Life history, taxonomy and ecology of the Faithful Beauty Moth *Composia fidelissima vagrans* (Lepidoptera, Erebidae, Pericopina) in the Pine Rocklands of South Florida

Tiffany Moore[1*], Frank Ridgley[1], Steven Whitfield[1] and Summer Sayre[2,3]

1. Zoo Miami, Conservation and Research Department, Miami FL 33177, USA; 2. Florida International University, 11200 SW 8th St, Miami FL 33199, USA; 3. Trileaf Corporation, 1051 Winderley Pl #201, Maitland FL 32751, USA; *Corresponding author

Date of issue online: 17 December 2021
Electronic copies (ISSN 2575-9256) in PDF format at: http://journals.fcla.edu/troplep; https://zenodo.org; archived by the Institutional Repository at the University of Florida (IR@UF), http://ufdc.ufl.edu/ufir; **DOI**: 10.5281/zenodo.5776933

Abstract: We describe the life history of the faithful beauty moth, *Composia fidelissima vagrans* Bates (Erebidae: Arctiini), based on individuals from the Richmond pine rocklands, Miami, Florida (Miami-Dade County, USA). We describe the life stages descriptively and quantitatively, and characterize larval development, growth, and duration based on a series of growth trials in an ambient laboratory. Using specimens in natural history collections, we provide comparative images of all three species in the genus *Composia* Hübner for the first time, which may help with systematic efforts to delineate species and subspecies in the genus. In addition, we provide images of the egg, larval instars and pupa of *Composia fidelissima vagrans*. We also provide comments on the ecology of the species, including seasonal patterns of appearance. Finally, while *Echites umbellatus* Jacquin (Apocynaceae) has been described previously as the only native host plant, we report four additional genera within the Apocynaceae.

Key Words: *Composia fidelissima vagrans*, developmental duration, natural history.

INTRODUCTION

Life history knowledge is lacking for many Lepidoptera species despite a strong increase in interest in Lepidoptera conservation (Lewandowski & Oberhauser, 2017). Basic life history knowledge is critical for effective conservation and for a fundamental understanding of Lepidoptera traits (New, 2014) which shape conservation and habitat management strategies, such as generation time, herbivory patterns, host plant preferences, fecundity, pupation characteristics and presence or absence of diapause. When these basic life history details are unavailable, effective conservation or management may not be possible. Understanding the basic life history and ecology of *Composia fidelissima vagrans* Bates (Erebidae: Arctiini) Faithful Beauty Moth, the subject of this paper, could help identify the interactions between the species, its host plants and the imperiled habitats in which it is found.

South Florida is a hotspot for imperiled Lepidoptera, with 38 species that are “considered to be rare, imperiled, on the decline, likely to be extirpated, or recently determined to be extinct” according to the Miami Blue Chapter of the North American Butterfly Association (NABA, 2021). *Composia fidelissima vagrans* is not listed by the Miami Blue Chapter of NABA as imperiled, but little information has been published about its life history within its distribution in central and South Florida. Its only native host plant recorded to date, *Echites umbellatus* Jacquin (Apocynaceae), has a geographic range restricted to only five South Florida counties, is not commercially propagated or often found in local nurseries and only occurs in five restricted habitat types (coastal strand, disturbed upland, marl prairie, pine rockland, and rockland hammock), of which many are endangered (IRC, 2020). The non-native *Nerium oleander* L. (Apocynaceae) has been recorded as a host plant, but only in a lab setting. Given that *C. fidelissima vagrans* and its natural host plant, *E. umbellatus*, are both very geographically restricted, the species is likely to face ongoing habitat loss as South Florida continues to develop (Carr & Zwick, 2016). Habitat fragmentation also happens when development occurs on adjoining natural habitats (FWC, 2019), which poses a concern for many Lepidoptera species and their host plants. As climate change progresses, the projected sea level rise for South Florida by the year 2030 is 15-25 cm (Sea Level Rise Work Group, 2015). Sea level rise, heavy rain events and more violent hurricanes increase the risk of flooding in low-lying coastal areas as well as inland flood plains (Heimlich & Bloetscher, 2011), which is projected to affect the habitats in which *C. fidelissima vagrans* and *E. umbellatus* occur. In one study, scientists found that coastal forests had declined in species richness and elevation as tidal flooding increased (Desantis *et al.*, 2007).

This study qualitatively and quantitatively describes the life history of *C. fidelissima vagrans* based on immature stages reared in an ambient laboratory. Our broad research goals are to look at Lepidoptera species that reside in South Florida’s critically endangered pine rockland ecosystem. Our specific objectives in researching *C. fidelissima vagrans* are to describe the life history stages, determine the generation time, and develop captive rearing or headstarting protocols that may provide management strategies and tools for similar endemic Lepidoptera species within the same ecosystem.

