Notes on the natural history of six nymphalid butterfly species from an Ecuadorian dry forest

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Abstract: We provide notes on the natural history and images of the immature stages of six butterfly species inhabiting west Ecuadorian dry forest, including *Magneuptychia libye*, *Memphis artacaena*, *Scada zemira, Opsiphanes cassina fabricii*, *Heliconius erato cyrbia* and *Dryas iulia moderata* (Lepidoptera: Nymphalidae). Five of these species have no previously published life history information from this region and habitat, and one species is an endemic. We report two new generic host plant records, *Hieronyma* (Euphorbiaceae) for *Memphis*, and *Piresia* (Poaceae) for *Magneuptychia*. Eggs or caterpillars of all species were collected in primary forest and reared to adult in the laboratory. The study was carried out in the Bosque Seco Lalo Loor Reserve located in western Ecuador, from June through August 2013, and was part of a capacity-building program to train local people in butterfly research, which included collection and rearing components.

Keywords: dry forest, western Ecuador, Nymphalidae, natural history, Lepidoptera.

INTRODUCTION

Nymphalid butterflies uses a wide range of host plants and some taxa are specialized feeders, such as the Ithomiini which feed almost exclusively on Solanaceae (Drummond & Brown, 1987; Beccaloni *et al*., 2008) and Heliconiinae which feed on Passifloraceae (see review in Gilbert, 1991; Rodrigues & Moreira, 2002; Beccaloni *et al*., 2008). Nevertheless, despite the abundance, large size and relative conspicuousness of many Nymphalidae, knowledge of their immature stages remains very fragmentary. Even for most species that been reared and have had their life histories published, we have little understanding of local or regional variation in immature morphology, host plant use, life history parameters, behavior or ecological interactions (e.g., Rodrigues & Moreira, 1999; 2002; Hill *et al*., 2012). In particular, some regions with distinctive but restricted habitats merit special attention, since knowledge from such regions is usually more limited and may be significant in understanding adaptations to varying environments. We believe that life history information from such regions therefore merits publication even if it is incomplete, and such is the case with this study.

West Ecuadorian dry forest is one of the most restricted and important areas of endemism worldwide (Davis *et al.*, 1997). With less than 5% of forests remaining and 70% of the people poor, sustainable development is urgently needed to improve living standards and reduce impacts on remaining natural habitat (Checa, 2008). In this region, climate change, along with agricultural expansion, is also a major challenge for conservation because of the positive feedback between forest fragmentation and drought (Laurance & Williamson, 2001).

Several development projects are being conducted in the region, and one implemented by our research group focused on a feasibility analysis of a butterfly farming initiative as a tool for promoting conservation and sustainable development for rural communities. Butterfly farming involves rearing butterflies in captivity and marketing them, mainly to local or international exhibitions; such exhibitions constitute an industry with a global turnover of US$ 100 million (Mpand *et al.,* 2014). A close link exists between butterfly farming and forest conservation, since farmers rely on natural forests to obtain butterfly species and seedlings/seeds of host plants to develop their captive populations, and to maintain genetic diversity by periodically bringing in wild individuals of butterflies and plants to mix with captive populations (Morgan-Brown *et al.*, 2010).

Important constraints on the development of butterfly-farming projects in western Ecuador are the lack of biological knowledge about the local butterfly species and the limited technical capacities of local people to do research on butterflies and manage captive populations. We therefore conducted a training program with local people to teach them techniques for butterfly collection (using bait traps and nets) and rearing immature stages. Here, we report observations on the natural history of the immature stages of several butterfly species reared as part of this project, while additional results from the feasibility study and ecological analyses are being published elsewhere (see Checa *et al.*, 2014). All species found were reared, not only those of commercial interest, since training local people in appropriate methods was a primary goal. The training program included locating eggs on host plants, finding females and observing how and where they oviposit, rearing techniques, and establishment of a host plant nursery. This paper includes information on the natural history of six nymphalid species, including five with no previously published life history information from Ecuadorian dry forest, of which one species is endemic to this biogeographic region.

