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Life history and larval performance of the common sailer butterfly, *Neptis hylas* (Linnaeus, 1758) (lepidoptera: nymphalidae) from Visakhapatnam, east coast of South India

Korupolu Chinna Rao[1], Matala Bhupathi Rayalu[2*], Pappu Kirankumar[3], M Satya Varalakshmi[3], T Venkateswara Rao[3]

[1] Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh, India
[2] Department of Botany, Government Degree College, Kovvur, East Godavari, Andhra Pradesh, India
[3] Department of Zoology, P.R. Government College (A), Kakinada, Andhra Pradesh, India

Abstract
This study presents the first detailed account of the life history of the common sailer butterfly, *Neptis hylas* (Linnaeus, 1758), focusing on larval performance in terms of food consumption, utilization, and the duration of its life cycle on the host plant *Triumfetta pentandra* A. Rich. Conducted in 2023 in Visakhapatnam (17° 42' N, 82° 18' E), South India, the research found that the butterfly completes its life cycle in 27 to 41 days, with an average of 34.00 ± 6.13 days. The stages of the life cycle include the egg stage (4 days), larval stage (16-26 days), and pupal stage (7-11 days). Nutritional indices measured across the instars included Approximate Digestibility (AD) ranging from 49.56% to 97.71%, Efficiency of Conversion of Digested food (ECD) ranging from 4.63% to 34.22%, and Efficiency of Conversion of Ingested food (ECI) ranging from 4.52% to 16.89%. These measurements were taken under controlled laboratory conditions at a temperature of 28 ± 2°C and relative humidity (RH) of 80 ± 10%. The relatively high values of ECD and ECI observed in this study partially explain the ecological success of *N. hylas* in the given environment.

Keywords: Life history, *Neptis hylas*, captive rearing, immature stages, food utilization indices

Introduction

The genus *Neptis* Fabricius, 1807 encompasses a group of butterflies within the family Nymphalidae, commonly referred to as the sailer butterflies. These butterflies are distinguished by their unique wing patterns, which typically feature bold white bands or spots on a darker background, giving them a striking appearance. They are known for their characteristic "sailing" flight pattern, which involves a series of rapid wing flaps followed by glides. The larvae of *Neptis* butterflies feed on a variety of host plants, which vary among species but often include members of the Leguminosae, Combretaceae, and Urticaceae families (Robinson *et al.*, 2001) [21]. Adult butterflies feed on nectar from various flowering plants and also engage in mud-puddling, extracting minerals from wet soil.

There are approximately 162 species of *Neptis* globally, with *Neptis hylas*, commonly known as the common sailer, being one of them. This species is distributed across various regions in Asia. In South Asia, it is commonly found in India, Sri Lanka, and Nepal, thriving in moist deciduous and semi-evergreen forests, gardens, and open woodlands. In India, it is particularly abundant in the Western Ghats and the foothills of the Himalayas (Haribal, 1992) [11]. We provide here the detailed information on the adult nectar resources, immature stages, larval performance on its host plant, *Triumfetta pentandra* A. Rich., and the duration of the life cycle from egg to adult emergence for *Neptis hylas* (Linneaus, 1758).

Materials and Methods

The study was conducted in Visakhapatnam, located on the east coast of South India (17° 42' N latitude and 82° 18' E longitude), during the year 2023. The methodology for captive rearing involved collecting eggs from wild-mated female butterflies, rearing the larvae to adulthood in captivity, and then releasing the adult butterflies or pupae back into the wild, as outlined by Crone *et al.* (2007) [8].

The reproductive activity of the common sailer butterfly, *Neptis hylas*, was monitored regularly between 0800 and 1500 hours at two locations: the Andhra University campus and the Zoo Park area, situated 5 kilometers from the campus. Upon locating adult butterflies, detailed observations were conducted to record the periods of copulation and oviposition. Leaves containing eggs were collected in Petri dishes (15 cm × 2.5 cm depth) and transported to the laboratory. These leaves were then placed in smaller Petri dishes (10 cm × 1.5 cm depth) lined with moistened blotter paper to prevent desiccation. The Petri dishes were kept in a clean, spacious cage fitted with a wire gauge. As no ants were detected, no additional protective measures against egg predation were deemed necessary. The eggs were examined at 6-hour intervals to record hatching times.

