

Active Mate Locating Behaviour:

Patrolling
+++ - frequent (>4 times/encounter); ++ - moderately frequent (2-4 times/encounter); + - rare (none or <2 times/encounter)

Seeking
+++ - long term (>60 secs/encounter); ++ - moderate (30-60 secs/encounter); + - short term (<30 secs/encounter)

Generally, the courtship flights rapidly increase during day times, trail off gradually over the afternoon and cease between the afternoon period

Table 5. Occasionally visited alternative resource utilization.

	Over ripe fruits	Herbivores' faeces	Cattle urine	Guano	Reptilian droppings	Rotten vegetation (leaves, stem, floral, fruit parts)	Decaying organic matters (vertebrate carcasses)	Mud Patches	Wet soil along riverbed
Danaus chrysippus	+	+	+	+	+	+	+	+	+
Hypolimnas misippus	+	+		+		+	+	+	+

Table 6. Mudpuddling activity.

	Frequency based				Duration based				Diurnal phase related			
	S	**M**	**PM**	**W**	**S**	**M**	**PM**	**W**	**S**	**M**	**PM**	**W**
Danaus chrysippus	LF	MF	F	MF	ST, MD	MD	LT	MD, LT	DAY, AFTN	DAY	DAY	DAY, AFTN
Hypolimnas misippus	LF	LF	F	MF	MD	MD	ST	LT	DAY, AFTN	DAY	DAY	MOR, DAY

Frequency based:

Frequent (F) - hourly >5 times; **Moderately frequent (MF)** - hourly 1-5 times; **Less frequent (LF) -** hourly once; **Very less frequent (VLF)** - <hourly once

Duration based:

Short Term (ST) < 1 min at a time; **Medium (MD) -** 1-3 mins at a time; **Long Term (LT)** ->3 mins at a time

Diurnal phase:

MOR-8 am to 10 am; **DAY**-11 am-1pm; **AFTN**- 2-4 pm

Utilization of similar-heighted host plants by the members of a particular mimetic set is reported to be correlated positively with their flight heights. The relationship between flight height and height of larval host plants, coupled with microhabitat dependant selection on colour pattern, thus may lead to the evolution of sympatry of vertically stratified mimicry complexes. Female butterflies use to attend plants of similar heights to their larval hosts more frequently than they encounter plants of other heights. Thus, host plant shifting often suggested to follow the similar height to their current host plants (Beccaloni 1997).

Both the model and the mimic go for faecal visits generally during afternoon throughout the year, except in winter (Table 5). In Table 6, their mudpuddling behaviour is documented. Generally, the study specimens share common association ship during mudpuddling. Apart from the vegetational hosts including the nectar and non-nectar host plants and larval host plants these lepidopterans occasionally scavenge for some alternate and to some extent detritus resources like herbivore's faeces, cattle urine, guano, rotten fruit and vegetables as alcoholic sources, and mud patches. These are rich in nitrogenous and mineral components and essential for their longevity and fecundity (Adler and Pearson 1982). Rotten vegetation often visited by them without any diurnal specificity. Mud patches are somewhat common destination for both during the later part of day at winter. *Hypolimnas misippus* never seen to visit the cattle urine and reptilian droppings which is frequently visited by *Danaus chrysippus.* Some of these alternative resource sites are reported to be repeatedly utilized throughout the year. Generally, these sites are visited in aggregation and the visiting individuals are commonly male and the younger ones. Sodium, which is otherwise scarce nutrient in adult diet, is the triggering element

for puddling. Sodium is essential for males, the more active fliers than the females, to support the neuromuscular activity, moreover it is required for egg production and transferred to females at mating by the males. Though, puddles are less rewarding and less easily depleted resources, puddling may act as an alternative foraging strategy, resulting from competitive exclusion of males or young from the richer nutrient resource i.e. flowers, by females or the older individuals.

4. CONCLUSIONS

It can be summarized that, pre-requisite for conservation of the lepidopteran assets includes the need of conservation both at the levels of adult and developmental phases. Particularly for maintenance of such group of ecologically interacting species awareness about adult and larval habitat and mode of optimisation of the natural resources by the individuals over a spatial and temporal scale is urgent (Venkataramana *et al.*, 2004). Both at habitat and landscape level conservation and restoration approaches should be adopted. Sustainable microhabitat management and methodical documentation of sufficient information regarding species autecology must be maintained on periodic basis. As pollinators, these native set of mimetic butterflies play a vital role as they exhibit polyphagy and multiple host dependence, particularly on the local wild flowered plants (Moeller, 2004). Being extremely sensitive to subtle environmental changes they can act as efficient global bioindicator for habitat quality, climatic changes and environmental degradation. They perform the role as the efficient value indicator of biotope quality (Van Strien *et al.*, 2009). The present documentation leaves further scope of detailed study at the level of community ecology of these mutually interacting

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