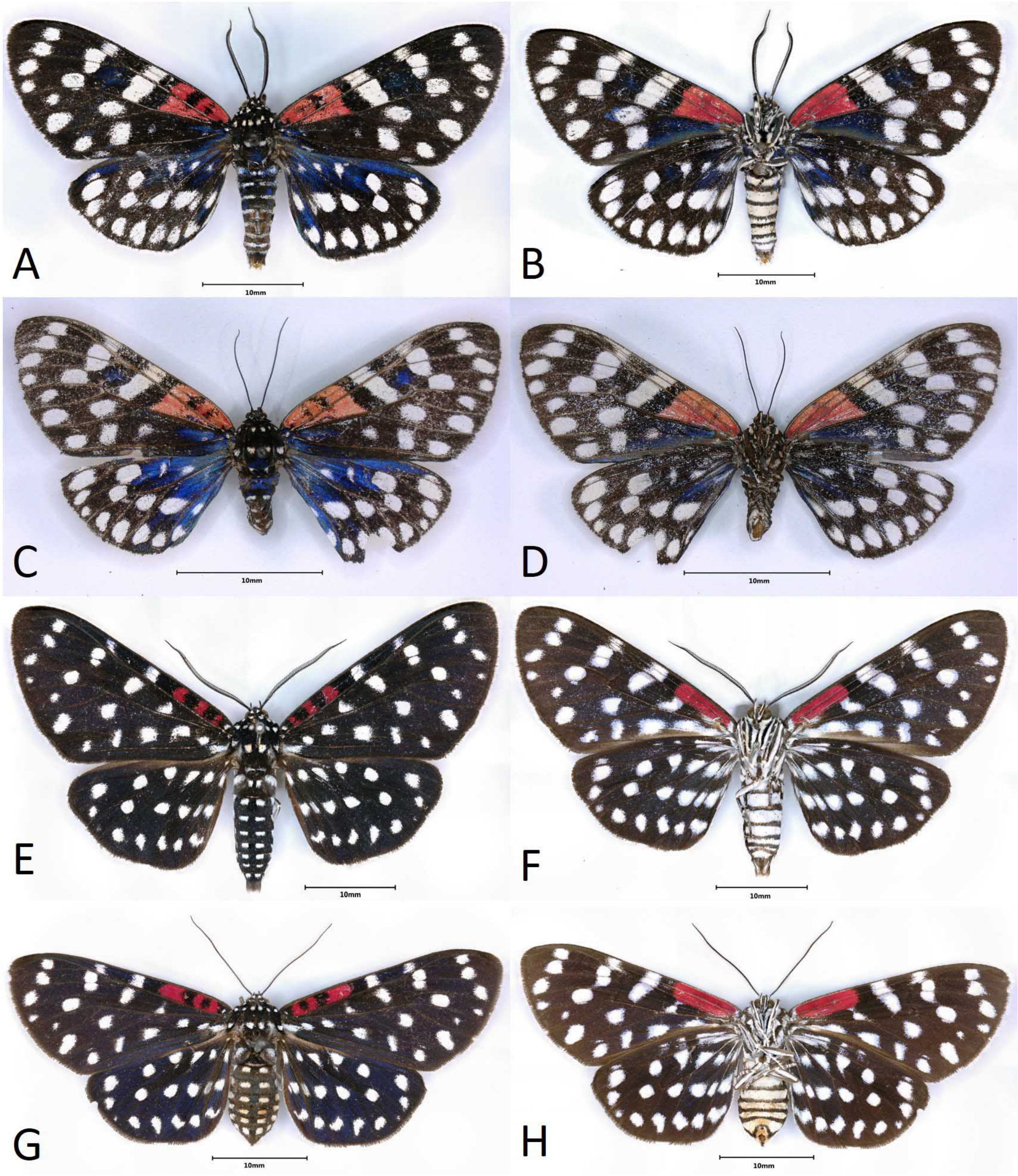

Figure 1. A) Dorsal view of male *C. utowna*. B) Ventral view of male *C. utowana*. C) Dorsal view of female *C. utowana*. D) Ventral view of female *C. utowana*. E) Dorsal view of male *C. credula*. F) Ventral view of male *C. utowana*. G) Dorsal view of female *C. credula*. H) Ventral view of female *C. credula*. Museum of Comparative Zoology, Harvard University. Photographs by Rachel Hawkins, reproduced with permission.

MATERIALS AND METHODS

Study species. The genus *Composia* Hübner contains three charismatic diurnal moth species (one of which has two subspecies): *Composia credula* (Fabricius), *C. utowana* Bates, *C. fidelissima fidelissima* Herrich-Schäffer and *C. fidelissima vagrans* Bates. *Composia* has a geographic distribution comprising South Florida, the Caribbean and the Yucatán region of Mexico (GBIF, 2021). Dyar (1896) placed *Composia* within 'Pericopidae', but was unable to determine its relatives and concluded the possibility that it was derived from 'Dioptidae'. *Composia credula* occurs in the Caribbean, from Haiti and to the British Virgin Islands (GBIF, 2021). There is little to no published information about *Composia utowana*, although Marston Bates described specimens from Mayaguana Islands, Bahamas (Bates, 1933) (Fig. 1). *Composia fidelissima* was described by Herrich-Schäffer in 1866 (Herrich-Schäffer, 1866), and its distribution is the same as that of the genus as a whole (GBIF, 2021). Bates (1933) found small differences between *C. fidelissima* specimens from Cuba and South Florida, and concluded that South Florida housed the subspecies *C. fidelissima vagrans*, while Cuba housed the subspecies *C. fidelissima fidelissima* (Bates, 1933) (Fig. 2).

