The larval host plant and ant associate of *Nacaduba pavana georgi* (Lepidoptera: Lycaenidae) in Negros, Philippines

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Abstract: The immature stages of the Small Four-Line Blue *Nacaduba pavana georgi* (Horsfield, [1828]) are described and illustrated from Mount Talinis, Negros Island, Philippines. Larvae fed on rambutan flowers (Sapindaceae: *Nephelium lappaceum* L.), a new host plant record, and associated with the ant *Philidris myrmecodiae* (Emery, 1887). We conclude by discussing the known host plant breadth and ant associates of other species of *Nacaduba* Moore, 1881.

Key words: host plant; life history; myrmecophily; *Nacaduba*; Negros; Philippines; rambutan.

INTRODUCTION

The Small Four-Line Blue, *Nacaduba pavana* (Horsfield, [1828]) (Lepidoptera: Lycaenidae), is widely distributed in Afghanistan, Pakistan, India, Nepal, Bangladesh, Myanmar, Thailand, Cambodia, Vietnam, Malaysia, Singapore, and the Philippines (Pinkert *et al.*, 2022), but is typically rare or locally distributed (Hardy & Lawrence, 2017; Corbet *et al.*, 2020). There are two recognized subspecies in the Philippines: ssp. *asaga* Fruhstorfer, 1916 in Palawan, and ssp. *georgi* Fruhstorfer, 1916, which occurs in Leyte, Luzon, Mindoro, Mindanao, Negros, Panay, and Sibuyan (Treadaway & Schroeder, 2012). Despite the wide distribution of the species, there are few records of host plants and none for its ant associates. In their field guide to Philippine butterflies, Hardy & Lawrence (2017) list three host plants for the species: *Andira inermis* (W.Wright) DC. and *Derris trifoliata* Lour. (both Fabaceae), and *Allophylus cobbe* (L.) Forsyth f. (Sapindaceae). No citation is provided for these records, and the first author (P. B. Hardy, pers. comm.) cannot confirm the source of these data, which are not from the authors' own rearing records. It seems likely that the records are from Singapore, as the same three host species are recorded by Tan *et al.* (2011). We are aware of no other host records and no ant associate records in the literature. This paper documents the life history of *Nacaduba pavana georgi* from the Philippine island of Negros, including a new host plant record and the first recorded ant associate, which is identified to the species level.

MATERIALS AND METHODS

An adult female butterfly (Figs. 1-2) was observed in May 2020 in a small, private rambutan plantation (Sapindaceae: *Nephelium lappaceum*) located along the Apolong Trail at the base of Mount Talinis. This area is a mosaic of secondary and primary forests with occasional or seasonal small-scale agriculture (600 m elevation; 9.281838 N, 123.206465 E). Inflorescences with eggs and three larvae were collected and reared.

The specimens were reared indoors in a space that was occasionally air conditioned. The flowers were periodically replaced, especially when showing signs of senescence. Two males and one female emerged from pupae. Voucher specimens of butterflies were deposited in the Rodolfo B. Gonzales Museum of Natural History, Biology Department, Silliman University, Dumaguete City, Negros Oriental, Philippines.

RESULTS

Nacaduba pavana georgi
(Figs. 1-26)

Immature stages:

Egg. We did not observe oviposition, but found eggs on flower buds of rambutan trees (Sapindaceae: *Nephelium lappaceum*) 5-10 m from the ground after observing a female fluttering in the treetops. The area had been modified into a lawn with remnant patches of forest trees, shrubs, and ferns. The sloping terrain of a small rambutan plantation made observations of the treetops easier (Fig. 27). The egg is white and cylindrical, with flat top and bottom (Figs. 3-4), and has a dorsal surface with dentations. The egg laid on the flower buds did not hatch when it was transferred to a container since the buds withered, so we were unable to document the first several instars.

Possibly 4th larval instar. We also found large, onisciform caterpillars in the inflorescences. They were pale green with 10-11 segments and whitish dorsal lines with conspicuous pale brown lines in the middle (Fig. 5). Midway between the dorsal

Figures 1-2 (1 above, 2 below). Adult female of *Nacaduba pavana georgi* preparing to oviposit.

Figures 3-4. Egg of *Nacaduba pavana georgi*.

Figure 5. Possible 3rd to 4th instar caterpillar of *Nacaduba pavana georgi*.

Figures 6-8. A *Philidris myrmecodiae* ant "piggy-back riding" on a *Nacaduba pavana georgi* caterpillar while the latter is searching for food.

Figures 9-12. *Nacaduba pavana georgi* caterpillar tended by five *Philidris myrmecodiae* ants.

