

Mass emergence of the tropical swallowtail moth *Lyssa zampa* (Lepidoptera: Uraniidae: Uraniinae) in Singapore, with notes on its partial life history

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Abstract: The tropical swallowtail uraniid moth *Lyssa zampa* is known to exhibit seasonal patterns of mass emergence throughout its range. These cyclical patterns of emergences are thought to correlate closely with oscillating host plant availability, as well as with interactions between herbivory and host plant defences. Because little has been reported concerning the biology of this species, the purpose of this paper is intended to serve as a starting point addressing the natural history of *L. zampa* in Singapore. Here we report on an instance of mass emergence of *L. zampa* in Singapore, with brief comments on host plant availability and utilization. We also include a partial life history of the species based on larvae collected from the wild, and reared under controlled conditions.

INTRODUCTION

Uraniine moths of the family Uraniidae comprise some of the most spectacular of the lepidopterans, with several species rivalling tropical butterflies in terms of size, bright colors, and popularity. The subfamily is represented by seven circumtropical genera mostly confined to tropical forests of the Old World (Sick 1937, Minet 1983). These are *Alcides* Hübner (1822), *Chrysidia* Hübner (1823), *Cyphura* Warren (1902), *Lyssa* Hübner (1823), *Urania* Fabricius (1807), *Urapteritra* Viette (1972), and *Urapteroides* Moore (1888). Of these, the Indo-Australian genus *Lyssa* (van Regteren Altena, 1953; Barlow, 1982; Lees & Smith, 1991) includes the largest, and some of the most charismatic of the uraniid moths.

The giant swallowtail moth *Lyssa zampa* (Butler) is widely distributed across tropical South-East Asia, from Indonesia, Singapore, Malaysia, Thailand, and the Philippines. The species is also recorded from southern China, the Andaman Islands, and the Himalayas (Holloway, 1998; Tokeshi & Yoko-O, 2007). Records of the species occurring in East Asia are comparatively less well documented, with sporadic records occurring in Taiwan (Inoue, 1992; Yen *et al.*, 1995; Hepner & Wang, 1996), and at least one vagrant record from mainland Japan (Tokeshi & Yoko-O, 2007).

Throughout its range, the early stages of *Lyssa* are reported to feed on plants of the Euphorbiaceae (Holloway, 1976; Tokeshi & Yoko-O, 2007), particularly those belonging to the genus *Endospermum* Benth (1861). The larvae of *L. zampa* are reported to defoliate their hosts preceding mass emergence and migration of the adults, paralleling the cyclical population explosion and migration of the African *Chrysidia* and New-

World *Urania* (Smith, 1983). However, despite the wide geographical distribution of *Lyssa* and its proclivity for mass emergence and migration, reports have largely been anecdotal, and larval herbivory and hostplant interactions have not been well documented.

Here we report on an instance of mass emergence of the tropical swallowtail moth *L. zampa* in Singapore during the month of June in 2014. We include a partial life history record based on three larvae and a pupa collected from the field that were reared under controlled conditions. In addition, we provide brief comments on interactions with hostplants and nectar utilization in the early and adult stages of *L. zampa* respectively.

MATERIALS AND METHODS

Field surveys, observations, and collections were conducted during the month of June 2014, coinciding with a mass emergence and population explosion of *Lyssa zampa* (as reported in the local media-Chen 2014; Ee 2014). Although outbreaks were also reported from Peninsular Malaysia and Thailand during the same period, data were collected only from Singapore.