Dyar (1891) noted that *C. fidelissima* exhibited a defensive yellow froth that was expelled from the mesothorax region. He noted that the defensive behavior resulted after the abdomen contracted on being disturbed, and theorized that the defensive froth was derived from the insect's "blood" (likely referring to hemolymph) (Fig. 3F). Recent studies in other Arctiinae species have shown that these secretions are often from the

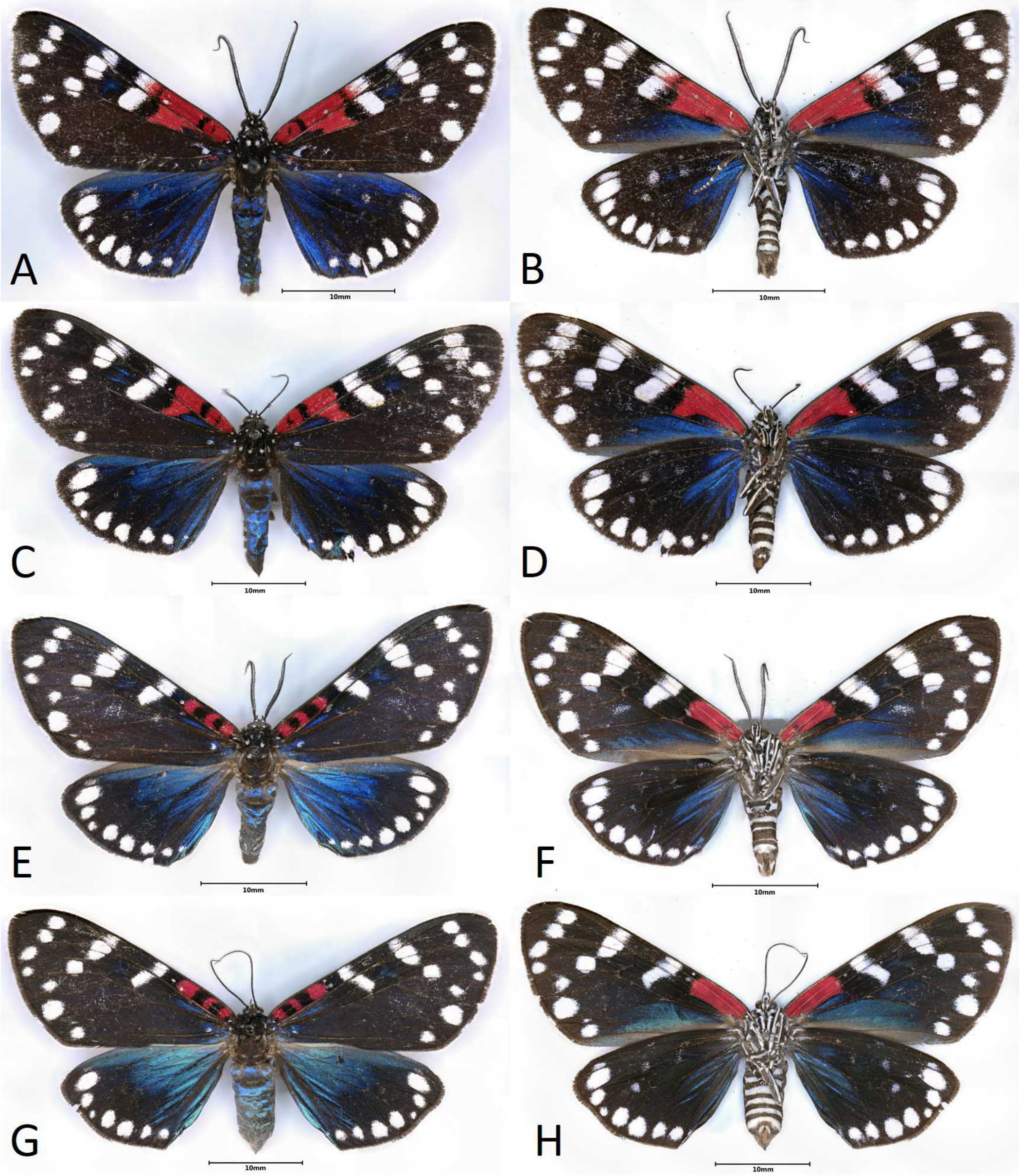

Figure 2. A) Dorsal view of male *C. fidelissima vagrans*. B) Ventral view of male *C. fidelissima vagrans*. C) Dorsal view of female *C. fidelissima vagrans*. D) Ventral view of female *C. fidelissima vagrans*. E) Dorsal view of male *C. fidelissima fidelissima*. F) Ventral view of male *C. fidelissima fidelissima*. G) Dorsal view of female *C. fidelissima fidelissima*. H) Ventral view of female *C. fidelissima fidelissima*. Museum of Comparative Zoology, Harvard University. Photographs by Rachel Hawkins, reproduced with permission.

prothorax, can contain toxic substances (both sequestered and synthesized) and are sometimes accompanied by hemolymph (Molina & Di Mare, 2017). Dyar (1896) was also the first to describe the larvae of *C. fidelissima*. He noted that the larvae often go through six instars, although some individuals only go through five. Host plants were noted as the native *E. umbellatus* Devil's Potato Vine, and the non-native *Nerium oleander* Oleander. Dyar stated that *C. fidelissima* would not feed on the non-native *N. oleander* in nature but would in captivity (Dyar, 1896).

