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Research article

ECOBIOLOGY OF THE SPOT SWORDTAIL *GRAPHIUM NOMIUS* (ESPER) (LEPIDOPTERA: RHOPALOCERA: PAPILIONIDAE) FROM THE EASTERN GHATS OF SOUTHERN ANDHRA PRADESH

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ABSTRACT: The Spot Swordtail *Graphium nomius* butterfly found in South and Southeast Asia that belongs to the Swallowtail family. *Graphium nomius* was one of the attractive Papilionidae butterflies that enliven the environment of Seshachalam Bio reserve forest, Tirupati, Southern Andhra Pradesh. The Spot Swordtail gets its name from the stunning line of distinct white spots along the margin of its wings it occurs throughout the year. It lays eggs singly on young leaves of the mast trees *Polyalthia longifolia* (Annonaceae), *Miliusa tomentosum*, *Miliusa velutina*. The eggs take 3-4 days to hatch. The larvae go through 5 instars over a period of 17-22 days. The pupal period is 12-13 days. The total period from egg to adult emergence spans over 32-35 days. Based on this short life cycle, and larval and pupal development success studied every month, this butterfly was multivoltine with a minimum of 7-8 broods in a year. Both CI and GR decreased with the age of larva, their average figures are 3.78 and 0.43 respectively. AD values are high (average 92%) and decreased through successive instars. Both ECD and ECI followed a similar array with an increase from instar I up to II, then a decrease up to IV and again an increase in instar V and the highest value was with fifth instar.
Key words: *Graphium nomius*, *Polyalthia longifolia*, life history, Seshachalam Bio reserve forest, Andhra Pradesh, Eastern Ghats.

INTRODUCTION

Butterflies show distinct pattern of habitat utilization. The nature of vegetation is an significant factor which regulates the dependence and survival of a species on a particular habitat. Being extremely sensitive to environmental changes, they are easily affected by even relatively minor disturbances in the habitat so much that they have been considered as indicators of ecological quality and are also treated as indicators of the health of an ecosystem. The presence of butterflies emphasizes availability of larval food plants in great abundance. Butterflies are taxonomically well studies group, which have received a equitable amount of attention throughout the world [1]. Many of butterfly species are strictly seasonal and prefer only a particular set of habitats [2] and they are good indicators in terms of anthropogenic disturbance and habitat quality [3]. Due to worldwide pressures on natural biomes, butterflies have already been shown to be highly sensitive indicators of climate change [4], [5], [6]. Butterflies offer inexhaustible stimulating material for those who are curious in carrying out applied and pure research [7]. They are instantly familiar and also universally popular. The development of colour, the range, diversity, brilliance and the kaleidoscopic assortment of patterns exhibited by butterflies is unrivalled anywhere in the animal kingdom, except possibly by the birds. Butterflies are truly the "jewels of creation." This warrants taking up to butterfly conservation immediately in India with tropical and subtropical environment [8]. Butterflies are typically active during the day and because they are so skilled in flight they have achieved an almost world-wide distribution, though as with most animal groups (particularly coldblooded ones) there is a superior diversity to be found in the tropics. Inopportunely, butterflies are threatened by habitat obliteration and fragmentation almost everywhere [7]. To avert the crisis, we need to prioritize and target conservation strategies and investments in the Eastern Ghats tract. To initiate a conservative programme for these 'flag ships', one need, first of all, a detailed knowledge of their life histories and their natural habitat conditions. The suitability of the habitat for butterflies depends on conditions providing protection and shade, the presence of food plants for the larvae and the presence of plants in flower providing a nectar source at the time the adults are flying [10].

In the most cases of Indian butterflies, such information needed for effective conservation management programme is lacking [11], [8]. However, to be successful in this direction, one needs a complete knowledge of its autecology including life history, voltinism, seasonality and habitat conditions. Since butterflies are holometabolous with distinct developmental stages - egg, larva, pupa and adult, their reproduction depends on the combined effect of larvae- and adult-derived nutrients. Among the Lepidoptera, the family *Papilionidae* contains about 700 species scattered throughout the world [9]. One of the Pailionidae butterfly *Graphium nomius* is the most widespread and common of the oriental species found in India, Sri Lanka, Myanmmar, Loas, Cambdia, China, Taiwan, Korea, Vietnam, Japan, The Philippines, West Malaysia, Sumatra, Borneo, Sulawesi and Java. We have assumed an analysis into these aspects of butterfly biology and ecology and the present paper on the Spot Swordtail *Graphium nomius* forms part of the major investigation for use in the conservation management.

STUDY AREA: (Fig: 1)

Seshachalam hills, one of the first Biosphere Reserve forest in Andhra Pradesh, was located in Southern Eastern Ghats of Chittoor and Kadapa districts. It was spread over 4755.99 Km^2 (Fig 1). Tirumala hills which are popularly known as the seven hills of Lord Sri Venkateswara. The elevation ranges from 150 to 1,130 m, the terrain was undulating, with deep forest covered valleys. Most of the rainfall was received from the northeast monsoon and a little from the southwest monsoon. The vegetation was a unique mix of the dry deciduous and moist deciduous types.

