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Ecobiology of the Tamil Bushbrown Butterfly, *Mycalesis subdita* Moore (Lepidoptera: Rhopalocera: Nymphalidae: Satyrinae) from Visakhapatnam, East Coast of Southern India

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Abstract
The Tamil Bushbrown butterfly, *Mycalesis subdita* Moore, exhibits seasonal occurrence at Visakhapatnam, South India, from July to March. It relies on *Brachiaria distachya* (Linn.) Stapf. For oviposition and as a larval host. The butterfly typically lays eggs singly, though occasionally two eggs are laid. The larvae undergo five instars, characterized by a light green color and a pair of head horns. The pupae are dark green with minute white spots. The developmental period from egg to adult emergence ranges from 28 to 37 days (average 32.40±3.53 days) under laboratory conditions, which include a temperature of 28±2 °C, 80±10% relative humidity, and a day length of 12-14 hours. Early life stages (eggs, larvae, pupae) are observed on *B. distachya* for 210 days, spanning July to January, resulting in four to five overlapping generations annually. There is a higher frequency of early life stages from September to December, aligning with the rainy and winter seasons. This suggests that *M. subdita* may require moist and shady conditions for year-round occurrence and reproduction, conditions that are not consistently present in the study habitat, hence its limited seasonal presence. The larvae demonstrate efficient consumption and utilization of the host leaves, as indicated by various nutritional indices: approximate digestibility (AD) of 97.25% - 72.12%, efficiency of conversion of ingested food to body substance (ECI) of 7.14% - 20.31%, and efficiency of conversion of digested food to body substance (ECD) of 7.34% - 28.16%.

Keywords: Life history, sexual diapause, population index, voltinism, nutritional indices

1. Introduction
Satyrids, commonly known as Browns, are shade-loving butterflies generally found in dense evergreen forests. They prefer cool, dense vegetation and rarely venture into open areas. These butterflies are typically dull brown or blackish brown, with distinctive eye spots (ocelli) and white or tawny bands on their wings. Their flight is weak and jerky, staying close to the ground. They are attracted to sap from trees, toddy, and rotting fruits on the forest floor. Most satyrid larvae feed on grasses or bamboos, with the exception of *Elymnias* species, which feed on palms. *Mycalesis* is a large genus within the Satyridae family, with about 150 species worldwide. *M. subdita* Moore, commonly known as the Tamil Bushbrown, is found in India and Sri Lanka [1, 2] and is considered endemic to Southern India [3]. Its larval food plants belong to the Poaceae family. The butterfly exhibits distinct wet and dry forms depending on the season. This study investigates its flight and reproductive seasonality, life history, and larval performance in terms of food consumption, growth, and utilization to understand its ecological success in the study environment.

2. Materials and Methods
This study was conducted from March 2022 to April 2023 on the Andhra University campus, spanning 168 hectares, in Visakhapatnam (17°42’ N, 82°18’ E) located on the east coast of Southern India. The natural plant community on the campus was surveyed to investigate the distribution and reproductive activities of the Tamil Bushbrown butterfly (*Mycalesis subdita* Moore). Adult butterflies were primarily found near the larval host plant *Brachiaria distachya* (Linn.) Stapf.

Detailed observations were conducted at ten sites to monitor flight activity, adult abundance, copulation periods, and oviposition behavior. Freshly laid eggs were collected to study the life history and developmental stages.

After oviposition, leaves with eggs were collected in Petri dishes (15 cm x 2.5 cm) and transferred to the laboratory. The leaf sections containing eggs were placed in smaller Petri dishes (10 cm x 1.5 cm) lined with moistened blotter paper to prevent desiccation. Five such samples were placed in a wire mesh-covered cage. Laboratory conditions were maintained at a temperature of 28±2 °C and relative humidity of 80±10%, with indirect natural light varying from 12 hours in November to January and 14 hours in June to July. Eggs were examined every six hours to record the time to eclosion.

Larvae were reared on fresh leaves, with the quantity weighed and supplied daily. The timing of each molt, along with morphological characteristics, body measurements, and body weight of each instar, was recorded. Fecal matter was collected daily. Pre-pupal behavior, pupal characteristics, and adult eclosion times were also documented. Larval performance was assessed in terms of food utilization indices, following the methods described by Waldbauer [4].