METHODS

Study area: The study was conducted in the Bosque Seco Lalo Loor Reserve BSLLR (80º10'W, 0º6' S), in Manabí province in northwestern Ecuador. The reserve is located at the transition between moist and dry forest (Clark *et al.*, 2006), a vegetation type that is nearly extinct in the region due to deforestation (Clark *et al.*, 2006).

The reserve has 200 ha of preserved forest and the altitude ranges from 10 to 300 m. The dry season may last 5 months, resulting in all trees of the lower hillsides and the coastal plain being deciduous (Clark *et al.*, 2006), in addition to those of some ridge tops, due to their greater exposure to direct sunlight and the resultant higher variability in temperature and humidity. Moist evergreen forests are also present, over hillsides and in the valleys between ridges. The Ceiba Foundation administers the BSLLR and pursued its creation in 2004, in order to complement broader efforts to form a corridor to connect several forest fragments in the region. Through several conservation agreements, up to 12,000 acres were part of this corridor by 2010 (Ceiba Foundation, pers. comm.).

Rearing methods: The study was carried out from June-August 2013. Butterfly immature stages were collected in the forest and reared at the reserve station at ambient temperature and humidity, an environment very similar to the forest interior since air-conditioning was not available. Immature stages were found by observations of female butterflies ovipositing or by searching potential host plants. After collection, immature stages were transported to the station and kept in plastic containers until adult emergence (see Mulanovich, 2007). Containers were washed with soap and water every day to prevent viral and bacterial infections, and caterpillars were fed daily with fresh host plant foliage. We recorded observations on development time and morphology and photographed life stages. Host plants were identified from photographs taken in the field since permits for collection were not available.

RESULTS AND DISCUSSION

Magneuptychia libye (Linnaeus, 1767)
(Nymphalidae, Satyrinae, Satyrini)

A female was observed ovipositing 2 eggs, one on the underside and one on the upperside of leaves of *Piresia* sp. (Poaceae, identified by H. Mogollón). The host plant was next to a trail which runs along a stream in forest understorey. This represents the first published observation of the genus *Piresia* as a host plant for *Magneuptychia* Forster, 1964 (see Beccaloni *et al.*, 2008).

Egg: Single, white, spherical, smooth, black head capsule visible before hatching (Fig. 1a).
Early instars (Fig. 1b): Head dark brown with two short diverging scoli on vertex, colored beige dorsally; stemmata black. Body greenish beige, covered with white spots. Two reddish brown subdorsal longitudinal stripes along each side of body. Two short caudal filaments projecting from terminal abdominal segment. Legs pale greenish beige. No observations available for later instars.
Pupa: Light brown mottled with dark brown; squat, very short, rounded ocular caps. Cremaster dark on ventral portion.
Duration: egg: 7 days; larval stages: 47 days, pupa: 15 days (n= 1).

The early instar larva described here from western Ecuador resembles the first instar larvae described by Kaminski & Freitas (2008) from Brazil. Both have two reddish brown subdorsal longitudinal stripes along each side of body and two short caudal filaments projecting from the terminal abdominal segment. However, the Ecuadorian individual has a greenish beige coloration along all body segments, whereas Brazilian individuals are green on the thoracic segments. The pupa is very similar for both populations. In terms of the duration of the life cycle, the Ecuadorian individual took longer to develop from egg to adult, a total of 69 days compared to 59-60 days for Brazilian individuals. Comparisons with Costa Rican larvae (Janzen & Hallwachs, 2018) were not possible since photographs only of late instars were available for those individuals. In the case of the pupae, the Costa Rican individuals showed the thoracic and abdominal areas conspicuously darker compared to the the Ecuadorian individual.

Host plants reported for this species include two genera of Poaceae in Costa Rica, namely *Panicum* (see Beccaloni *et al.*, 2008) and *Ichnanthus pallens* (Janzen & Hallwachs, 2018), and five more genera of Poaceae and two of Cyperaceae in Trinidad (see Beccaloni *et al.*, 2008). Larvae have also been reared in laboratory conditions with *Axonopus compressus* (Poaceae) (Kaminski & Freitas, 2008). Note also that Costa *et al*. (2016) regarded *M. libye* of Lamas (2004) as constituting two species, without providing a very clear diagnosis or revision of the distribution of these putative species. The identification of the species reared by us may therefore change as the taxonomy of this species is investigated in more depth.