Field surveys were conducted in Sime Forest, within the Central Catchment Nature Reserve of Singapore (1.36077° N, 103.81246° E). On 5 June 2014, several trees from the genus *Endospermum diadenum* (Miq.) Airy Shaw were identified to have undergone severe defoliation (Fig. 1). Closer inspection of the canopy revealed the extensive presence of mature lepidopteran larvae agreeing with those of *L. zampa* (Fig. 2; identification based on Barlow, 1982; Holloway, 1989; Leong,

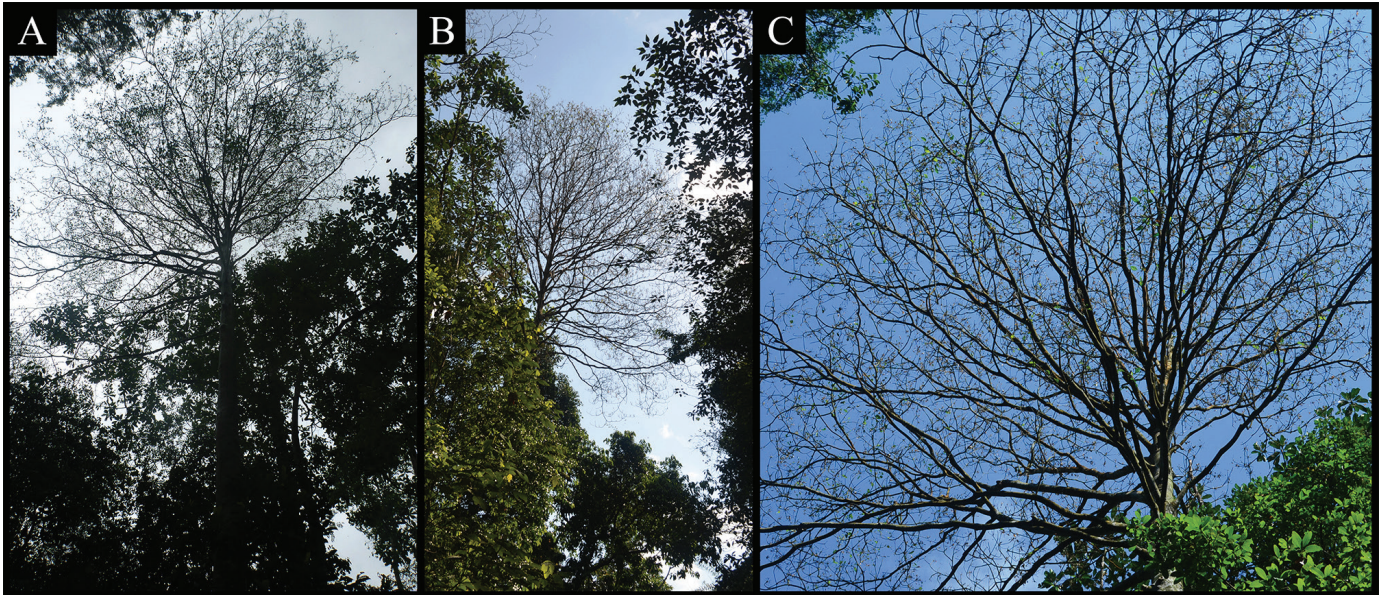


Figure 1. Defoliated trees of *Endospermum diadenum* in Sime forest within the Central Catchment Nature Reserve of Singapore, where congregations of *Lyssa zampa* caterpillars were observed on 5 June 2014. Figures A, B and C are of different trees. Photographs by Anuj Jain.



Figure 2. Late instar caterpillars of *Lyssa zampa* (white arrows) feeding on *Endospermum diadenum*. *In situ* images from Sime Forest, Singapore. Photographs by Anuj Jain.

2014). Three final instar larvae, and a pupa, were measured, collected, and reared in controlled conditions. Measurements were made with digital callipers, recorded to the nearest 0.1 mm. Measurements of larval lengths were made from the tip of the head capsule to the posterior tip of the anal plate. Due

to the variability of body length with larval condition and degree of extension in life, all measurements provided serve only as a general guide of larval size and larval age. Adult body length was measured from the tip of the head to the tip of the abdomen. Body width was measured at the widest point along

Table 1: *Lyssa zampa* larval and pupal rearing records and measurements.