Study site. Surrounding Zoo Miami is the largest fragment of pine rockland in South Florida that remains outside of Everglades National Park (Possley *et al.*, 2018). One of the relicts from the property's former function as the Richmond Naval Air Base is a World War II munitions bunker that was repurposed into a Lepidoptera laboratory (hereafter "bunker"). Lighting within the bunker is part natural and part LED, and temperature is ambient but buffered from extreme temperature swings due to bunker's construction. The mean temperature inside the bunker during the study period was 25.9 ˚C with a min and max of 20.6 ˚C and 29.44 ˚C, respectively. The mean humidity was 80% during the study period with a min and max of 45% and 97%, respectively.

Field sampling and data collection. Wild *C. fidelissima vagrans* eggs and larvae were collected to form the P generation in the laboratory. To allow for full data collection on egg hatch time, hatching rate, and instar development, the P generation was allowed to produce eggs for the F1 generation to allow

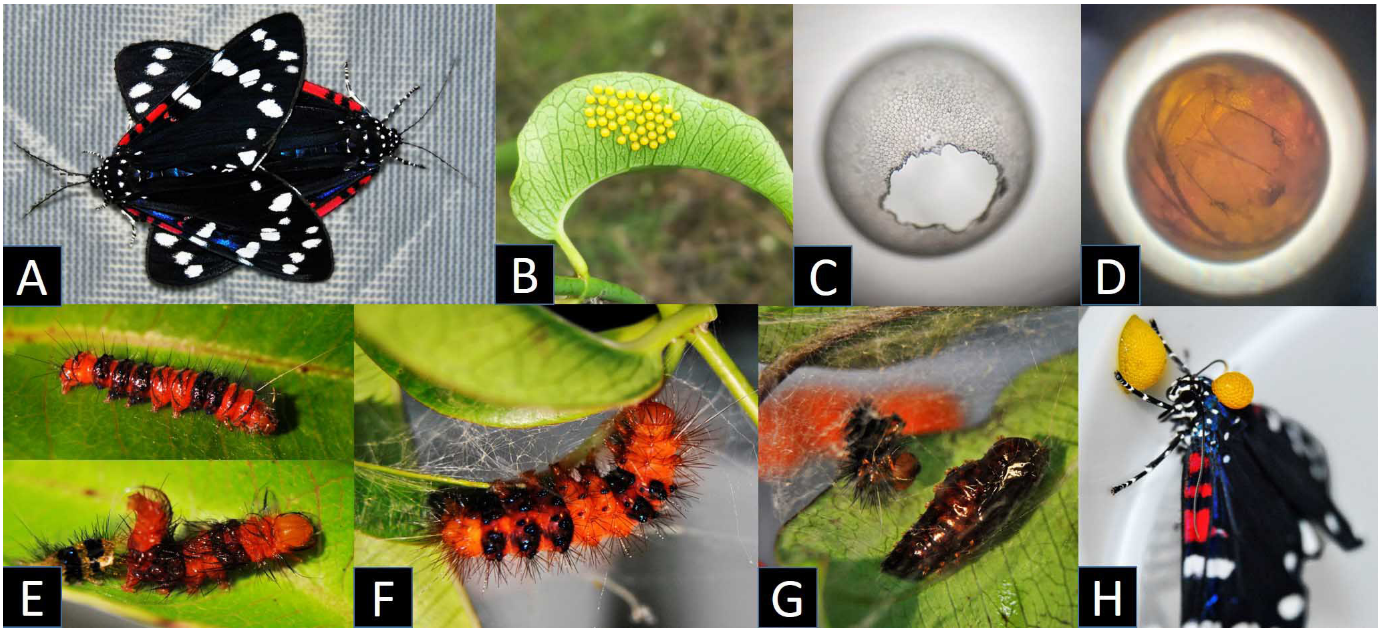

Figure 3. A) *C. fidelissima vagrans* adults mating. B) Eggs of *C. fidelissima vagrans* laid on the underside leaf of *E. umbellatus*. C) An egg shell from a larva that previously hatched. Hexagonal patterns can be observed on the surface of the egg shell. D) The development of a *C. fidelissima* larva through the egg chorion. The ocelli and mouthparts are visible. E) Top photo shows a larva of *C. fidelissima vagrans* exhibiting the pre-molting black line markings. Abdominal segments A4 show the "X" markings. The bottom photo shows a *C. fidelissima* larva just after molting and before the setae dried. F) *C. fidelissima vagrans* larva making a cocoon web to begin the pre-pupation stage. G) Pupa of *C. fidelissima vagrans* inside the sparse cocoon webbing. An exuviae of the final larval instar can be seen inside the cocoon webbing. H) Adult female *C. fidelissima vagrans* exhibiting defensive froth from the mesothorax region.