Freshly emerged larvae were transferred to clean Petri dishes lined with moistened blotter paper using a camel hairbrush. They were fed daily with a weighed amount of tender leaf pieces from the host plant. Daily collections and weight measurements of faeces and leftover food were recorded. The growing larvae were observed regularly for changes in instar, and their length, breadth, and weight were measured. As the larvae grew, they were provided with larger Petri dishes (15 cm × 2.5 cm depth) to accommodate their increased space requirements. Larval performance, in terms of food utilization indices, was calculated as described by Waldbauer (1968) [28].

All parameters were studied in five replicates using fresh weight measurements. The development from larva to pupa, including characteristics such as color, shape, size, weight, and the timing of adult emergence, were documented. Measurements were taken using millimeter graph paper. The laboratory conditions were maintained at a temperature of 28

± 2°C and a relative humidity of 80 ± 10%, with normal indirect sunlight varying between 12 hours during November to January and 14 hours during June to July.
To describe the adult butterfly characteristics, both laboratory-emerged specimens and those captured in the wild were utilized.

Results

Adult Stage (Figure 1a)

Field characters: The adult butterfly has a wingspan of 50–60 mm. The upper side of the wings is black with distinctive white markings, including triangular streaks and a series of spots on the forewings, and a broad basal white band with an outer series of squarish white spots on the hindwings. The underside is golden brown with similar white markings sharply edged with black lines.

Behavior: This butterfly typically flies with its wings spread flat and glides with minimal effort. During both activity and rest periods throughout the day, it sits with its wings spread flat. However, when roosting, it closes its wings completely.

Nectar host plants: The butterfly obtains nectar from the flowers of *Antigonon leptopus* Hook. & Arn. (Polygonaceae), which blooms from January to April and August to December, and *Lantana camara* L. Var. (Verbenaceae), which flowers year-round with yellow and pink flowers.

Oviposition host plants: The larval host plants are diverse, spanning various families and growth forms, from herbs to large trees. These include:

- *Bombax ceiba*, *Ceiba pentandra* (L.) Gaertn. (Bombacaceae)
- *Canavalia gladiata* (Jacq.) D.C., *Cylista* sp., *Dalbergia sissoo* Roxb. fl., *Flemingia* sp., *Mucuna purpurea* DC ex. Pammel, *Paracalyx scariosa* (Roxb.) Ali, *Pongamia pinnata* (L.) Pierrie, *Spatholobus roxburghii* Benth., *Vigna cylindrica* (L.) Skeels, *Vigna unguiculata* (L.) Walp., *Wagatea spicata* Dalz., *Xylia xylocarpa* (Roxb.) Taub. (Leguminosae)
- *Mappia foetida* Miers (Icacenaceae)
- *Loranthus* sp. (Loranthaceae)
- *Hibiscus* sp., *Thespesia populnea* (L.) Soland. (Malvaceae)
- *Ziziphus* sp. (Rhamnaceae)
- *Helicteres isora* L. (Sterculiaceae)
- *Corchorus olitorius* L., *Elaeocarpus* sp., *Grewia tiliaefolia* Vahl., *Triumfetta* sp. (Tiliaceae)
- *Celtis australis* L. (Ulmaceae)

In the study region, the following were present: *Ceiba pentandra*, *Canavalia gladiata*, *Pongamia pinnata*, *Triumfetta pentandra*, *Helicteres isora*, and *Grewia tiliaefolia*. *Triumfetta pentandra* A. Rich. was used for oviposition.

Description of *Triumfetta pentandra* A. Rich. (Tiliaceae): This plant is an erect annual herb with scarcely branched stems that are slightly pubescent. The leaves are simple, serrate, and three-lobed. The yellow flowers are sessile. The capsule is ovoid with long ascending spines and a line of spreading hairs on the upper side. Seeds are reddish-brown and minutely beaked.

Breeding and egg laying patterns: Mating typically occurs in the morning hours, with the copulating pair often flying together. Females lay eggs primarily between 0900 and 1630 hours. Eggs are laid singly at the tips of leaves on the host plant. The female lands on a selected leaf, reverses along the surface until the abdomen tip reaches the leaf tip, and then deposits an egg.

Egg Stage (Figure 1b)

Each egg is globular, marked with hexagonal pits and thin spines at the pit corners. Freshly laid eggs are green, turning pale green and then yellowish as they mature. Eggs measure 0.90–1.00 (0.96 ± 0.05) mm in length and 0.80–0.90 (0.86 ± 0.05) mm in width, hatching after an incubation period of 4 days. The young caterpillar emerges by eating part of the eggshell and consumes the remaining shell as its first meal. The larval stage includes six instars over 16–26 (21.40 ± 4.46) days.