To determine the developmental success of early stages, a set number of eggs were placed in Petri dishes monthly, and the number of larvae hatched, pupae formed, and adults emerged were recorded. To assess the population index of various early stages on the natural host plant, five one-square-meter patches were thoroughly searched every ten days each month. The early stages found were enumerated and pooled for each month. During these visits, the flight frequency of adults was also noted using a scale of rare, less common, and common.

3. Results

3.1 Adult Stage (Fig 1a)

The wingspan of the adult stage ranges from 45 to 50 mm, with a body length of 23.0 to 27.0 mm (average 25.3±0.16 mm). Both wings feature three brown wavy marginal lines on both the upper and lower sides. Males and females exhibit similar characteristics. The dorsal forewing has two ocelli—one larger, dark brown with a light brown border and a central white spot, and a smaller, indistinct one. The hindwing has a single, indistinct ocellus. The ventral wing coloration varies seasonally. During the wet season, a white longitudinal stripe appears on both wings. In the outer discal area, there are three ocelli on the forewing and seven more prominent ocelli on the hindwing. In the dry season, the white stripe turns into a brown line, and the ocelli reduce to minute white spots with dark brown borders. The butterfly exhibits a weak, jerky flight close to the ground, settling during the day in dense bushes, and never visiting flowers. It feeds on rotten fruits, animal droppings, and tree sap. The species is opportunistic, using various grasses (Poaceae) for oviposition, with *Brachiaria distachya* being the primary grass used in the study area.

3.2 Egg Stage (Fig 1b)

Breeding females lay eggs singly, occasionally in pairs, on the underside of leaves, primarily between 0930 and 1400 hours. The eggs are round, cream-colored, transparent, soft, and measure 0.90 to 1.00 mm (average 0.95±0.04 mm) in height. Hatching occurs after three days, with larvae consuming their egg-shell immediately. The larval stage consists of five distinct instars over 17 to 24 days.

3.3 Larval Stage (Fig 1c-g)

3.3.1 Instars I - III: Each of these instars lasts 3 to 4 days. On hatching, larvae measure 3.00 to 3.30 mm (average 3.16±0.12 mm). Instar I grows to 4.00 to 4.50 mm (average 4.28±0.20 mm) in length and 0.70 to 0.80 mm (average 0.76±0.04 mm) in width. The body color changes from creamish white to green, with a reddish brown stripe mid-dorsally towards the posterior end. The head, initially green, turns black, measuring 0.50 to 0.60 mm (average 0.53±0.04 mm), with conical black horns. Instar II reaches 5.00 to 6.00 mm (average 5.50±0.40 mm) in length and 0.80 to 0.90 mm (average 0.83±0.04 mm) in width. The head measures 0.70 to 1.00 mm (average 0.86±0.12 mm), and the body is light green with a dark green mid-dorsal stripe, which is reddish brown towards the posterior. Instar III grows to 8.00 to 14.00 mm (average 11.30±2.49 mm) in length and 1.00 to 1.50 mm (average 1.23±0.20 mm) in width. The head is reddish brown, measuring 1.00 to 1.50 mm (average 1.28±0.20 mm), with reddish brown horns around 0.2 mm long. The body shows clear segmentation and retains the same characteristics as the previous instar.

3.3.2 Instar IV: Lasting 3 to 5 days, this instar reaches 18.00 to 20.00 mm (average 19.10±0.00 mm) in length and 2.50 to 3.00 mm (average 2.63±0.26 mm) in width. The body turns yellowish green with minute hairs, and the head is reddish brown with light brown spots, measuring 1.50 to 2.00 mm (average 1.83±0.23 mm). Head horns are hairy, measuring 0.30 to 1.00 mm (average 0.63±0.28 mm), and anal processes grow to 0.50 to 0.80 mm (average 0.66±0.12 mm).

3.3.3 Instar V: This instar attains full growth in 5 to 7 days, reaching 24.00 to 30.00 mm (average 27.00±0.24 mm) in length and 4.30 to 5.00 mm (average 4.68±0.28 mm) in width. The head, measuring 2.00 to 3.00 mm (average 2.33±0.47 mm), and its horns are dark brown with light brown triangular markings. The body turns light brown from green, with a curved line on both lateral sides, a light reddish brown mid-dorsal stripe with cream-colored minute dots, and darker diamond-shaped markings. The body is rough with minute hairs, and the appendages are dark brown.