Parameter	Moth 1	Moth 2	Moth 3	Moth 4
Date of collection from wild	5-Jun-14	5-Jun-14	5-Jun-14	19-Jun-14*
Stage at which collected	Final instar caterpillar	Final instar caterpillar	Final instar caterpillar	Pupa
Size when collected (cm)	5.87	5.66	6	2.7
Sex	Male	Male	Female	Female
Date of pupation	7-Jun-14	7-Jun-14	7-Jun-14	-
Date of eclosion	18-Jun-14	19-Jun-14	20-Jun-14	22-Jun-14
Eclosion time	11:05 pm	9:25 pm	3:30 am	7:30 pm
Date of adult moth death	29-Jun-14	23-Jun-14	22-Jun-14	23-Jun-14
Survival as adult in captivity (days)	10.5	4	2	1
Feeding	Fed on nectar solution regularly	Fed occasionally	Refused to feed on nectar solution	Refused to feed on nectar solution
Body length (adult) (cm)	3.2	4.24	3.74	2.7
Wing length (adult) (cm)	5.8	6.1	6.21	4.3
Body width (adult) (cm)	0.67	0.68	0.94	0.55
Proboscis length (cm)	1.7	1.8	1.9	1.32

* Moth 4 is suspected to belong to the same batch of caterpillars as observed on 5 June 2014 and pupated around 7 June 2014.

the abdomen. Wing length was the horizontal distance from the apex of the forewing to the distalmost wing base. Proboscis length was measured from the tip to the extreme base.

Adult moths were maintained in 0.5 m x 0.5 m x 0.5 m cages, and fed with artificial nectar solution specially formulated for butterflies, comprising of a nutritional mix of glucose, fructose, calcium, halide salt and amino acids (Butterfly Nectar 2014) and mixed in the recommended concentration of one tablespoon nectar with three oz. water. Cages were cleaned once each day. A summary of measurements and rearing records are presented in Table 1.

The trees at the location were visited on numerous occasions within the first month of the discovery of host plants and then visited every three months after to record signs of defoliation.

RESULTS

Mass emergence of *Lyssa zampa*: The number of *L. zampa* sightings reported by citizen scientists (Habitatnews, 2020; Singapore Moths, 2020) and systematic moth surveys in 2014 approached nearly 2,000 individuals. Citizen science records were verified by photographs that were submitted online. Records for the years between 2010 to 2019, except 2014, were of less than 40 individuals per year (Jain, A., unpublished data). This suggests a once in a decade (or longer) time period of mass emergence of *L. zampa* in Singapore. However, a longer term dataset would be needed to truly ascertain the observed trend in mass emergence of *L. zampa*.

Field observations: An estimated 15,000 to 20,000 caterpillars were present on each host tree *in situ* on 5 June 2014, most of which were in their later instars. The estimate was based on extrapolation of the number of caterpillars observed using binoculars and photographs taken from selected branches that were closest to the observer, multiplied by the number of prominent branches of each host tree. Given the difficulty in accurate observations and sampling inaccessibility, particularly on obscured terminal branches, the density of larvae should be taken as a conservative estimate. The host trees were then re-examined on 9 June 2014 and were found to be nearly completely defoliated. Silk threads were observed around the main trunk and at the base of the trees with larvae hanging from

them (Fig. 3A-D). The bases of each host tree were covered in frass (Fig. 4A). Several pupae were observed in the leaf litter around the base of the host tree on 19 June 2014 (Fig. 4B). The leaves of the trees grew again within a period of about three months post-dating the mass emergence episode. No sign of mass herbivory-related damage were observed until December 2019.

Early stages in captivity: Eggs were photographed in the field but were not collected for rearing (Fig. 5A). Early instar larvae were observed in the field on the host tree but they could not be collected. The collected final instar caterpillars gradually turned dark brown and pupated on 7 June 2014 (Figs 5B–D). They eclosed successfully on 18, 19 and 20 June 2014 respectively. Of these, the first two moths that emerged were males and the last was a female (Figs 5E; 6A-C). Another pupa, collected and measured from the same locality and batch of larvae, eclosed on 22 June 2014 and was female. From the four moths collected and reared from the same batch above, males were recorded to emerge first (18 and 19 June), with a pupal time of 11-12 days, followed by females (eclosion on 20 and 22 June), with a pupal time of more than 13 days. Three of four moths fed occasionally and survived for less than four days. One moth fed relatively regularly on the nectar solution and survived for 10.5 days (Table 1).