It was the richest floristic hot spot harboring many endemic and rare plants. The entire sanctuary was an uninhabited large chunk of dry deciduous Red Sanders bearing forest, forming catchments to Swarnamukhi and Penna rivers, both in Chittoor and Kadapa districts. Talakona was located in Nerabailu village in Yerravaripalem Mandal of Chittoor District. It was located 49 kilometres (30 mi) from Pileru, 58 kilometres (36 mi) from Tirupathi. Talakona was a resort with waterfalls, dense forests and wildlife. The area was declared a biosphere reserve in 1989 due to the presence of rich variety of flora and fauna.

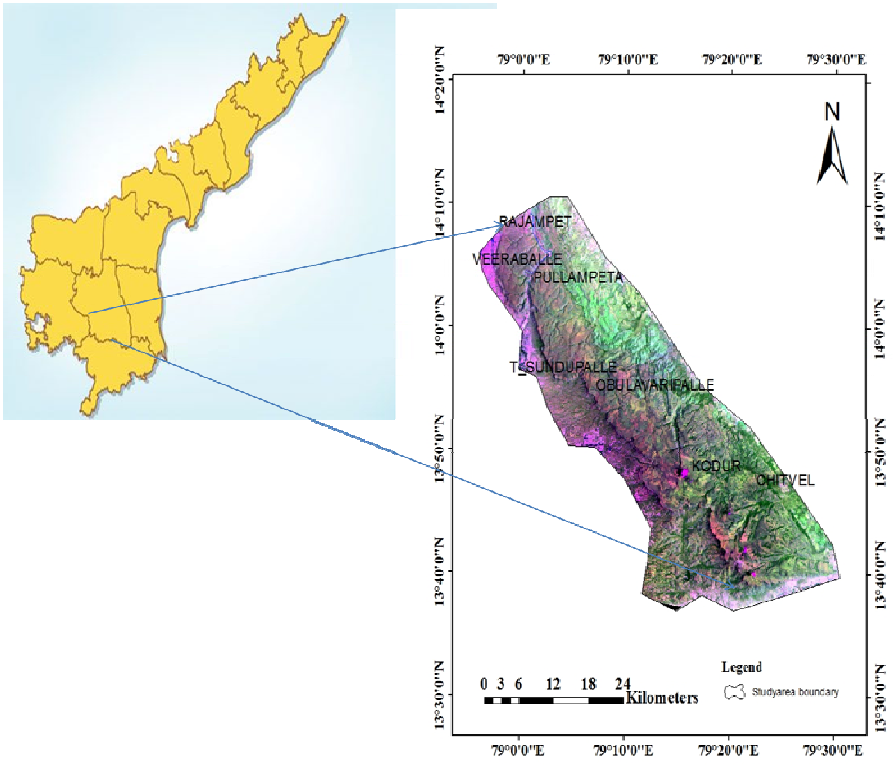

Fig: 1. Study Site: Tirumala hill region

MATERIALS AND METHODS

During our major study on the biology and ecology of south Indian butterflies, we noticed the Spot Swordtail *Graphium nomius* was studied in the butterfly biology laboratory of Yogi Vemana University, Kadapa for two consecutive years of 2013- 2014. The climate of the study area (Fig: 1), South east monsoons spreading over April-October.

The difference between maximum temperatures rarely exceeds 30-35ºC. In the rainy season a variety of herbs and shrubs appear giving a somewhat compactness to the vegetation. Two study areas were chosen. The present study areas i.e., Southern Andhra Pradesh has rich vegetation. We have chosen two different areas (both plains and hill regions) i.e., Seshachalam hills, Thalakona hill forest region. Seshachalam hills, one of the first Biosphere Reserve in Andhra Pradesh, located in southern Eastern Ghats of Chittoor and Kadapa districts. It was spread over 4755.99 Km. Both areas support the vegetation was a unique mix of the dry deciduous and moist deciduous types.

The Spot Swordtail *Graphium nomius* was found frequently laying eggs on the young leaves of *Polyalthia longifolia* (Annonaceae). The time and behaviour of ovipositins were recorded when female butterflies oviposting on the tender leaves of host plants. The number of eggs laid, 45 % were brought from the host plant of *Polyalthia longifolia* to laboratory along with twings and stems and were put inside the culture cage of 29×29 inches in size with extreme care to keep the normal humidity and temperature at laboratory condition. The accurate time and of laying and hatching were recorded by close watching in natural and laboratory conditions [12]. The eggs were collected along with the leaf material and kept in Petri dishes (9.5 cm diameter), brought to our Butterfly Biology laboratory and incubated at room temperature (around 28 ºC). The newly hatched caterpillars (in laboratory culture conditions) were carefully transferred to the freshly leaves, young leaves and matured leaves. The twings were kept fresh by putting in water full glass container [12], [13]. The measurements of length and breadth of the eggs, caterpillars, and pupa, adult butterflies were taken using slide callipers. The climatic factors like temperature and relative humidity (Table: 1),(Fig:2) were measured with help of thermometer and hygrometer respectively. After the larvae have hatched out, tender leaves were fed. The Petri dishes holding the larvae were kept clean by removing the waste including the faecal matter of larvae. The leaf area consumption was measured with the help of a digital planne-meter [12], [13]. The characters of different larval instars, pre-pupal and pupal stages were recorded. Food consumption and the growth of the larvae at each instar stage were measured. The generation duration was studied as per the methods of [14], [15]. The food utilization indices were calculated following. Five replications were made in respect of each parameters of food efficiency. The weights are expressed in the units of milligrams. The relation between food consumption and growth of larvae was analysed statistically by using larval performance in terms of food utilization indices were calculated as described by [15] as.,