Memphis artacaena (Hewitson, 1869)
(Nymphalidae, Charaxinae, Anaeini)

Four last instar larvae were found on shrubs (1-1.5 m tall) of *Hieronyma macrocarpa* (Euphorbiaceae, identified by H. Mogollón); this is a previously unreported host plant genus for *Memphis* Hübner, [1819] (see Beccaloni *et al.*, 2008). Host plants were only found on or close to the ridge top, which is deciduous forest habitat. However, a trapping study of adults over 4 consecutive years found a similar number of individuals in ridge top and valley (evergreen forest). Larvae and adults were collected only in May and July. Larvae were found inside tubular shelters built by rolling leaves with silk, with an opening at the top of the shelter to allow caterpillars to leave for feeding.

Last instar: Head black with beige vertical bands forming inverted 'V' shapes on frons. Thorax and abdomen olive-green with black and white lateral spots on segment A2 (Fig. 2). Lateral black bands on segments A5-A7 and three abdominal segments black dorsally. Body tapers posteriorly. Two stubby black epicranial horns and yellow and beige knobby protuberances (varying in size) scattered around dorsal and lateral areas of head.
Pupa: Pupa pale greenish brown with patches of dark brown. Cremaster black. Wingpads lined along anal and distal margins with white. Abdomen area with three lines of black spots running longitudinally in the abdomen area.
Duration: pupa: 11 days (n= 4).

Larval and pupal stages are very similar in terms of coloration and form between individuals from western Ecuador and Costa Rica, despite the populations in these countries being geographically isolated (photographs available in Janzen & Hallwachs, 2018). However, Ecuadorian larvae have yellow and beige knobby protuberances scattered around the dorsal

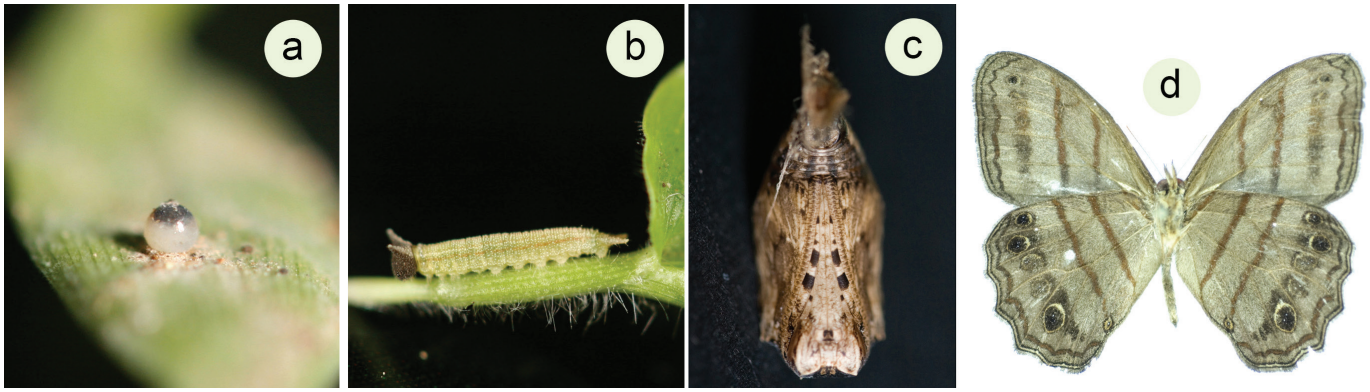

Figure 1. Life cycle of *Magneuptychia libye*: (a) egg, lateral view, (b) early instar, lateral view, (c) pupa, ventral view, and (d) ventral view of an adult male.