DISCUSSION

Moths of the subfamily Uraniinae can be broadly categorized into two groups: those whose adults are brightly colored and strictly diurnal (*Chrysidia*, *Urania*, and *Alcides*), and those whose adults are somber and nocturnal and/or crepuscular (*Cyphura*, *Urapteritra*, *Urapteroides* and *Lyssa*; Fig. 6D) (Smith, 1983; Kite *et al.*, 1991; Lees & Smith, 1991). Interestingly, this grouping is reflected in the utilization of host plants in the early stages of these genera, with *Chrysidia*, *Urania* and *Alcides* utilizing *Omphalea* (Euphorbiaceae), and *Cyphura*, *Urapteritra*, *Urapteroides* and *Lyssa* restricted to *Endospermum* (Figs 1 & 2). The evolution of diurnality has been linked to the sequestration of alkaloidal glycosidase inhibitors in *Omphalea*-utilizing species, with the bright colors of the adults serving as aposematic coloration (Kite *et al.*, 1991).



Figure 3. Final instar caterpillars of *Lyssa zampa* preparing for pupation. Caterpillars descend from the canopy via silk threads (A & B) onto low lying plants on the forest floor (white arrows; C & D) before finally pupating in the leaf litter. *In situ* photographs from Sime Forest, Singapore. Photographs by Gan Cheong Weei (A) and Anuj Jain (B, C & D).

Foraging behaviour during the day and night however has been recorded for at least *L. zampa* (Fig. 7; Lees & Smith, 1991), suggesting that either diurnal behaviour is less tightly constrained by hostplant preference, or that nectar foraging outweighs the cost of predation. Indeed, adults that were raised in captive conditions took to artificial nectar formula mostly at night (Table 1). In the African *Chrysidia*, fecundity is related to nectar foraging (Smith, 1983), suggesting that nectar is important for reproductive fitness, at least in diurnal species.

Although the phytochemistry of *Endospermum* has not been extensively explored, it is possible that *Endospermum* offers some protection against predators, allowing for diurnal forays in otherwise nocturnal or crepuscular species.

Although our sample size of captive individuals was small, the phased emergence of male *L. zampa* preceding the eclosion of females is noteworthy. In other lepidopteran species, eclosion of males are tightly correlated to females, with the males emerging a day or more earlier in an effort to maximize



Figure 4. A. Frass pellets around the base of the host tree from caterpillars of *Lyssa zampa* feeding in the canopy. B. In situ pupa of *Lyssa zampa* in leaf litter beneath host tree. Photographs by Anuj Jain.