$$\text{CI (Consumption Index)} = \frac{\text{Weight of food consumed}}{\text{Weight of instar} \times \text{Number of feeding days}}$$

$$\text{GR (Growth rate)} = \frac{\text{Weight gain of instar}}{\text{Mean weight of instar} \times \text{Number of feeding days}}$$

$$\text{AD (Approximate Digestibility)} = \frac{\text{Weight of food consumed} - \text{weight of faeces}}{\text{Weight of food consumed}} \times 100$$

$$\text{ECD (Efficiency of Conversion of Digested food)} = \frac{\text{Weight gain of instar}}{\text{Weight of food consumed} - \text{weight of faeces}} \times 100$$

$$\text{ECI (Efficiency of Conversion of Ingested food)} = \frac{\text{Weight gain of instar}}{\text{Weight of food consumed}} \times 100$$

DESCRIPTION

Habitat &Habitats

Generally found in deciduous forest areas, among bushes with lesser secondary growth. Locally found abundant up to 3000 feet and less common above this level. It stays close to hilly and forested country. Has a dodgy and fast flight, especially when disturbed. Often visits flowers. Spot Swordtails may be seen to cluster around flowering trees. Large numbers can be seen settling on damp roads and wet patches, especially in hot summers, basks close to the ground, with wings partially open or completely spread. It was a known migrant in Sri Lanka.

The Spot Swordtail *Graphium nomius* was essentially a butterfly of evergreen forest zone, and in the Sheshachalam bio reserve forest large number occur just before the onset of south-east monsoon and when the monsoon changes in September/ October [16]. At Tirumala with plains and the hilly-regions supporting scrub vegetation, the butterfly occurs rather commonly during April- October. Thus there seems to be uniformly in the seasonal occurrence of this butterfly irrespective of a change in the topography and altitude.

The butterfly lays eggs singly. Egg laying habits in butterflies are critically analysed in relation to the advantages derived by adult females, eggs and larvae. The single egg- laying females may use many host plants and different species of the host genus within a habitat, thus *G. nomius* uses all species of annonaceae because single larvae are less likely to defoliate their host plant.

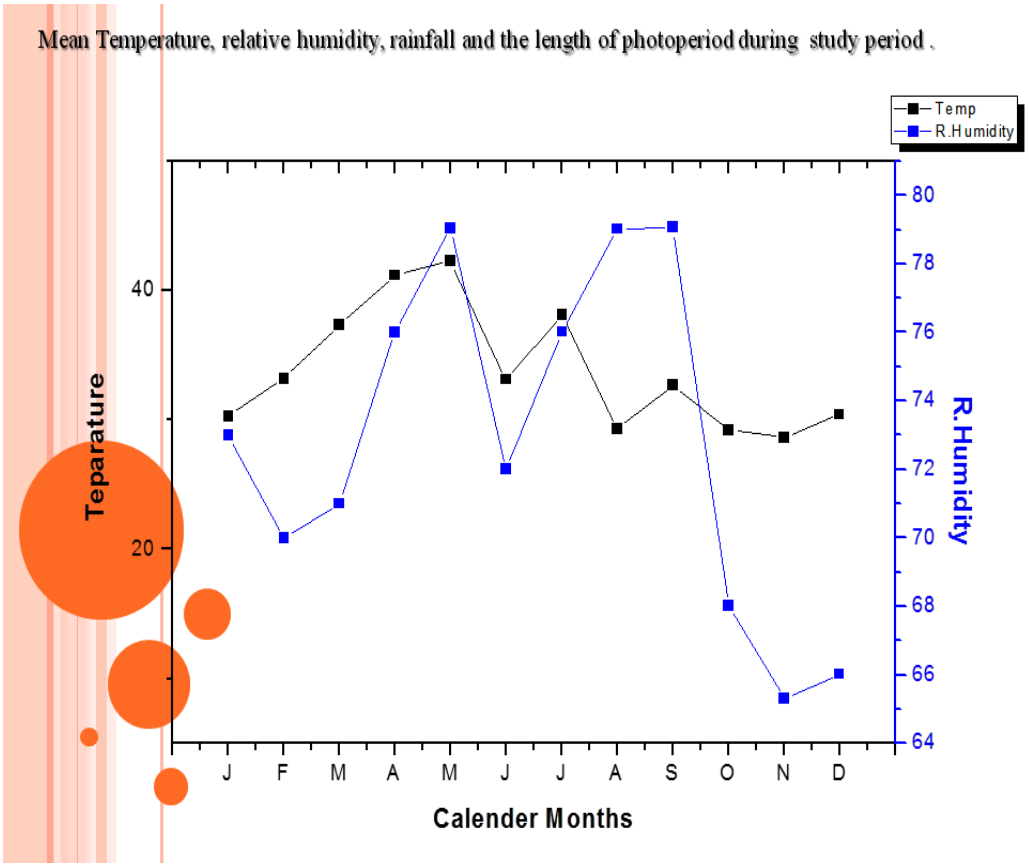

Fig: 2 Mean Temperature, relative humidity, rainfall and the length of photoperiod during study period.