Larval Stage

Instar I (Figure 1c): This stage lasts 3-5 (4.20 ± 1.09) days, with larvae growing to 2.60–3.10 (2.94 ± 0.19) mm in length and 0.80–1.10 (0.90 ± 0.12) mm in width. The head, measuring 0.50–0.60 (0.52 ± 0.04) mm in diameter, is brown and dotted with short setae. The dark green cylindrical body is covered with small tubercles and short setae.

Instar II (Figure 1d): Lasting 2-3 (2.80 ± 0.44) days, larvae grow to 4.00–5.70 (5.06 ± 0.65) mm in length and 1.00–1.30 (1.20 ± 0.14) mm in width. The head measures 0.70–0.90 (0.82 ± 0.08) mm in diameter. Four pairs of sub-dorsal tubercles on specific thoracic and abdominal segments become more prominent.

Instar III (Figure 1e): This stage lasted for 3-4 days (3.40 ± 0.54). The larvae grew to a length of 5.70-8.30 (7.24 ± 1.03) mm and a width of 1.50-1.80 (1.62 ± 0.16) mm. The head diameter ranged from 1.30-1.70 (1.52 ± 0.17) mm, exhibiting a yellowish-brown coloration dotted with numerous whitish conical tubercles, with the apical pair being the longest. The body displayed a yellowish-green to dull green hue, covered with numerous tiny pale tubercles and obscure, oblique dark patches laterally. The short white-tipped branched spines, yellowish-brown in color, replaced the four pairs of sub-dorsal tubercles observed in the first instar.

Instar IV (Figure 1f): This stage spanned 2-5 (3.80 ± 1.09) days. The larvae attained a length of 9.00-14.00 (11.50 ± 1.91) mm and a width of 1.70-2.60 (2.12 ± 0.38) mm. The head diameter measured between 2.00-2.40 (2.24 ± 0.15) mm. The head capsule became proportionately longer vertically, with the apical spines elongating, becoming more pointed and yellow-brown tipped. The four pairs of sub-dorsal spines grew significantly larger, with the pair on the third thoracic segment being the longest, followed by those on the second thoracic and eighth abdominal segments.

Instar V (Figure 1g): This stage lasted for 3.00 days (3.00 ± 0.00). The fully-grown larvae measured 13.00-19.10 (16.18 ± 2.56) mm in length and 1.90-2.90 (2.52 ± 0.39) mm in width. The head diameter was 2.70-3.10 (2.94 ± 0.20) mm. Other characteristics remained unchanged.

Instar VI (Figure 1g): This stage lasted 3.00-6.00 days (4.20 ± 1.30). The larvae reached a length of 20.20-23.00 (21.70 ± 1.10) mm and a width of 2.90-3.00 (2.92 ± 0.04) mm. The head diameter was 4.20-4.80 (4.46 ± 0.23) mm. The sub-dorsal pairs turned pale pinkish. This instar featured much larger and longer sub-dorsal spines on the third thoracic segment, with the two thoracic pairs pointing forward and the two abdominal pairs pointing backward. By the final day, the body color faded, with whitish areas adopting a pinkish hue.

Pupal Stage (Figure 1i)

Upon ceasing to feed, the fully grown fifth instar contracted and entered the pupal stage, which lasted 7-11 days (8.60 ± 1.67). The pupa measured 7.00-11.00 (13.50 ± 0.41) mm in length and 4.40-5.70 (4.92 ± 0.55) mm in width at the broadest point. The pupa was primarily yellowish, except for the thoracic area on the dorsum, which was pale pinkish-brown. A silvery sheen developed on the body surface a day after pupation. The thoracic segments were notably large, with wing cases dilating laterally. The anterior part extended into a pointed snout. The pupa weighed approximately 109.90-123.90 (116.50 ± 5.28) mg.

Details of all biological observations are provided in Table 1.

Duration of Life Cycle: The development from egg to adult stage took 27-41 days (egg: 4 days, larva: 16-26 days, pupa: 7-11 days).