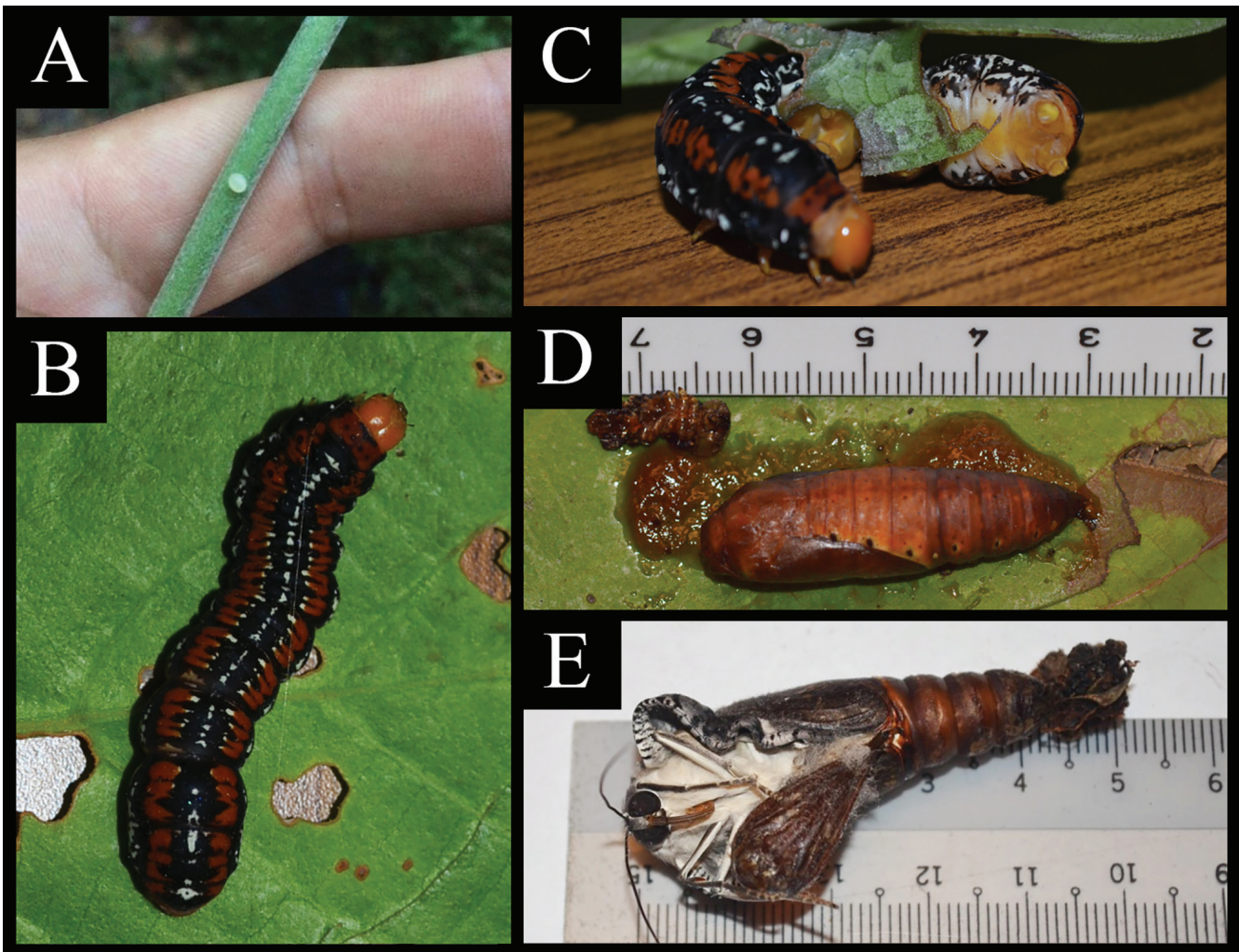


Figure 5. Life stages of *Lyssa zampa*. A. Egg; B, C. final instar larvae dorsal (B), and partial ventral view (C). D. Pupa with exuvia and frass. E. Eclosing adult. Photographs by Craig Williams (A), and Anuj Jain (B, C, D & E).

the encounter of receptive females producing pheromones (Scott, 1974). Whether this applies to *Lyssa*, or other species of uraniine moths, would require further study.

In other uraniine moths, mass emergence of adults is closely followed by a precipitous reduction in numbers over subsequent generations as a result of increased host plant toxicity in response

to herbivory (Smith, 1983). As a response, adults migrate over considerable distances in search of new hosts, often becoming trapped in light-polluted urban environments. A more detailed study of this phenomenon in the context of urban Singapore is currently in preparation by the authors.