Table: 1. Distribution of early stages of *Graphium nomius* and the associated weather Conditions

Life cycle stage ↓	Calendar month											
	J	F	M	A	M	J	J	A	S	O	N	D
Early life stages	2	3	2	05	30	32	34	28	11	05	3	2
Adults	*	*	*	**	***	***	***	***	**	**	*	*
Temperature	30.3	33.21	37.32	41.2	42.31	33.12	38.13	29.31	32.71	29.24	28.65	30.42
Relative humidity	73	70	71	76	79.05	72	76.02	79.02	79.08	68.03	65.31	66.02
	* Rare, ** Common, *** Very common											

Table-2: Nectar plants

S.No	Name of the Nectar host plant	Flowering season	Flower colour
1	*Tribulusterrestris L.*	Jun to Oct	Yellow
2	*ZizyphusmauritianaLamk.*	Aug to Oct	Green
3	*Zizyphusoenoplia Mill*	Aug to Oct	Green
4	*Borreriahispida*, K.Sch.	Jul to Oct	Pink
5	*Lagascamollis.* Cav.	July to Oct	White
6	*Merremia tridentate*Hallierf.	Aug to Oct	Yellow
7	*Justiciaprocumbens* L.	Jun to Oct	Pink
8	*Leucasaspera*	Jun to Oct	White
9	*Santaalum album* L.	Jun to Oct	Purple-red
10	*Waltheriaindica* L.	Jul to Oct	Yellow
11	*Nerium odorum* L.	Throughout year	Pink
12	*Jasminum angustifolium.* Wild.	Jun to Aug	White
13	*Wrightia tinctoria*, R.B.R.	Apr to Jun	White
14	*Cadaba fruiticosa* (L.) Druce	Throughout year	Green
15	*Capparis spinosa* L.	Dec. to Feb	Green
16	*Cleome viscose*	Jun to Feb	Yellow
17	*Hibiscus rosasynensis* L.	Throughout year	Red
18	*Sida acuta* ;Burm.	Aug to Dec	Yellow
19	*S. cardifolia* L.	Aug to Dec	Yellow
20	*Zizyphus mauritiana* Lamk.	Aug to Oct.	Green

The Spot Swordtail *Graphium nomius* is a seasonal flier and was seen during April – October. A considerable number of floral species were available in flower in the two study localities and The Spot Swordtail foraged on nearly 20 plant species which are listed in Table -2 along with their flowering periods.

RESULTS

Life history stages (Fig: 4)

The adults were found to breed during the period from April – October. Egg laying activity in a day occurred during 0600- 1000 h. A breeding female after locating the oviposition host, *Polyalthia longifolia*, fluttered over the host leaves and exhibited 'touch and go 'behaviour in the process of testing the suitability of leaf for egg laying. This process continued for 2-10 minutes. Eggs are spherical, yellowish and lightly shiny. They are laid singly on the upper surface or at the margin on the under-side of young leaves or buds.

The eggs measures 1.8-2.0 mm (1.9±0.12m) in diameter. Hatching takes place 3 days after incubation and the larvae pass through five successive instar stages. Newly hatched larva was Black with green& yellow underside. The anterior and posterior segments are yellowish with a pair of spines on each thoracic and anal segment. Glossy green osmeterium appears. Sluggish caterpillar feeds mainly in the evening and at night. It has four pairs of spines which are small but sharp. The most usual colour was black, banded on the sides with narrow white stripes, except on the first three or four segments and the last on which there is more or less rusty red; but the shade varies very much, and in some the ground colour was green. [20].The first instar larva lasts 2-3 days. It grows up to 2.8 - 3.4 mm (3.1 ± 0.11mm) in length; head was round, smooth and 0.9- 1.4 mm (1.2±0.02mm) in diameter. Thorax was hairy. The body was snuff coloured, except at the anal region. The second instar lasts 2-4 days. It is 4.3 -6.0mm) long. Head is 1.3-2.2mm (1.8 ± 0.11mm) in diameter. Segmentation was clear. Ventral side of the body was pale white. The third instar lasts 3-4 days. It grows up to 8-22 mm (21.0 ± 0.06mm) in length. Remaining characters are same as in second instar. The fourth instar lasts 3-4 days. It grows up to 34- 36 mm (35.0 ± 0.12mm) in length and 3.8 – 1.9 mm (1.6 ± 0.14mm) in width. Body colour changes to green eyes are blue. There was no changes in other characters from fourth instar.