more complete life history data to be recorded. Data collection for the study occurred in two phases, from September 2016 through May 2017 and September 2020 through January 2021, although *C. fidelissima vagrans* can be observed year round. We collected a total of 126 eggs and 16 early instar larvae for the P generation from the underside of leaves of planted specimens of *E. umbellatus* surrounding the bunker. We assigned seven sample groups based on similar size and development from collected eggs and larvae. We placed groups in biosecure mesh pop-up enclosures inside the bunker lab. One of the collected sample groups contained the early instar larvae, and another a group of 26 eggs that failed to hatch. The total number of hatched larvae from the remaining five groups used for growth rate analysis was 94, and we recorded the number of eggs that successfully hatched as a percentage of the total number of eggs. We recorded total body length by measuring from the tip of the head capsule to the posterior tip of the anal plate using a millimeter caliper (SPI 2000 #31-415-3) during consecutive weekdays, excluding weekends when the lab was not staffed. We excluded some data from analysis when individuals eclosed, died or entered into the pre-pupation stage on days when the lab was not staffed to accurately record these life cycle stage changes. There was some error in measuring body length due to the larval behavioral posture during measurement. We made efforts to obtain measurements when the larvae appeared in the longitudinally straightest position. When a larva exhibited the pre-molt black lines, the larvae's body became longitudinally contracted causing the total body length measurement to be less than on the prior day. On occasion, we observed the larvae stretch their body longitudinally while resting on the stem of *E. umbellatus*, which likely caused a slightly higher total body length measurement. We documented the number, as well as duration, of larval instars as evident by the presence of exuviae, change in physical characteristics and shed head capsules. Because we could not confidently record every discrete molt event for every caterpillar, we instead calculated the instar duration using the total average duration for a particular instar and then subtracted the previous instar(s) average development time. We collected the head capsules and measured their width using a ɥRuler Q (I-Seeing, QingYing E&T LLC) under light microscopy for each instar. Cuttings of young *E. umbellatus* leaves in floral tubes were supplied to early larval instars and more mature leaves to later larval instars. Groups of *C. fidelissima vagrans* eggs were held in individual 90 mm petri dishes until hatch and then individuals were transferred to separate petri dishes. After their first molt, we transferred individual larvae to plastic containers with perforated lids until eclosion. The containers were cleaned daily during consecutive 5-day periods to remove frass and aged plant material. The containers were wiped clean with 95% ethanol and then allowed to dry before returning the larvae. Individuals were allowed to begin pre-pupation and then pupate inside their containers. Once eclosed, adults were housed together in 61 x 61 x 92 cm mesh pop-up enclosures (Bioquip #1466CV) with *E. umbellatus* in floral tubes. Nectar sources provided to adults included daily fresh cuttings of native nectar plants and 20% honey water in a 90 mm petri dish with a 3D printed mesh standing plate. The number of eggs oviposited was recorded daily and they were then used to rear the F1 generation.

RESULTS

Description of life stages

Eggs: The adult female laid eggs in irregular groups, evenly spaced from one another, on the underside of leaves of *E. umbellatus*. The eggs were round, evenly domed and smooth in appearance with hexagonal patterns (Fig. 3C). The eggs were initially bright yellow and then turned darker, reaching an eventual dull orange-yellow before emergence.

Larvae: The larvae passed through five to six instars. In the day prior to molting, the larvae developed lateral black lines on their dorsal thoracic and abdominal segments. On abdominal segments A3-A4, the black lines made an "X" shape (Fig. 3E). Herbivory slowed or ceased in the day prior to molting and during this period the larvae contracted their total body length. After molting, larvae remained stationary for several minutes as their body dried (Fig. 3E), and then rolled their head back towards the anal plate several times to shed the head capsule and any remaining exuviae.

Pharate-Pupa: When larvae of *C. fidelissima vagrans* began to enter the pre-pupal stage they ceased herbivory and began to make cocoon webbing. Webbing was sparse and attached to host plant leaves and stems. Larvae remained in the webbing, dorsal side down, forming a J-shape as they transitioned into pupae (Fig. 3F). Larvae remained as pre-pupae for up to two days.

Growth and rearing trials

Eggs: The ocelli and mouthparts were visible through the egg chorion in late-stage development (Fig. 3D). Of the 126 P generation eggs collected, 94 hatched, resulting in a 74.6% hatch rate. The hatched larvae fed on the egg chorion. In the F1 generation, there were 394 eggs that successfully hatched resulting in a hatch rate of 54.2%. The F1 generation of eggs hatched at a mean of 7.5 days (n=394). Among those that did not hatch, there were two groups, with a total of 36 eggs, in the F1 generation that did not hatch. These eggs appeared to be unfertilized with no development observed and eventually became desiccated.