3.4 Pupal Stage (Fig 1h)

The fully grown fifth instar stops feeding, contracts its body, and pupates within 24 to 48 hours, measuring 11.00 to 12.00 mm (average 11.50±0.04 mm) in length and 5.00 to 6.00 mm (average 5.66±0.47 mm) in width at its broadest region. The pupa is broad anteriorly and narrow posteriorly, dark green with cream to yellow spots on the abdominal segments dorsally in two rows, and minute white spots over the entire pupa. A dark green mid-dorsal line and a pair of black ventral

spots are present. The pupal stage lasts 8 to 10 days, including the prepupal period, and the pupa weighs 228.0 mg.

3.5 Development Success and Population Index

Eggs of *Mycalesis subdita* were found on host plants from July to January. The hatching success rate varied between 75% in December and 100% in January, July, August, October, and November. The success rate of larvae becoming pupae ranged from 50% in July and August to 100% in December. Pupal emergence rates into adults varied between 80% in November and 100% in December, January, and July to September (Table 1). Searches for the three early life stages (eggs, larvae, and pupae) across five 1-square-meter patches of *Brachiaria distachya* plants showed reproduction from July to mid-January, with adults present from July to March. The highest frequency of early stages and adults occurred from September to December (Table 2).

3.6 Food Consumption, Growth, and Utilization

Table 3 presents data on food consumption and corresponding weight gain by larvae. Food intake increased with each instar, reflecting in weight gain. The proportions of food consumed by each instar were 1.48%, 2.45%, 5.07%, 16.74%, and 74.23%, with the last two instars consuming over 91% of the total food. Weight gain proportions were 0.49%, 1.03%, 5.61%, 21.95%, and 70.89%, indicating that the last two instars accounted for over 92% of the total weight gain. Growth rate (GR) and consumption index (CI) generally decreased across instars, except for a rise from instar II to III. GR values ranged from 0.22 to 0.45 mg/day/mg, and CI values ranged from 1.08 to 6.38 mg/day/mg, with the highest values in the first instar and the lowest in the final instar. Table 3 also includes data on approximate digestibility (AD), efficiency of conversion of digested food (ECD), and efficiency of conversion of ingested food (ECI). AD values decreased with larval age, ranging from 97.25% in the first instar to 72.12% in the final instar. ECD and ECI values generally increased with age, except for a slight decrease from instar IV to V. ECD values ranged from 7.34% to 32.51%, and ECI values ranged from 7.14% to 27.88%, with the highest values in the fourth instar and the lowest in the first instar.

4. Discussion

The tropical climate, characterized by minimal seasonal temperature variation, allows butterflies to fly and reproduce throughout the year, though they may have specific favorable periods [5, 6]. The Tamil Bushbrown (*Mycalesis subdita*) is observed from July to March, with a reproductive peak from September to December, aligning with the rainy and winter seasons. According to Mathew and Rahamathulla [7], this butterfly is abundantly present year-round in the dense, humid rainforests of the Silent Valley. It is likely that *M. subdita* requires moist and shaded conditions for its survival and reproduction. Such conditions are not consistently available in the study area, which limits its presence to specific parts of the year. During the remaining months, the adults might enter a reproductive diapause.

The total developmental period from egg laying to adult emergence is approximately 32.40±3.53 days at around 28 °C, allowing for 4-5 overlapping generations per year. This pattern aligns with the expectation that tropical butterflies have short life cycles and multiple generations annually [6]. Temperature affects the duration of each life stage and the overall development time [8-11]. Consequently, the number of generations per year in other parts of *M. subdita*'s range might differ based on local temperatures. In Visakhapatnam, particularly at the Andhra University site, the life cycle duration remains relatively consistent across overlapping seasons due to the absence of extreme temperatures.

Adult butterflies feed on overripe or decaying fruits and sap from tree wounds, which provides them with essential proteins and carbon sources [12], thereby enhancing egg production [13].