The body of the final instar larva ultimately undergoes contraction. It measures 42-44mm (41.0 ± 0.18mm) in length. Contraction occurs for a day. Then the larva attaches itself to the substratum with its entire body. This stage lasts 2-3 days, and the pupal stage begins. Pupa is the usual horn shaped with two short processes on the head and it was attached by the tail and a close band and was not on the food plant but in crevices or under stones or roots. The pupa was 28-30mm (29.2 ± 0.04mm) in width; its posterior end was pointed. This stage lasts 12-13 days after which the adult emerges out.

Table: 3. Hatching rate, Pupal and adult development success of *Graphium nomius* in Laboratory

Month	Number of eggs	Number of larvae	Number of pupae	Number of adults
April	12	07	04	02
May	30	28	27	27
Jun	42	40	40	40
July	36	35	35	34
August	32	30	30	30
September	18	17	17	15
October	08	06	06	05

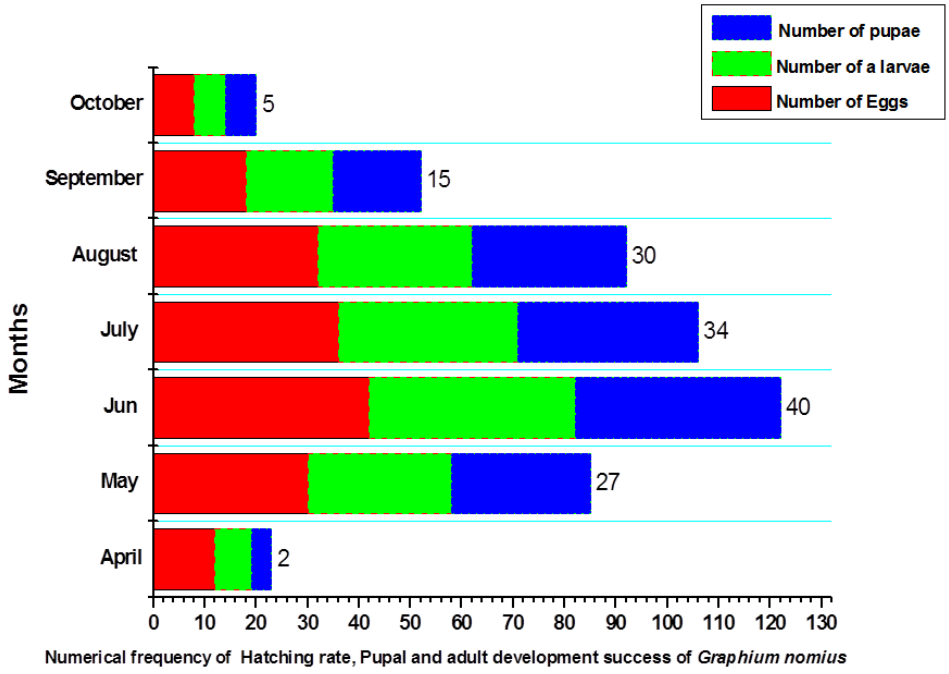

Fig: 3 Hatching rate, Pupal and adult development success of *Graphium nomius* in Laboratory

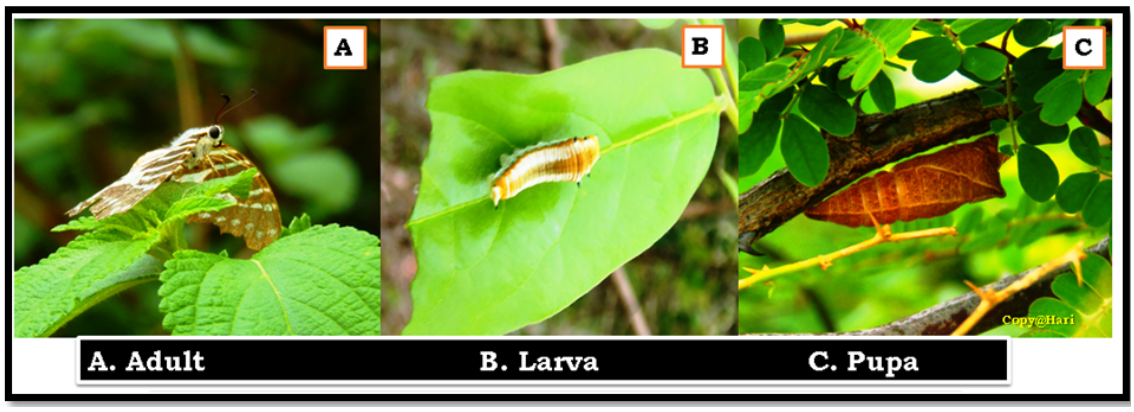

Fig-4: Life cycle stages of *Graphium nomius*

POPULATION INDEX :(Fig: 5**)** (Table: 4)

Searches for eggs, larvae and pupae of *G.nomius* on 15 *Polyalthia longifolia* trees were made for assessing their population indices (Table –4). These stages occurred on *P.longifolia* during April- October, with a higher frequency from May to August. Observations in the laboratory on hatching success, larval, pupal and adult developments are given in table - 4.