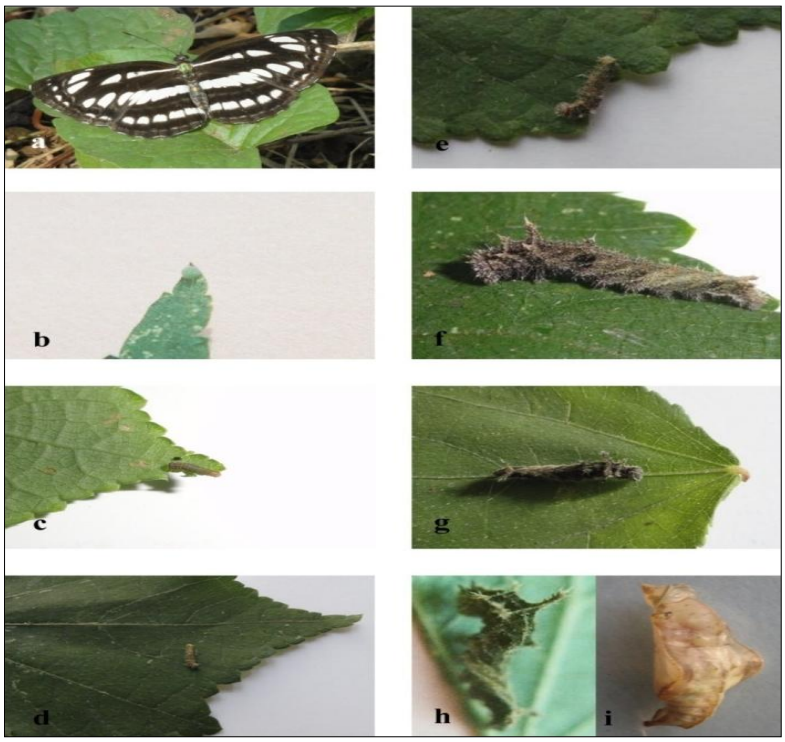

Fig 1: Life stages of *Neptis Hylas*: (a) Adult (b) Egg (c) Instar I (d) Instar II (e) Instar III (f) Instar IV (g) Instar V (h) Instar VI (i) Pupa

Table 1: Biological observations of early life stages of *Neptis hylas* on *Triumfetta pentandra*

Stage	Length(mm)			Width (mm)			Duration (days)	
	Min.	Max.	AV.±S.D.	Min.	Max	AV. ±S.D.	Range	AV.±S.D.
Egg	0.90	1.00	0.96 ± 0.05	0.80	0.90	0.86 ± 0.05	4	4.00 ± 0.00
I	2.60	3.10	2.94 ± 0.19	0.80	1.10	0.90 ± 0.12	3-5	4.20 ± 1.09
II	4.00	5.70	5.06 ± 0.65	1.00	1.30	1.20 ± 0.14	2-3	2.80 ± 0.44
III	5.70	8.30	7.24 ± 1.03	1.50	1.80	1.62 ± 0.16	3-4	3.40 ± 0.54
IV	9.00	14.00	11.5 ± 1.91	1.70	2.60	2.12 ± 0.38	2-5	3.80 ± 1.09
V	13.00	19.10	16.18 ± 2.56	1.90	2.90	2.52 ± 0.39	3	3.00 ± 0.00
VI	20.20	23.00	21.7 ± 1.10	2.90	3.00	2.92 ± 0.04	3-6	4.20 ± 1.30
Total larval period days							16-26	21.40 ± 4.46
Pupa	7.00	11.00	13.50 ± 0.41	4.40	5.70	4.92 ± 0.55	7-11	8.60 ± 1.67

Food Consumption, Growth and Utilization

The quantities of food consumed by each of the six instars and the corresponding weight gains are presented in Table 2. Both food consumption and weight gain increased across the instars. The relationship between weight gain and food consumption is illustrated in Figure 2, indicating a direct correlation. The proportions of total food consumed by successive instars were 5.52%, 6.55%, 10.77%, 12.89%, 22.05%, and 42.21%, respectively. Correspondingly, the proportions of weight gain were 1.79%, 6.13%, 11.06%, 10.66%, 19.10%, and 51.23%. These profiles suggest that the last two instars accounted for the majority of food consumption (over 64.25%) and weight gain (70.33%). Both the Growth Rate (GR) and Consumption Index (CI) decreased progressively with the age of the instars, with GR values ranging from 0.24 mg/day/mg to 0.06 mg/day/mg and CI values from 7.01 mg/day/mg to 0.47 mg/day/mg.