Figure 13. Posterior region of *Nacaduba pavana georgi* caterpillar showing the dorsal nectary organ (white arrow) and the tentacle organ (red arrow).

Figures 14-15. Flower inflorescence of rambutan (Sapindaceae: *Nephelium lappaceum*).

and lateral part is a pale green wavy pattern. The body has setae especially anteriorly where they are longer and the body can be wider (appear flatter) or narrower (Fig. 6), likely assisting with moving along floral pedicels/peduncles and among tightly clustered flower buds. The anterior region is rounder while the posterior can be rounder or flatter. The larva was tended by ants.

Last larval instar. The last instar is greenish with tiny brown spots on mid-dorsum and a large brown, diamond-shaped marking on the posterior. The segments are not pronounced due to suture-like impressions. While feeding on flower buds, the larvae periodically secreted a droplet from their dorsal nectary organ (DNO) on the seventh abdominal segment. The ants did not appear to solicit these droplets, for example by antennating the area around the DNO, but eagerly consumed them (Fig. 9).

Prepupa. The prepupa is greenish with a slight purple composition, with brown spots and markings now more pronounced (Figs. 16-17). The larva is slightly shortened and the segments became visible as well as the suture-like impressions. The prepupa is held to the substrate by its cremaster and a silk girdle around the thorax.

Pupa. The late larval stage was documented in June 8, 2020 and pupated after 3 days (11 June). During the first few hours (Fig. 18) the pupa was pale brown, with greenish composition on the regions where wings develop, then turning brownish with dark brown spots (Figs. 19-20). Due to the impressions of the pupa, the future head, thorax, and abdomen are visible, even though the wings and the venation of the wings are visible (except during the later pupal stage). Adults emerged after 5-7 days.

Habitat: *Nacaduba pavana georgi* is found in primary and secondary forest at middle elevations of Mount Talinis, where rambutan trees are commonly planted. Females were seen flying around treetops, laying eggs on flower buds, and sipping rambutan nectar. Another female (Fig. 25) imbibed nectar from a nearby Tree-vine (*Leea manillensis* Walp. (Vitaceae)). We observed a male (Fig. 26) puddling at a nearby creek around 10:00 hrs and males were observed occasionally feeding on Tree-vine flowers from April to June (C. Chafer, pers. comm).

Hostplant: On Negros, the larvae were documented feeding on the inflorescences of rambutan (Sapindaceae: *Nephelium lappaceum*). This tree species is native to Southeast Asia and is widely cultivated for its fruit.

Ant associates. *Philidris myrmecodiae* (Emery, 1887) (Dolichoderinae) ants tended late larval instars; early larval instars were not observed. Identification of the ant was based on characters in Shattuck (1992) including the relative anterior position of the compound eye. During the middle instars, a single ant was observed "piggy-back riding" on the caterpillar (Figs. 6-8). It is possible that the ant, riding the caterpillar while it was foraging, was waiting for the caterpillar to find an inflorescence. Once the caterpillar starts feeding, the ant returns to its nest, leaving scent trails to recruit others from its colony. While feeding, the caterpillar was tended by approximately five ants. When threatened (as when the first author got close to take photographs), the ants seemed to assume defense positions in

Figures 16-17. Prepupa of *Nacaduba pavana georgi.*

Figures 18-20. Early and later stages of the pupa of *Nacaduba pavana georgi*.

Figures 21 (left) **- 22** (right). Upperside and underside of male *Nacaduba pavana georgi*.

Figures 23 (left) **- 24** (right). Upperside and underside of female *Nacaduba pavana georgi*.

which one ant stood on the head, another on the posterior, two on the dorsum, and another collected honeydew from the dorsal nectary organ (Figs. 9-13).

DISCUSSION

Nacaduba seems to be a genus of generalist herbivores that facultatively associate with ants. Of the 46 recognized *Nacaduba* species, only 14 have host plant records and 6 have records of ant associates, though the true number of ant-associated species in this genus is likely higher (Robinson *et al.*, 2020, 2021; Fiedler, 2021; Pierce & Dankowicz, 2022b). Eleven of the species with host plant records include Fabaceae in their host repertoire, which seems to be the most commonly eaten host plant family of the genus. Further, most *Nacaduba* species with known life histories appear to be polyphagous. For example, *N. kurava* (Moore, 1857) larvae feed on plants in 9 families from 6 orders, *N. berenice* (Herrich-Schäffer, 1869) larvae consume plants in 7 families from 7 orders, and *N. hermus* Felder, 1860 larvae feed on plants from 6 families in 4 orders (Robinson *et al.*, 2020).