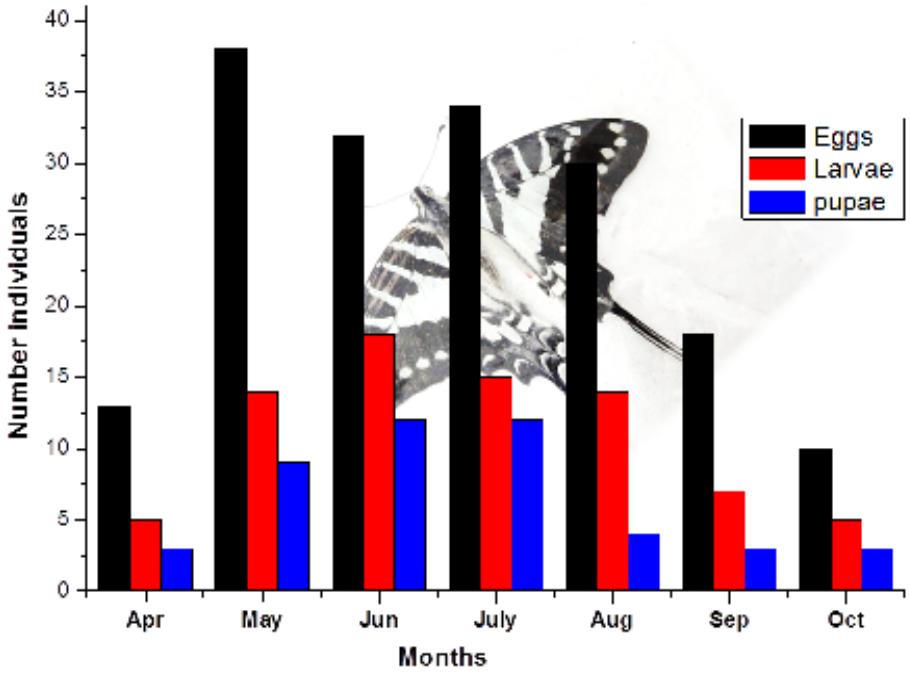

Fig-5: Population index of *Graphium nomius* on *Polyathian longifolia* at study areas

Table: 4 Population indexes of *Graphium nomius on Polythia longifolia*

Month	Number of eggs	Number of larvae	Number of pupae
April	13	05	03
May	30	14	09
Jun	32	18	12
July	34	15	12
August	30	14	04
September	18	07	03
October	10	05	03

Larval feeding activity and growth (Fig: 6)

The newly hatched larvae first are the empty egg shell from which they emerged out. Then they moved to feed on the host leaves supplied. The records of feeding activity during 4-h observation period in the laboratory indicated that instar I and II engaged in feeding activity 2-4 times, the total consumption time amounting to 8-20 minutes. Instar III engaged in feeding activity 3 times, the total time of consumption coming to 18-34 minutes. Instar IV and V fed 5-6 times, each time consuming for 24-42 minutes. Evidently, instar I and II fed slowly compared to the other three instars. There was a progressive increase in weight gain from instar I to V the rare being low with instar I and II and high with the other three instars (Table:6).

Table: 5 Food indices & utilization efficiency of larval stages of *Graphium nomius*

Instar No	GR (mg)	CI Mg/day/mg	AD%	ECD%	ECI %
I	0.57	7.47	99	07.7	07.7
II	0.49	2.41	95	20.3	19.3
III	0.55	3.48	92	17.2	15.9
IV	0.25	1.86	91	14.7	13.3
V	0.18	0.97	84	22.8	19.3

CONSUMPTION AND UTILIZATION OF FOOD AND GROWTH

The data on the weight of the food consumed (Table-5, Table-6, and Fig 6 & 7), weight gained by larvae on weight of food ingested was plotted in Figure 6 and 7 &8 .This correlation indicated a direct relation between food consumption and growth. the values of growth rate (GR), Consumption index (CI) and approximately digestibility (AD) Values of both ECD (Efficiency of conversion of digested food) of the successive instars followed a similar pattern of increase from 1st instar to 2nd instar, then a decrease up to 4thinstar and again an increase in 5th instar.