The values of Approximate Digestibility (AD), Efficiency of Conversion of Digested food (ECD), and Efficiency of Conversion of Ingested food (ECI) are also included in Table

2. AD values decreased from 97.71% in the first instar to 49.56% in the sixth instar. ECD values increased from 4.63% in the first instar to 34.22% in the final instar. ECI values did not exhibit a specific trend, ranging from 4.52% to 16.89%.

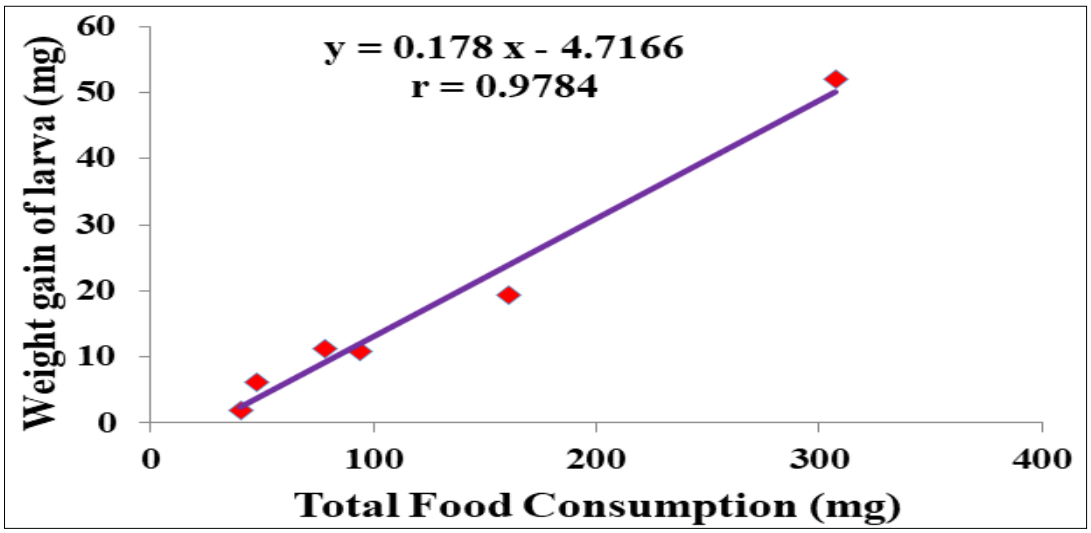

Fig 2: Relationship between food consumption and growth in *Neptis hylas* on *Triumfetta pentandra*

Table 2: Food consumption, growth and food utilization efficiencies of *Neptis hylas* on *Triumfetta pentandra*.

Instar	Wt. of food ingested (mg)	Wt. of faeces (mg)	Wt. gained by larva (mg)	GR (mg/day/mg)	CI (mg/day/mg)	AD (%)	ECD (%)	ECI (%)
I	40.2 ± 11.44	0.92 ± 0.29	1.82 ± 2.06	0.18	7.01	97.71	4.63	4.52
II	47.76 ± 18.40	3.48 ± 2.83	6.22 ± 6.90	0.24	3.59	92.71	14.05	13.02
III	78.50 ± 31.33	9.14 ± 5.09	11.22 ± 4.28	0.19	1.45	88.36	16.18	14.29
IV	93.90 ± 44.50	33.02 ± 4.88	10.82 ± 6.33	0.07	0.82	64.83	17.77	11.52
V	160.70 ± 78.59	71.82 ± 14.43	19.38 ± 15.77	0.06	0.62	55.31	21.80	12.06
VI	307.54 ± 97.98	155.72 ± 17.21	51.96 ± 39.33	0.07	0.47	49.56	34.22	16.89

Discussion

The complete development cycle from egg laying to adult emergence averaged 25.40 ± 4.46 days at approximately 28 ± 2°C. This duration aligns with the expectation of shorter life cycles in tropical butterflies (Owen, 1971) [16]. As temperature significantly affects the duration of each instar and the overall development time (Mathavan and Pandian, 1975; Palanichamy *et al.*, 1982; Pathak and Pizvi, 2003; Braby, 2003) [6, 13, 17, 20], the life cycle duration may vary based on ambient temperatures. However, due to the absence of extreme temperature variations in Visakhapatnam, the life cycle duration remained relatively consistent across overlapping seasons.