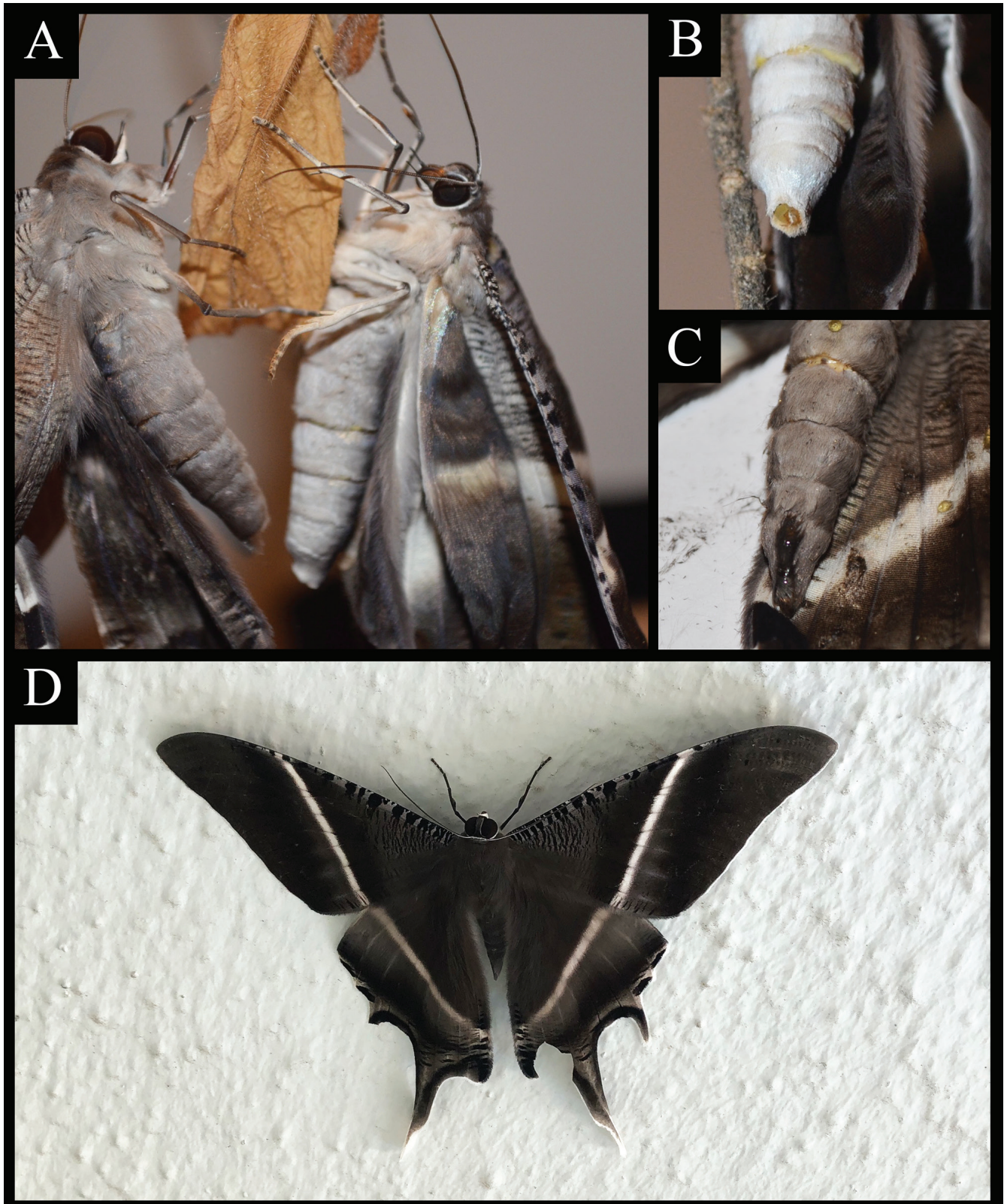


Figure 6. A. Newly eclosed adults of *Lyssa zampa* in captivity. B,C. Magnified view of female (B) and male abdomen (C). D. Adult perched on an urban building in Singapore. Photographs by Anuj Jain.