Larval ant associations are recorded sporadically throughout the Lepidoptera, but are most common in the family Lycaenidae. In a typical association, a small number of ants "stand guard" over a butterfly larva as it feeds, attempting to protect it from predators and parasites, while the larva plies the ants with nutritious secretions from the dorsal nectary organ and apparently also from its cuticle (Pierce, 1984; Pierce *et al.*, 2002; Daniels *et al.*, 2005; Pierce & Dankowicz, 2022a). The DNO secretions of at least one lycaenid species alter the brain chemistry of their ant associates by decreasing dopamine, which reduces the ants' locomotory ability and causes them to remain near the larva (Hojo *et al.*, 2015). Some lycaenid-ant associations are obligate, meaning that larvae are always found with ants in the field, while others are facultative: larvae are occasionally observed without ants in nature. Pierce & Dankowitz (2022b) record 881 species of ant-associated lycaenid butterflies, and examination of their data and the tables of Fiedler (2021) suggest that this report is the first record of ant association in *Nacaduba pavana*.

Most other *Nacaduba* species that have been observed as larvae in the field seem to be facultatively myrmecophilous. In Sri Lanka, for example, *N. berenice*, *N. hermus*, *N. sinhala* (Ormiston, 1924) associate with *Technomyrmex* Mayr, 1872 spp. (Dolichoderinae), and *N. pactolus* (C. Felder, 1860) associates with *Camponotus* Mayr, 1861 sp. (Formicinae) (van der Poorten & van der Poorten, 2016). *Nacaduba kurava* and *N. calauria* (C. Felder, 1860) larvae have also been observed with unidentified ants. All of these interactions appear to be facultative, as larvae are sometimes found without ants (van der Poorten & van der Poorten, 2016). *Nacaduba berenice* is also reported to be facultatively myrmecophilous in Australia, where it has been recorded in association with *Camponotus* sp., *Oecophylla smaragdina* Fabricius, 1775, *Paratrechina* Motschulsky, 1863 sp., *Polyrhachis rufifemur* Forel, 1907, *P. vermiculosa* Mayr, 1876 (all Formicinae), and *Crematogaster* Lund, 1831 sp. (Myrmicinae) (Braby, 2000). In Papua New Guinea, *N. berenice* larvae are facultatively associated with

Figure 25. A female *Nacaduba pavana georgi* feeding on the flowers of a Tree-vine plant (*Leea manillensis*). Photograph by C. Chafer.

Figure 26. A male *Nacaduba pavana georgi* puddling on the side of a creek. Photograph by C. Chafer.

Figure 27. The first author documenting the larvae of *Nacaduba pavana georgi* on a rambutan tree. Photograph by J. H. Oracion.

an unidentified ant in the subfamily Dolichoderinae and *Anoplolepis gracilipes* F. Smith, 1857 (Formicinae) (Parsons, 1998).

Philidris Shattuck, 1992 ants frequently form mutualistic partnerships. *Philidris myrmecodiae* was originally described as a subspecies of *P. cordatus* (Emery, 1887), and this latter species associates with larvae of *Hypochrysops apollo* Miskin, 1891, *H. elgneri* (Waterhouse & Lyell, 1909), *H. narcissus* Fabricius, (1775), *H. theon* Felder & Felder, 1865, *Jamides cyta* (Boisduval, [1832]), and *Ogyris aenone* (Waterhouse, 1902) (all Lycaenidae) in Australia (Braby, 2000). The specific epithet *myrmecodiae* suggests this ant species also associates with *Myrmecodia* spp. (Rubiaceae), which are epiphytic ant-plants endemic to Southeast Asia and Australasia. Arboreal ants, including *Philidris cordatus* (Huxley, 1978), live in the modified rhizomes of *Myrmecodia* Jack, with mutual benefits for both parties (Janzen, 1974; Wallace, 1989).

Interactions between lycaenid larvae and ants are highly variable. Most are presumed to be mutualistic, including the association documented here. Other relationships can be parasitic, with butterfly larvae engaging in trophallaxis with the ants or consuming their larvae or Hemiptera symbionts (Pierce & Dankowitz, 2022b). The ability to make strong conclusions about evolutionary patterns of butterfly-ant associations, and to some extent butterfly-host associations, are constrained by the dearth of natural history observations recording larval biology (Kaliszewska *et al.*, 2015; Kawahara *et al.*, 2023). Observations like ours, which document novel interactions by identifying all organisms to the species or subspecies level and vouchering specimens in public museums, are necessary to fully understand the evolution of insects and their interactions with other organisms.

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