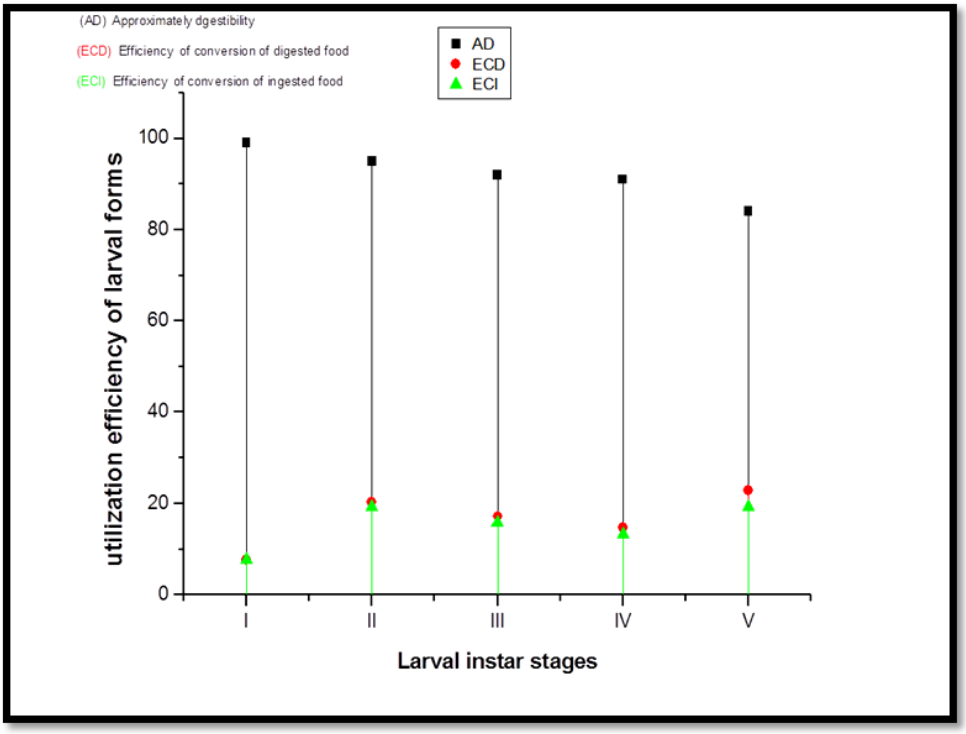

Fig: 6 Food indices & utilization efficiency of larval stages of *Graphium nomius*

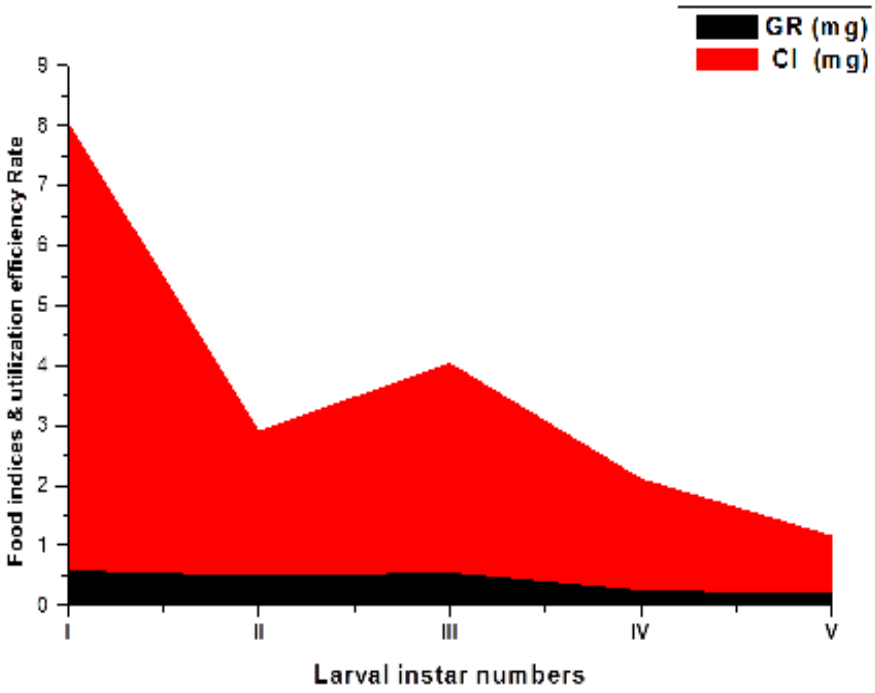

Fig: 7. *Graphium nomius* larval Growth rate & Consumption Index

Table: 6. Food consumption and larval weight gain of *Graphium nomius* larva on *Polyalthia longifolia* leaves

Instar No	Weight of food ingested (mg)	Wt. of faecal matter(mg)	Wt. gain by larva (mg)
I	21.6±0.34	0.015±0.09	2.2 ± 0.10
II	88.5 ± 0.84	3.42 ± 0.18	18.0 ± 0.18
III	1397 ± 8.40	1105 ± 0.91	222.6 ± 1.80
IV	2371.6 ± 11.20	194.5 ±1.90	3213 ± 2.40
V	3497.3 ± 16.40	528 ± 5.30	678 ± 3.80

Growth rate (GR), Consumption index (CI), Approximate digestibility (AD), Efficiency of conversion of digested food (ECD), Efficiency of conversion of ingested food (ECI) (Weight by mean ± SE)