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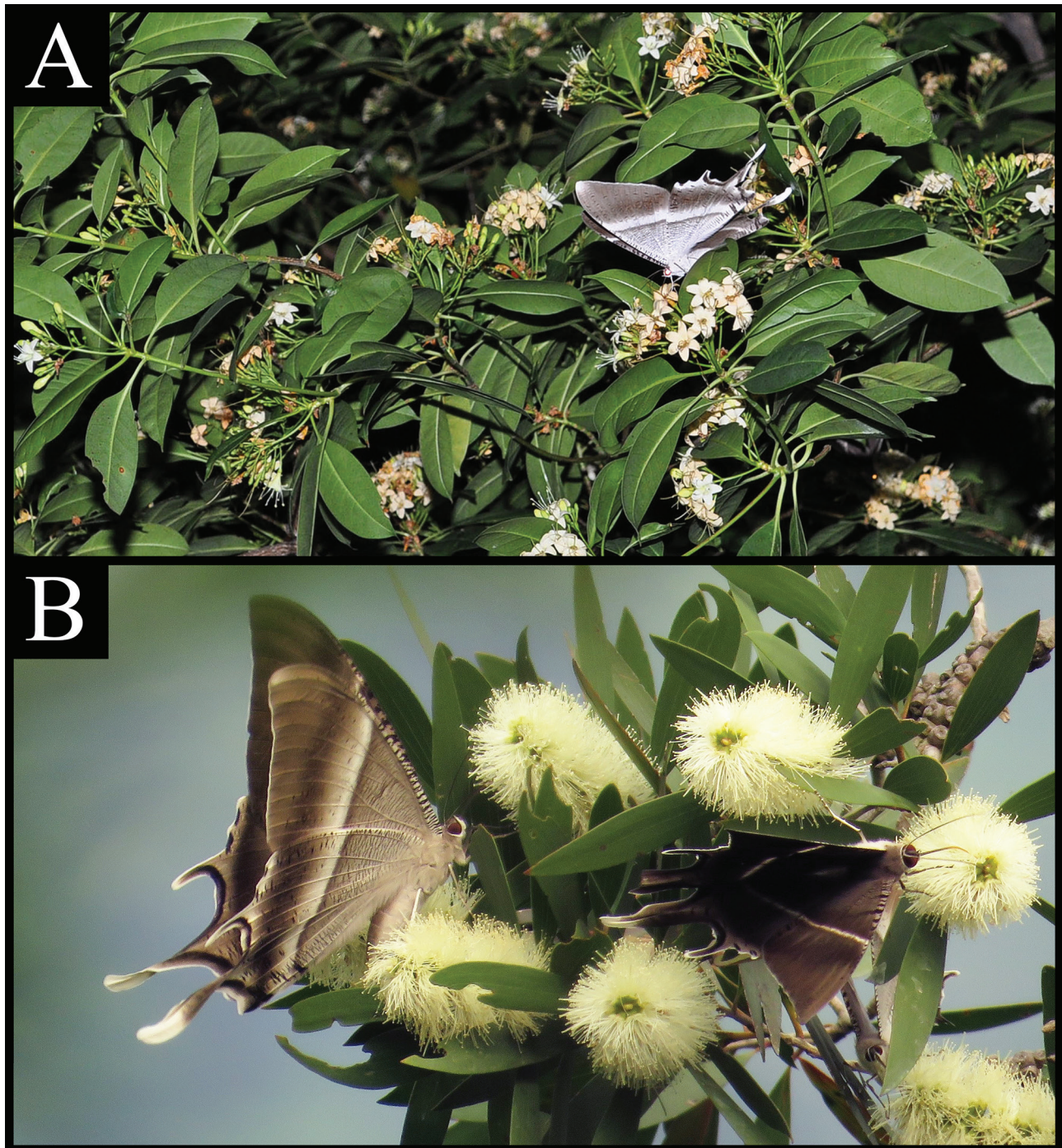


Figure 7. A. Nocturnal feeding behaviour of *Lyssa zampa* observed on 'Tembusu' (*Cyrtophyllum fragrans*) flowers from St. Johns Island, Singapore in May 2014. B. Diurnal feeding behaviour of two *Lyssa zampa* observed on *Acacia* flowers in Mang Gui Kiu, Hong Kong. Photographs by Marcus Chua (A) and Chesity Chan (B).