Throughout its growth, the larvae consumed an average of over 0.72 g of leaf material, with a marked increase in consumption during the last two instars. This increased consumption during later stages is a common characteristic observed in lepidopterous larvae (Waldbauer, 1968; Mathavan and Pandian, 1975; Scriber and Slansky, 1981; Palanichamy *et al.*, 1982; Selvasundaram, 1992; Gosh and Gonchaudhuri, 1996) [10, 13, 17, 24, 25, 28], compensating for the energy demands of the non-feeding pupal stage (Pandian, 1973) [18]. The Consumption Index (CI) values closely align with the predicted range (0.27 – 6.90, averaging 2.03 mg/day/mg) for forb foliage chewers (Slansky and Scriber, 1985) [26]. The food consumption rate is influenced by the efficiency of converting ingested food into biomass (ECI); as conversion efficiency decreases, the consumption rate increases, and vice versa (Slansky and Scriber, 1985) [26]. The high CI value (7.01) for the first instar likely results from low conversion efficiency, reflected in the low ECI values for the initial instar compared to subsequent ones. Higher growth rates are typically observed in penultimate instars compared to final instars (Scriber and Feeny, 1979) [23], and the growth rates (GRs) of the penultimate and final instars of *Neptis hylas* align with this decreasing trend.

The Approximate Digestibility (AD) values obtained in this study fall within the range (19 – 81%) reported for lepidopterous larvae (Pandian and Marian, 1986) [19]. The average AD percentage exceeds 74.75%, supporting Slansky and Scriber's (1985) [26] assertion that foliage chewers often achieve high AD values, especially when the food is rich in nitrogen and water (Pandian and Marian 1986) [19]. Similar findings have been reported for *Pieris brassicae* (L.) (Yadava *et al.*, 1979) [29], *Ariadne merione merione* (Cramer) (Atluri *et al.*, 2009) [1], *Byblia ilithyia* Drury (Bhupathi Rayalu *et al.*, 2011) [4], *Helicoverpa armigera* (Hübner) (Hemati *et al.*, 2012) [12], *Phalanta phalantha* Drury (Bhupathi Rayalu *et al.*, 2014) [3], *Spodoptera frugiperda* J. E. Smith (Chaithra *et al.*, 2020) [7], and *Zizula hylax hylax* Fabricius (Bhupathi Rayalu and Suneetha, 2022) [5].

The Efficiency of Conversion of Digested food (ECD) values increase from early to later instars (Slansky and Scriber, 1985) [26]. This trend is observed in *Neptis hylas*, with the lowest ECD in the first instar and the highest in the sixth instar. The ECD values are lower than the AD values, a common occurrence (Waldbauer, 1968) [28], indicating low efficiency in converting digested food into body tissues. This poor food utilization can often be attributed to a deficiency in essential nutrients in the food (Bailey and Mukerji, 1976) [2] or factors that increase metabolic energy expenditure (Muthukrishnan, 1990) [15]. The Efficiency of Conversion of

Ingested food (ECI) values closely followed the ECD pattern, ranging from 4.52% to 16.89%, comparable to the expected range for forb foliage chewers (1% – 78%) (Slansky and Scriber, 1985; Hemati *et al.*, 2012; Chaithra *et al.*, 2020) [12, 26]. The ECI pattern mirrored that of the AD, as suggested by Waldbauer (1968) [28]. The relatively high ECD and ECI values in the last two instars (21.80% and 34.22%; 12.06% and 16.89%, respectively) indicate efficient tissue growth and ecological growth efficiency, enabling *Neptis hylas* to thrive successfully in the study environment.

Conclusions

This study offers valuable insights into the oviposition larval host, *T. pentandra*, and evaluates the larval performance in terms of food consumption, growth, and utilization, as well as the complete life cycle duration from egg to adult emergence for the common sailor, *Neptis hylas*. The plants consumed by larvae significantly affect the performance of adult butterflies (Ebada *et al.*, 2023) [9]. Consequently, the findings from this research can be effectively applied to the conservation management of this butterfly species in parks, zoos, butterfly houses, and natural fields. Butterfly houses, which are popular zoo exhibits, possess substantial educational and conservation value (Veltman, 2009; Mathew, 2001) [14, 27]. Additionally, the study suggests that rearing larvae in captivity at approximately 28 ± 2°C can maintain a sufficient stock of adults for repopulating areas with low butterfly populations (Schultz *et al.*, 2009) [22].

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