The food consumption index (CI) for most forb-chewing Lepidoptera ranges from 0.27 to 6.90 (average 2.03) mg/day/mg [14]. The average CI of 2.80 mg/day/mg for *M. subdita* fits within this range. Food consumption rate is influenced by the efficiency with which ingested food is converted to biomass (ECI), increasing as conversion efficiency decreases or vice versa [14]. The high CI value (6.38 mg/day/mg) in the first instar is likely due to low conversion efficiency, reflected in the low ECI value (7.14%) for this stage compared to later instars. Growth rates are higher in the first four instars than in the final ones [15].

The approximate digestibility (AD) values obtained in this study are comparable to the reported range (19-81%) for lepidopterous larvae [16]. The average AD percentage is 86.99%, supporting Slansky and Scriber's [14] assertion that foliage chewers often achieve high AD values. High AD values are also expected when the food is rich in nitrogen and water [16]. Similar results have been observed in various other lepidopterous larvae, including *Pieris brassicae* [17], *Ariadne merione merione* [18], *Byblia ilithyia* [19], *Helicoverpa armigera* [20], *Phalanta phalantha* [21], *Spodoptera frugiperda* [22], and *Zizula hylax hylax* [23].

It is generally believed that ECD values increase from early to late instars [14]. For *M. subdita*, ECD values increased from early to penultimate instars but sharply decreased in the final instar. These findings are consistent with the range reported for *Danaus chrysippus* by Mathavan and Bhaskaran [24]. The decline in ECD in the fifth instar may be attributed to increased energy expenditure on metabolism [25, 26]. The pattern of ECI values closely followed that of ECD. The values obtained (7.34%-32.51%) are within the expected range for forb foliage chewers [14, 20, 22]. The relatively high ECD and ECI values in the last two instars (32.51%, 28.16% & 27.88%, 20.31%) indicate efficient tissue and ecological growth, enabling *M. subdita* to thrive in the urban environment of Visakhapatnam.