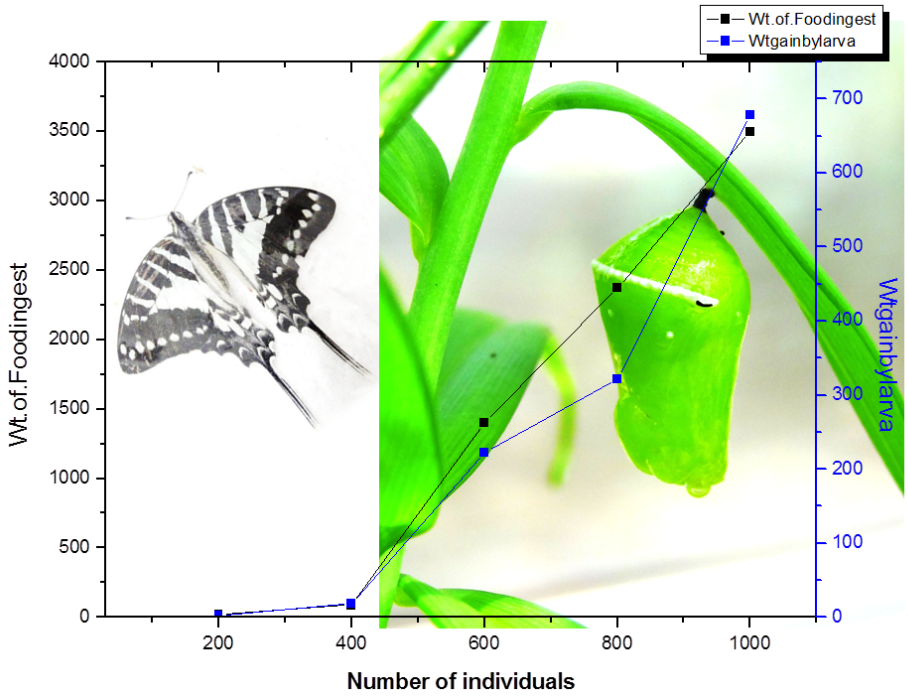

Figure 8: Larval growth as a function of food consumption rate in *Graphium nomius*

DISCUSSION

The total larval period spans over 17-22 days after which the final instar prepares for pupation. Metamorphosis within the pupa occurs over a period of 12-13 days after which the adult emerges. Thus, the total time taken for the completion of the life cycle from the egg stage to the emergence of adult id estimated to be 32-35. Since the prevailing temperature influences instar during [17], the developmental time from egg- laying to the emergence of adult from pupae may vary from region to region depending on the weather conditions [18],[19]. But in any case, the development time from eggs to emergence of adults was much shorter in the tropical environments, and the duration of the life cycle of *G.nomious* was in the line with this observation of Owen (1971). Shorter life cycle coupled with population index of eggs, larvae and pupae (Table: 5) (Fig: 2), and the development of success of eggs, larvae and pupae and adult emergence of *G. nomious* (Table: 4), (Fig: 3) suggest that breeding takes place more than once during April- October when the adults are on their wings. Since most adult butterflies survive for 7-10 days, it is estimated that *G. nomius* may yield 4-5 broods in the period from April – October. While *G. nomious* was highly seasonal in its occurrence, *G. Agememnon* (the tailed jay) in the same study locality occurs throughout the year, and has a developmental period of 29-35 days giving rise to an estimated 3-4 broods in a year. The seasonality of butterflies and their voltinism patterns are mostly determined by length of growing season, the availability of suitable larval and available adult food, and the peculiarities of each butterfly's life cycle adaptation [19]. The temperatures prevailing in the study region during April – October are relatively higher than those prevailing during November – March, *G. nomius* then appears to be adaptive to relatively higher temperature region (Fig: 6) (Table: 6).

The approximate digestibility (AD) steadily decreased with the age of larvae from the first instar (99%) to the last instar (84%) and was inversely related to food consumption .This decline trend was generally attributed to the consumption of more of soft tissues by the early larval instars, and to the consumption of more of indigestible fibrous tissues by the growing instars [21], [22],[3]. This declining trend in the assimilation efficiency with age of instars has also been reported in other insects and in other butterfly species, and [24] on *Euploea core*.

The average AD value obtained was over 92% and this high AD substantiate the statement of [23] that foliage – chews often attain high AD values. Such high AD was also expected when the food item was rich in nitrogen. Similar results were expected with *pieris brassica*e and *Euploea core* [24].

The reviews on food utilization by insects showed that ECD may increase, and ECI may increase or decrease from early to late instars [23]. As against this general trend of ECD and ECI the ECD and ECI percentage of *G.nomius* displayed first an increasing trend, followed at decrease and again an increase. Some workers reported gradual rise of both indices from first to fifth instars [22], and some recorded increased ECDs and ECI up to fourth instar and there after a decline in the fifth stage in different insects [25], [26], [27].Despite the variations between the instars from the reported trends, the first instar registered lowest percentage of ECD (7.7%) as well as ECI (7.7%) and the final instar the highest – ECD 22.8%, ECI 19.3%. The percentage of ECD averaged to 16.5 and of ECI 15.5. These values are not different from the range of values reported for foliage- chewers [23]. Food utilization efficiency is affected by the quality of food. The nutritional quality of leaves depends on their age, and tender leaves are nutritionally adequate than older leaves. The slight decline in both ECD and ECI values in the third and fourth instars from the values of second instars might be due to some error that might have taken place in supplying leaves of similar age throughout the larval period. The information on the oviposition, larval host and larval performance in terms of food consumption, growth and utilization, and the length of life cycle from egg to adult eclosion of *Graphium nomius* in the present study may be profitably utilized in the successful conservation management of this butterfly species either in parks, Zoos and butterfly houses or in the field. Butterfly houses are popular exhibits in Zoos and have an immense educational [28] and conservational potential [7], [28]. The present study also indicted that captive rearing of larvae and stock of adults for restocking the areas poor in populations of the Spot Swordtail butterfly.

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