We recorded the total body length measurements for the entire larval development (Fig. 4). We calculated instar development time at 95% confidence using a sample size of 36 individual larvae (Fig. 5). In one group (n=9) in the F1 generation, four exhibited five instars while five exhibited six instars before pupation. There were 13 individuals from this group that successfully pupated. Those which had five instars pupated between 24-28 days. Those which had the extra sixth instar pupated between 31-35 days.

First Instar: The mean duration from hatch of the first instar larvae was 3.6 ± 0.26 (n=32) days. The minimum was 2 days and maximum was 4 days. Individuals that went through five instars had a mean head capsule size of 0.6 mm ± 0.176 mm (n=10). Individuals that went through six instars had a mean head capsule size of 0.6 mm ± 0 mm (n=7).

Second Instar: The mean duration from hatch of the second instar larvae was 7.0 ± 0.43 (n=21) days. The minimum was five days and maximum was ten days. The mean duration of the second instar was 3.4 days. Individuals that went through five instars had a mean head capsule size of 1 mm ± 0 mm (n=11). Individuals that went through six instars had a mean head capsule size of 1 mm ± 0 mm (n=7).

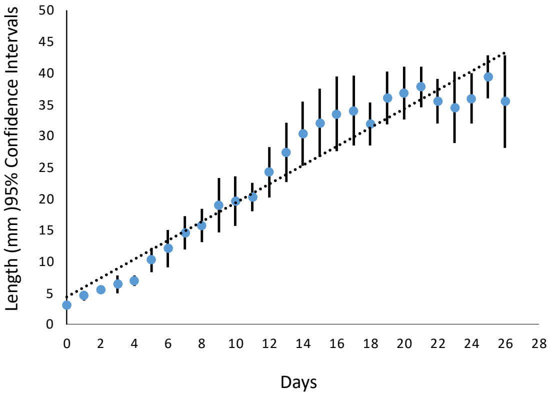

Figure 4. The total body length of *C. fidelissima vagrans* larvae over time. On the y-axis, the error bars indicate 95% confidence intervals.

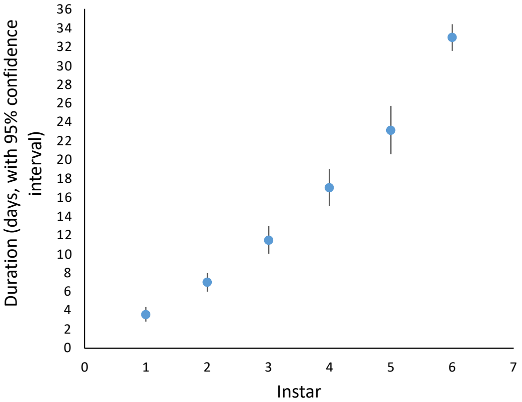

Figure 5. *C. fidelissima vagrans* larval instar time development until pupation in days with 95% confidence intervals. Points represent the average day at which larvae molted. Between instar five and six, duration includes the time when the larvae were formed in "J-shape" and length measurements were not taken. Therefore, the point for instar six is the average day the pupa was complete.

Third Instar: The mean duration from hatch of the third instar larvae was 11.5 ± 0.53 (n=30) days. The min was 9 days and maximum was 15 days. The mean duration of the third instar was 4.5 days. Individuals that went through five instars had a mean head capsule size of 1.65 mm ± 0.2 mm (n=10). Individuals that went through six instars had a mean head capsule size of 1.5 mm ± 0.2 mm (n=9).

Fourth Instar: The mean duration from hatch of the fourth instar larvae was 17.1 ± 1.00 (n=14) days. The minimum was 14 days and maximum was 21 days. The mean duration of the fourth instar was 5.6 days. Dorsal warts on segments 4-5 and 7-9 became less 'band like' and more like singular deep blue warts. Individuals that went through five instars had a mean head capsule size of 2.42 mm ± 0.3 mm (n=9). Individuals that went through six instars had a mean head capsule size of 2.2 mm ± 0.3 mm (n=9).

Fifth Instar: The mean duration from hatch of the fifth instar larvae was 23.2 ± 1.00 (n=25) days. The minimum was 18 days and maximum was 28 days. The mean duration of the fifth instar was 6.1 days. Individuals that went through five

Figure 6. Head capsules of two *C. fidelissima* larvae. A) A larva that exhibited six instars. B) A larva that exhibited five instars. Starting at instar three, individuals that exhibited five instars had a larger head capsule while individuals that exhibited six instars had a larger head capsule in the last instar stage, before pupation.

instars had a mean head capsule size of 3.75 mm ± 0.3 mm (n=3). Individuals that went through six instars had a mean head capsule size of 3 mm ± 0.4 mm (n=9).

Sixth Instar: The mean duration from hatch of the sixth instar larvae was 33.0 ± 1.00 (n=7) days. The mean duration of the sixth instar was 9.8 days. The minimum was 31 days and maximum was 35 days. Individuals that went through six instars had a mean head capsule size of 3.8 mm ± 0.4 mm (n=5).

Pharate-Pupa: There were 73 individuals that survived to pre-pupa. With a 95% confidence interval, it took a mean of 21.9 ± 0.50 (n=73) days for larvae to form into the J-shape or pre-pupa from hatch (Fig. 5). The minimum was 18 days and the maximum was 27 days to form the pre-pupa.