LITERATURE CITED

- Barlow, H. S.** 1982. *An Introduction to the Moths of South East Asia*. Kuala Lumpur, The Malaysian Nature Society. 306 pp.
- Bentham, G.** 1861. *Flora Hongkongensis: A Description of the Flowering Plants and Ferns of the Island of Hong Kong*. London, L. Reeve. 304 pp.
- Butterfly Nectar.** 2014. *BIRDS choice. Specially formulated for butterflies*. <https://www.amazon.com/Birds-Choice-NP1005-Butterfly-Nectar/dp/B001QLKSL8>. Accessed on 25 August 2019.
- Chen, H.** 2014. *Malaysia swarmed by giant moths*. *BBC News*. 11 June 2014. <https://www.bbc.com/news/world-asia-27758640>. Accessed on 25 August 2019.
- Ee, D.** 2014. *Flurry of sightings of tropical swallowtail moth in Singapore*. *The Straits Times*. 22 May 2014. <https://www.straitstimes.com/singapore/environment/flurry-of-sightings-of-tropical-swallowtail-moth-in-singapore>. Accessed on 25 August 2019.
- Habitatnews** 2020. *Habitatnews: Records of Singapore's fauna and flora*. <http://tinyurl.com/habitatnews-records>. Accessed on 29 February 2020.
- Hepner J. B., Wang, H-Y.** 1996. *Lyssa zampa* in Taiwan (Lepidoptera: Uraniidae). *Tropical Lepidoptera* 7(2): 146.

- Holloway, J. D.** 1998. The moths of Borneo, part 8: Family Castniidae, Callidulidae, Drepanidae and Uraniidae. *Malayan Nature Journal*. 52(1 & 2): 1-155.
- Inoue, H.** 1992. *Uraniidae*, p. 110. In: Heppner, J. B., Inoue, H. (Eds.), *Lepidoptera of Taiwan. Volume 1. Part 2: Checklist*. Gainesville, Association for Tropical Lepidoptera.
- Kite, G. C., Fellows, L. E., Lees, D. C., Kitchen, D., Monteith, G. B.** 1991. Alkaloidal glycosidase inhibitors in nocturnal and diurnal uraniine moths and their respective foodplant genera, *Endospermum* and *Omphalea*. *Biochemical Systematics and Ecology* 19(6): 441-445.
- Lees, D. C., Smith, N. G.** 1991. Foodplant associations of the Uraniinae (Uraniidae) and their systematic, evolutionary, and ecological significance. *Journal of the Lepidopterists' Society* 45(4): 296-347.
- Leong, T. M.** 2014. Metamorphosis of the swallowtail moth *Lyssa zampa*. *Singapore Biodiversity Records* 158-159.
- Minet, J.** 1983. Étude morphologique et phylogénétique des organes tympaniques des Pyraloidea. 1- Généralités et homologues (Lep. Glossata). *Annales de la Société Entomologique de France* 19: 175-207.
- Regteren Altena, C. O. van.** 1953. A revision of the genus *Nyctalemon dalman* (Lepidoptera, Uraniidae) with notes on the biology, distribution, and evolution of its species. *Zoologische Verhandelingen* 19(1): 1-58.
- Scott, J. A.** 1974. Mate-locating behavior of butterflies. *American Midland Naturalist* 91(1): 103-117.
- Sick, H.** 1937. Die Tympanalorgane der Uraniden und Epiplemiden. *Zoologische Jahrbucher, Abteilung für Anatomie und Ontogenie der Tiere* 63: 351-398.
- Singapore Moths.** 2020. <https://www.inaturalist.org/projects/singapore-moths>. Accessed on 29 February 2020.
- Smith, N. G.** 1983. Host plant toxicity and migration in the day-flying moth *Urania*. *Florida Entomologist* 66(1): 76-87.
- Tokeshi, M., Yoko-O, M.** 2007. New record of the tropical swallowtail moth *Lyssa zampa* (Butler) (Lepidoptera: Uraniidae) from mainland Japan. *Entomological Science* 10(1): 103-106.
- Yen, S. H., Yu, H. S., Mu, J. H. and Tan, H. J.** 1995. On *Lyssa zampa* (Butler, 1867) (Uraniidae) from Taiwan. *Japan Heterocerists' Journal* 186: 173-175.