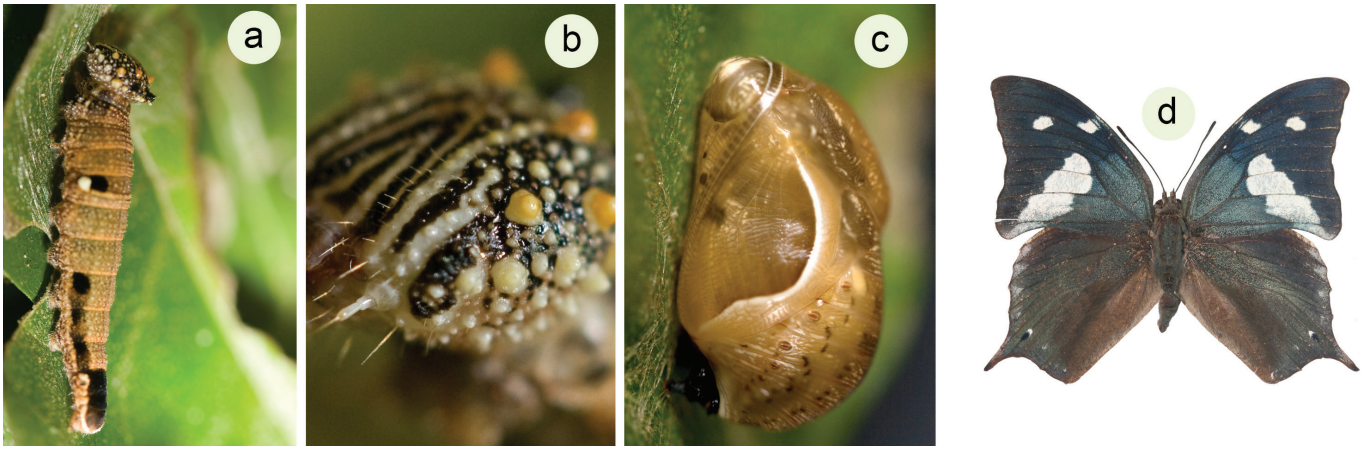

Figure 2. Life cycle of *Memphis artacaena*: (a) last instar, lateral view, (b) last instar head capsule, frontal-lateral view, (c) pupa, lateral view, and (d) dorsal view of an adult male.

and lateral areas, but these protuberances are red, orange and yellow in Costa Rican individuals. Larval shelters also appear to be very similar in both populations.

The reported host plant in Costa Rica is *Croton schiedianus* (Euphorbiaceae) (DeVries, 1987; Janzen & Hallwachs, 2018). Other reported host plants for *Memphis* include *Croton* (Euphorbiaceae), *Piper* (Piperaceae) and Lauraceae (*Camphoromoea, Goeppertia, Nectandra* and *Ocotea*) (Neild, 1996; Beccaloni *et al.*, 2008). The natural history of the majority of *Memphis* species is unknown or poorly described (but see Dias *et al.*, 2010a,b; Alfaro & Murillo-Hiller, 2014).

Scada zemira (Hewitson, 1856)
(Nymphalidae, Danainae, Ithomiini)

A single female was observed ovipositing one solitary egg on a small seedling of *Solanum* sp. (Solanaceae, identified by H. Mogollón) inside closed forest. The egg was laid on the underside of the leaf of a seedling 40 cm tall. Although there were several seedlings of the same species in the vicinity, the female did not oviposit more eggs.

Egg: White and barrel-shaped (Fig. 3), laid singly.
Early instar: Head black, body green with pale green lateral semi-circular projections on each abdominal segment.
Last instar: Head dark orange with black stemmata, body dark olive green with paler gray dorsal stripe and collar on the prothorax, yellow laterally with lateral series of yellow tubercles. Legs and prolegs very pale green.
Duration: egg: 5 days, larvae: 20 days, pupa: 10 days (n= 1).

Host plants for *Scada* are all in *Solanum* (Solanaceae) (Beccaloni *et al.*, 2008). The life history of *S. zemira*, a species endemic to moist and dry forests of western Ecuador to northwestern Peru, has not previously been described, and indeed there is also very limited information on the immature stages of other species in the genus (Brown & Freitas, 1994).