Pupation: Pupae were dark brown in color and remained in sparse webbing until eclosion (Fig. 3 - G). The mean time it took for pupae to eclose was 11.5 ± 0.51 (n=31) days. The minimum was 9 days and the maximum was 15 days to eclosion.

Adults: There were 47 individuals that survived to eclosion in the P generation. Of the eclosed adults, there were 26 females and 21 males. Eclosed adults paired for mating quickly, often the same day or even hours after eclosion (Fig. 3A) There were 727 eggs collected in the F1 generation. The mean female adult wing chord measurement in millimeters was 29.9 ± 0.94 (n=11). The mean female adult body length in millimeters was 19.8 ± 0.49 (n=11). The mean male adult wing chord length in millimeters was 26.8 ± 1.03 (n=10). The mean male adult body length in millimeters was 19.8 ± 0.58 (n=10).

The mean generation time to adult from when adult females laid eggs was approximately 41 days.

DISCUSSION

We provide new details on the life history, number of instars, and immature stage development for *C. fidelissima vagrans*. Larvae went through five to six instars, and head capsules of two individuals, one that exhibited five instars and one that exhibited six instars, are illustrated in Fig. 6. Head capsule size was relatively similar for individuals that went through five instars as well as six instars. After the third instar molt, individuals that exhibited five instars had a larger head capsule while individuals that exhibited six instars had a larger head capsule in the last instar stage, before pupation. Dyar (1896) noted that stage six was an interpolated stage whereas some of his brood examples omitted it completely. Esperk *et al.* (2007) found that there were six species in the subfamily Arctiinae that had variability in the number of instars, including *Apantesis phalerata* (Harris, 1841), *Apantesis vittata* (Fabricius, 1787), *Apantesis radians* (Walker, 1855), *Hyphantria cunea* (Drury, 1773), *Pyrrharctia isabella* (Smith, 1797), and *Spilosoma lubricipedum* (Linnaeus, 1758). Individuals may develop an extra instar for a number of reasons, such as host plant quality and quantity, temperature and humidity, photoperiod (Esperk *et al.*, 2007) or inheritance and genetics (Saastamoinen *et al.*, 2013). Saastamoinen *et al.* (2013) found three candidate genes that may be linked to an extra instar. In one butterfly species, Glanville Fritillary (*Melitaea cinxia* (Linnaeus)), larvae pass through an extra instar when body mass is low going into diapause for the winter, which allows for a greater post-diapause survivability when the larval mass is greater. The study found that those individuals that exhibited an additional instar had increased development time as well as a disproportionate male to female eclosion ratio (Saastamoinen *et al.*, 2013). Most Lepidoptera species are unlikely to go through diapause in South Florida due to the subtropical climate, but some are known to exhibit this behavior when dependent on disturbed habitats (Grimshawe, 1940; Davidsson *et al.*, 2021). With the same environmental conditions across all groups in this study, temperature and humidity seem to be an unlikely cause of an extra instar. We collected the host plant material for all groups from the same region of the study site where there were no topical or systemic chemicals introduced, so host plant quality seems to be equal for all individuals studied. More detailed data on host plant herbivory would be required to measure larvae consumption.

We observed adults and larvae of *C. fidelissima vagrans* year-round in South Florida. We recorded the complete generation time from egg to adult as approximately 41 days during our study period and would estimate that there could be up to nine generations of *C. fidelissima* in a single year.

The only natural host plant noted in previous publications was *E. umbellatus*, with *N. oleander* utilized in lab conditions, but we observed larvae of *C. fidelissima vagrans* in natural conditions consuming *Funastrum clausum* (Apocynaceae) (White Twinevine), *Asclepias tuberosa* (Apocynaceae) (Butterfly Weed), *Metastelma blodgettii* (Apocynaceae) (Blodgett's Swallowwort), and *Angadenia berteroi* (Apocynaceae) (Pineland-allamanda), when availability of *E. umbellatus* appeared exhausted.

We observed adults exhibiting various behaviors, including feeding, coupling and oviposition. Adults were observed to nectar from cuttings of *Bidens alba* DC. (Asteraceae) and a hybrid of native *Lantana depressa* Small (Verbenaceae) and non-native *Lantana camara* Sanders (Verbenaceae), as well as 20% honey water. We observed coupling occurrences which varied, with some adults pairing quickly after eclosion and others pairing several days later. Paired adults remained together for several hours. We often observed oviposition on the sides of the enclosure where there was already a cluster of eggs present. We provided cuttings of *E. umbellatus* for oviposition, but the majority of eggs oviposited were on the sides of the enclosure in our lab conditions. The lifespan of the adult was not calculated as the adults were released back into the pine rockland habitat after 2-5 days.

The defensive froth emitted from the adult thorax when threatened presents another unexplored aspect of this species that warrants further study. It should be determined if the substance contains novel chemicals or is the result of the sequestration of host plant toxins. While other members of the subfamily Arctiinae have exhibited such froth (Molina & Di Mare, 2017), it has yet to be investigated for *C. fidelissima* as a deterrent to predators through visual or olfactory means and/or taste.