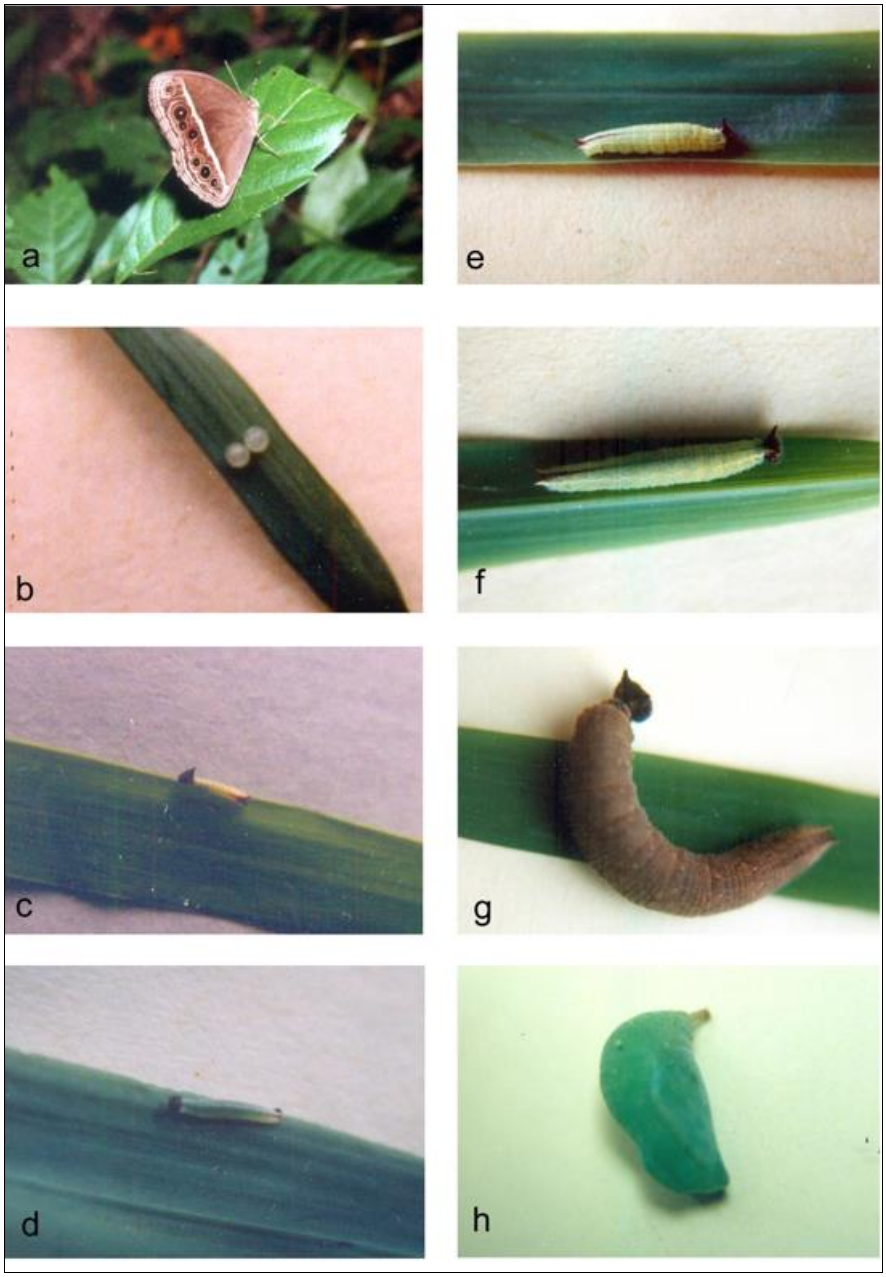

Fig 1: (a) Adult, (b) Eggs, (c) Instar (d) Instar H, (e) Instar III, (f) Instar IV, (g) Instar V, (h) Pupa.

Table 1: Development success of eggs, larvae and pupae of *Mycalesis subdita* on *Brachiaria distachya* leaves in the laboratory.

Life cycle stage	Calendar Months											
	M	J	J	A	S	O	N	D	J	F	M	A
# eggs studied	0	0	2	2	5	10	7	4	3	0	0	0
# larvae hatched	0	0	2	2	4	10	7	3	3	0	0	0
# pupae formed	0	0	1	1	3	8	5	3	2	0	0	0
# adults emerged	0	0	1	1	3	7	4	3	2	0	0	0

Table 2: Population index of different life stages of *Mycalesis subdita* on *Brachiaria distachya* leaves in the field.

Life cycle stage	Calendar Months											
	M	J	J	A	S	O	N	D	J	F	M	A
Adult abundance	-	-	*	**	***	***	***	***	**	*	*	-
# eggs	0	0	2	3	6	13	8	5	3	0	0	0
# larvae	0	0	0	2	3	10	5	3	2	0	0	0
# Pupae	0	0	0	1	2	5	2	2	1	0	0	0

Absent, *Rare, **Less common, *** Common

Table 3: Food consumption, growth and food utilization efficiencies of *Mycalesis subdita* larva fed with *Brachiaria distachya* leaves.

Instar number	Wt. of food ingested (mg)	Wt. of faeces (mg)	Wt. gained by larva (mg)	GR CI (mg/day/mg)		AD (%)	ECD (%)	ECI (%)
I	18.20±04.85	0.56±0.15	1.30±0.10	0.45	6.38	97.25	07.34	07.14
II	30.00±06.94	2.90±0.64	2.70±0.13	0.29	3.27	90.30	09.96	09.00
III	62.10±09.97	6.50±0.86	14.60±0.50	0.42	1.80	89.53	26.25	23.51
IV	204.80±15.52	29.20±4.70	57.10±1.05	0.41	1.49	85.74	32.51	27.88
V	907.66±20.41	253.00±9.74	184.40±7.05	0.22	1.08	72.12	28.16	20.31

5. Conclusion

This study provides valuable insights into the oviposition, larval host plant (*B. distachya*), population index, and larval performance of the Tamil Bushbrown (*M. subdita*) in terms of food consumption, growth, and utilization, as well as the duration of its life cycle from egg to adult emergence. More over the plants consumed by larvae significantly influence the performance of the adult butterflies [27]. The data from this research can be effectively used for the conservation and management of this butterfly species in various settings, including parks, zoos, butterfly houses, and natural fields. Butterfly houses, which are popular zoo exhibits, offer significant educational and conservation benefits [28, 29]. Additionally, the study suggests that rearing larvae in captivity at approximately 28±2 °C can produce a sufficient number of adults for restocking areas where the Tamil Bushbrown populations are low [30].

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