Opsiphanes cassina fabricii (Boisduval, 1870)
(Nymphalidae, Satyrinae, Brassolini)

A female was observed ovipositing on a small palm (70 cm tall) of *Weittinia* sp. (Arecaceae, identified by H. Mogollón) in an open area adjacent to both pasture and a main road. Six eggs were oviposited at the base of leaves on the underside. Eggs and subsequent immatures were not collected but were left to develop on the host plant, with the exception of two last instar larvae, which were taken and reared in the lab.

Last instar: Head brown with beige on middle and lateral parts of face; three pairs of horns, one on vertex brown with black at tip and longer than rest, others beige; many setae around mandibles. Body yellowish green with light green dorsal stripe bordered thinly with yellow and red subdorsal stripes, turquoise sublateral stripe (Fig. 4), brown collar on thoracic segments, terminal segment with yellowish caudal filaments that are turquoise dorsally with black tips.
Pupa: Pupa pale green, without spines or projections, white spot in wingpad and cremaster white on ventral portion.
Duration: egg: 12 days, larval stages: 35 days, pupa: 16 days (n= 1).

Although there are broad similarities between larvae of *O. cassina fabricii* from western Ecuador and Costa Rica (see

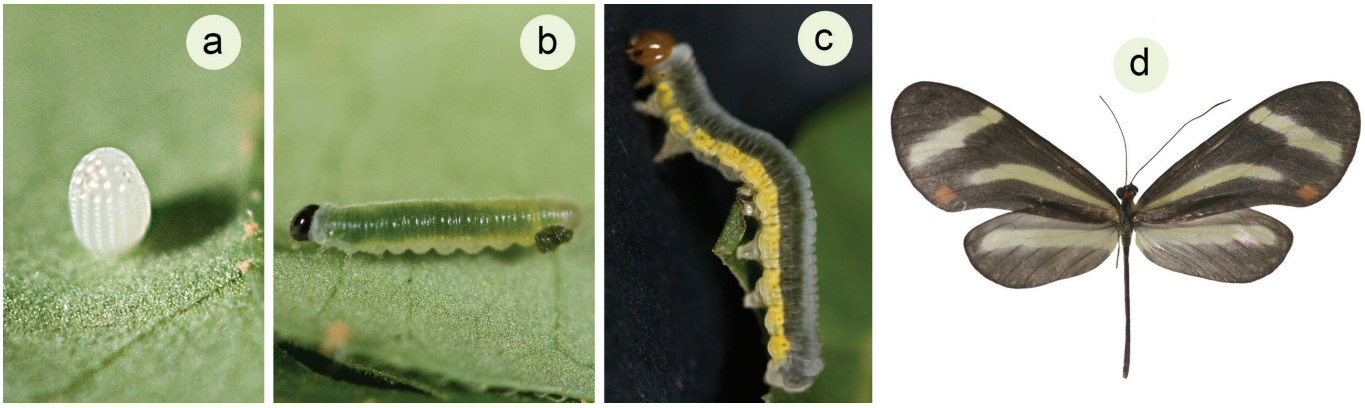

Figure 3. Life cycle of *Scada zemira*: (a) egg, lateral view, (b) early instar, dorso-lateral view, (c) last instar, lateral view, (d) dorsal view of an adult male.

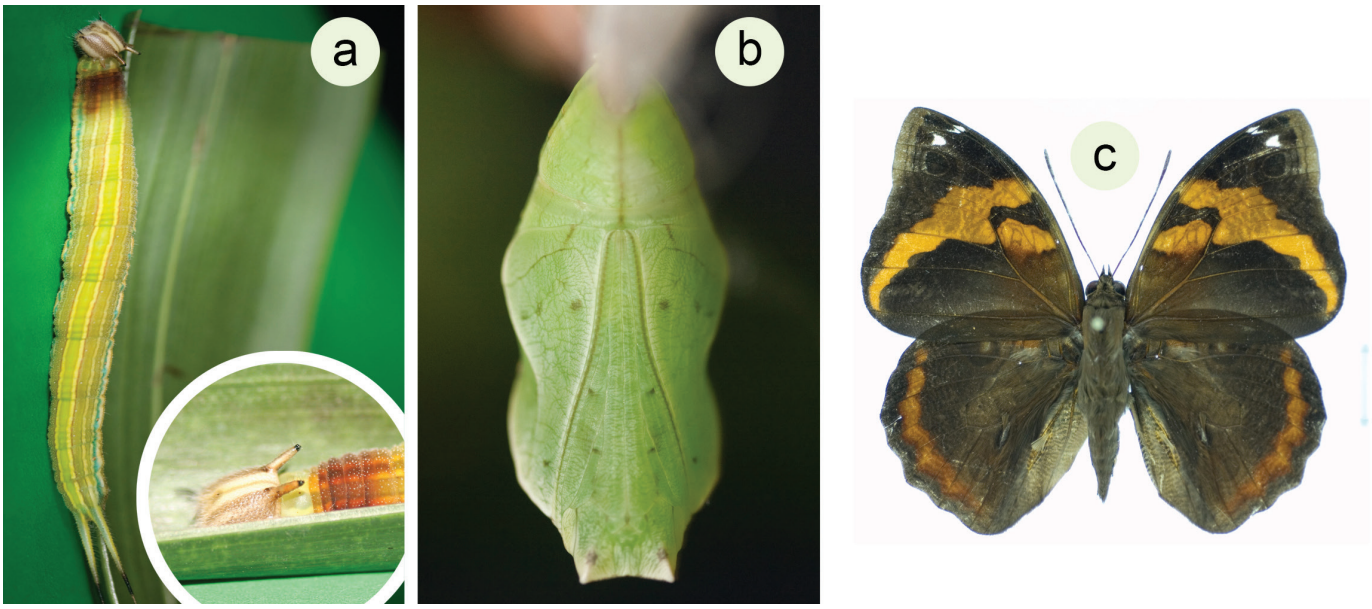

Figure 4. Life cycle of *Opsiphanes cassina fabricii*: (a) last instar, dorso-lateral view, and magnified dorso-lateral view of head capsule, (b) pupa ventral view and (c) dorsal view of an adult male.

Chacón *et al*., 2012), there are some color pattern differences. Both larvae have a yellowish green body with a light green dorsal stripe, but this stripe is bordered thinly with green and yellow subdorsal stripes in Costa Rican individuals. In the Ecuadorian individual, the dorsal stripe is bordered thinly with yellow and red subdorsal stripes. Moreover, the specimen included in Chacón *et al.* (2012) lacks the brown collar on the thoracic segment of *O. cassina fabricii* from western Ecuador; however, it seems likely that this may be a character related to the larval age. The pupae of both populations are very similar.

Host plants recorded for this species include *Centrosema sagittatum* (Fabaceae) (Janzen & Hallwachs, 2018) and other species of Agavaceae, Cannaceae, Lecythidaceae, Musaceae and Palmae (Beccaloni *et al*., 2008). In urban areas, host plants include the palms *Brahea saldorensis, Royotonea regia, Cocos* sp., *Bactris minor* and *Guillielma utilis* (Bristow, 1991). The caterpillars are a pest of African oil palm plantations in Central America (Hernández-Martínez *et al.,* 2016).

This is a common and widespread species in western Ecuador, and it is part of a complex of species (Chacón *et al.,* 2012). As a result, some authors (see Janzen & Hallwachs, 2018; Chacón *et al.,* 2012) refer to this taxon as *Opsiphanes fabricii* (Boisduval, 1870), but the taxonomy used by Bristow (1991), *Opsiphanes cassina fabricii*, is used in this study, since a comprehensive taxonomic review has yet to be done. Several years of butterfly monitoring in western Ecuador have resulted in the collection of phenotypes apparently referable to *O. jacobsorum* Chacón & Montero, 2012, *O. cassina barkeri* Bristow, 1991 and *O. cassina fabricii*, at least. These phenotypes likely represent distinct species, as supported by DNA barcoding (Checa, unpublished data), but the correct nomenclature requires further study. To this end, morphological characters from the larvae may potentially be significant.

Heliconius erato cyrbia Godart, 1819
(Nymphalidae, Heliconiinae, Heliconiini)

Caterpillars were found along trails on a ridge top (deciduous forest) and in a forest gap next to a stream in a valley (evergreen forest). Larvae used *Passiflora punctata* and *P. suberosa* (Passifloraceae, identified by H. Mogollón) as host plants. These host plants were growing as vines over other plant species 0.5-2 m tall.

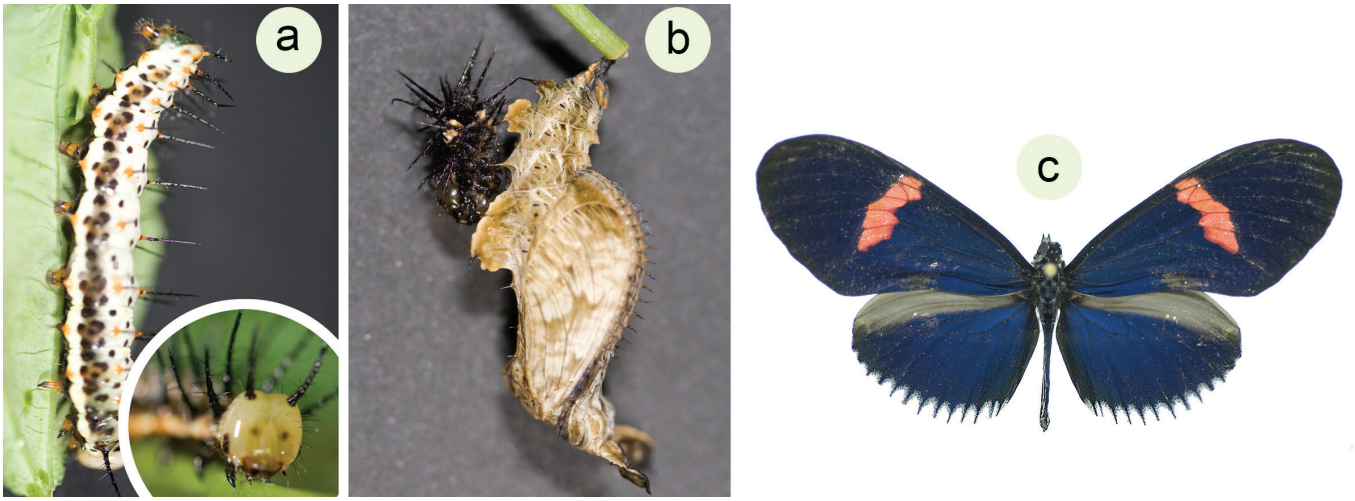

Figure 5. Life cycle of *Heliconius erato cyrbia*: (a) last instar, lateral view and magnified frontal view of head capsule, (b) pupa with the last molt attached, lateral view and (c) dorsal view of an adult male.

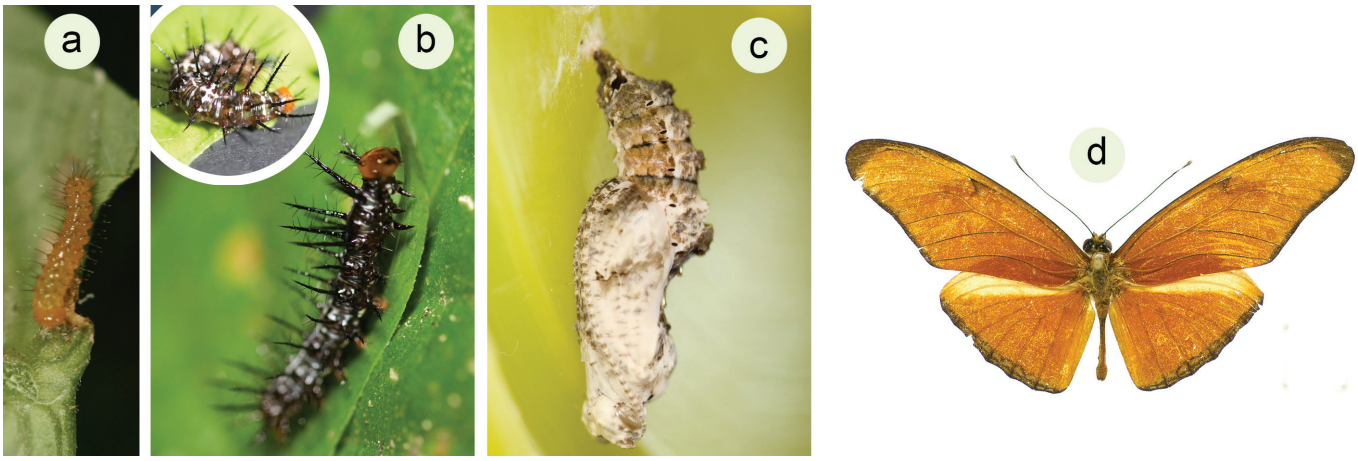

Figure 6. Life cycle of *Dryas iulia moderata*: (a) early instar, dorsal view, (b) last instar, lateral and dorso-lateral views, (c) pupa, lateral view and (d) dorsal view of an adult male.

Last instar: Head pale yellow with dark scoli and setae. Body white with black and orange spots (Fig. 5), with black scoli emerging from orange spots and covering the body dorsally and laterally. Black secondary setae and verrucae along body and prolegs with light orange coloration.
Pupa: Pupa brown with gold highlights. Cremaster black with orange ridges on final abdominal segment, many short black spines on antennae and five pairs of black spines on abdomen. Long cephalic projections present.
Duration: egg: 4-5 days, larval stages: 14-16 days, pupa: 9 days (n= 4).

Heliconius erato (Linnaeus, 1758) feeds on a wide range of passion vines (DeVries, 1987; Beccaloni *et al*., 2008), and experiments have shown that host plant use affects adult body size (e.g., Rodrigues & Moreira, 2002; Jorge *et al*., 2011). Larvae have been reported to be cannibalistic and solitary, but these behaviors were not observed in this study. Newly hatched larvae did prefer the youngest shoots as previously reported, which increases survivorship and development rates (Rodrigues & Moreira, 1999). A number of studies have been published on *H. erato*, including the west Ecuador subspecies reared here, in particular focused on speciation and genetics (Jiggins *et al.*, 1997, Tobler *et al.*, 2004), hybrid zones (Jiggins *et al.*, 1996), and genomics (Counterman *et al.*, 2010, Nadeau *et al.*, 2014).

***Dryas iulia moderata* Stichel, 1907**
(Nymphalidae, Heliconiinae, Heliconiini)

Eggs were found in forest gaps in the valley (evergreen forest) and ridge top (deciduous forest). Larvae used *Passiflora punctata* and *P. suberosa* (Passifloraceae, identified by H. Mogollón) as host plants.

Early instar: Head orange, including stemmatal region, thorax and abdomen orange (Fig. 6). Body covered with dark spines dorsally and laterally, dark spines white apically. Setae present on head.
Last instar: Body dark brown with transverse white stripes. Dark scoli cover body dorsally and laterally, and black secondary setae and verrucae present. Head entirely orange with dark cephalic scoli, shorter than body spines, with several apical setae.
Pupa: Pupa a combination of dark brown and white with cremaster and spiracles dark colored. Pupa lacks spines and thorax is strongly bowed ventrally.
Duration: egg: 4-5 days; larval stages: 18-20 days, pupa: 7-8 days (n= 4).

Numerous species of *Passiflora* are known as host plants of *Dryas iulia* (e.g., Beccaloni *et al.*, 2008). *Dryas iulia alcionea* is known to construct resting sites during larval stage as a protection against ants (Mega & Araujo, 2008), but this behavior was not observed in the present study.

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