We present for the first time images of all described *Composia* species and subspecies. The nominate subspecies, which resides in Cuba, is very similar in appearance to the South Florida subspecies, *C. fidelissima vagrans*, but there are many subtle differences in pattern and pigmentation. There is much greater obvious visual disparity between *C. credula, C. utowana* and *C. fidelissima.* Genetic analysis of *Composia* would be valuable to further clarify the taxonomy and relationships of its species and populations throughout the generic range.

In summary, we here provided details on the generation time and immature stage development, expanded the known host plants for the species and described captive rearing and headstarting protocols (e.g., Mills *et al*., 2010; Thomas *et al*., 2018) for *C. fidelissima vagrans* that further the knowledge base for Lepidoptera and their host plants in South Florida.

ACKNOWLEDGMENTS

The Fernandez Pave the Way Foundation and FIU Tropical Conservation programs provided financial and logistical support to S. Sayre. Funding was provided by the Zoo Miami Foundation and visitors of Zoo Miami. The authors would also like to thank the reviewers for their time and thoughtful comments.

LITERATURE CITED

Bates, M. 1933. The pericopid genus *Composia* (Lepidoptera). *Psyche* 40: 121-124.

Carr, M., Zwick, P. 2016. *Mapping Florida's Future - Alternative Patterns of Development in 2070 (Issue September 2016)*. Technical Report. Gainesville, GeoPlan Center, University of Florida. http://1000friendsofflorida.org/water2070/wp-content/uploads/2016/09/florida2070technicalreportfinal.pdf

Davidsson, A., Johansson, M., Bonander, C. 2021. Desirable effects from disturbance ecology - A paradox within conservation management. *Sustainability* 13(13): 7049.

Desantis, L. R. G., Bhotika, S., Williams, K., Putz, F. E. 2007. Sea-level rise and drought interactions accelerate forest decline on the Gulf Coast of Florida, USA. *Global Change Biology* 13(11): 2349-2360.

Dyar, H. G. 1890. Two species of Lepidoptera new to our lists. *Entomological News and Proceedings of the Entomological Section of the Academy of Natural Sciences of Philadelphia* 1(7): 105-106.

Dyar, H. G. 1891. *Composia fidelissima* versus *C. olympia*. *Entomological News and Proceedings of the Entomological Section of the Academy of Natural Sciences of Philadelphia* 2(3): 49-50.

Dyar, H. G. 1896. On the probable origin of the Pericopidae: *Composia fidelissima* H.-S. *Journal of the New York Entomological Society* 4(2): 68-72.

Esperk, T., Tammaru, T., Nylin, S. 2007. Intraspecific variability in number of larval instars in insects. *Journal of Economic Entomology* 100(3): 627-645.

French, G. H. 1890. Another tropical species of Lepidoptera in Florida. *Entomological News and Proceedings of the Entomological Section of the Academy of Natural Sciences of Philadelphia* 1(10): 153-154.

Fish and Wildlife Conservation Commission (FWC). 2019. *Florida State Wildlife Action Plan*. Tallahassee, Fish and Wildlife Conservation Commission. 254 pp. https://myfwc.com/media/22767/2019-action-plan.pdf

Global Biodiversify Information Facility (GBIF). 2021. *GBIF Backbone Taxonomy. Checklist dataset*. https://www.gbif.org/species/1804755; https://www.gbif.org/species/1804760; https://www.gbif.org/species/1804759. Accessed 17 November 2021.

Grimshawe, F. M. 1940. "Place of Sorrow": The world's rarest butterfly and Matecumbe Key. *Nature Magazine* 33: 565-611.

Heimlich, B., Bloetscher, F. 2011. Effects of sea level rise and other climate change impacts on southeast Florida's water resources. *Florida Water Resources Journal* 9: 36-46.

Herrich-Schäffer, G. 1866. Schmetterlinge aus Cuba. *Korrespondenz-Blatt des zoologisch-mineralogischen Vereines in Regensburg* 20: 103-109.

Institute of Regional Conservation (IRC). 2020. The Floristic Inventory of South Florida - *Echites umbellatus*. https://regionalconservation.org/ircs/database/plants/PlantPage.asp?TXCODE=Echiumbe. Accessed 19 January 2021.

Lewandowski, E. J., Oberhauser, K. S. 2017. Butterfly citizen scientists in the United States increase their engagement in conservation. *Biological Conservation* 208: 106-112.

Miami Dade County. 2014. *Metrozoo Finding of Necessity Study. Final Report.* Miami-Dade, Calvin, Giodano & Associates. 15 pp. https://www.miamidade.gov/redevelopment/library/studies/metrozoo-finding-of-necessity.pdf

Mills, D., Marchant-Forde, J., McGreevy,P., Morton, D., Nicol, C., Phillips, C., Sandoe, P., Swaisgood, R. 2010. *The Encyclopedia of Applied Animal Behaviour and Welfare*. Oxfordshire, CABI. 270 pp.

Mining, B., Kalahandi, I. N. 2011. *U.S Navy Richmond Naval Air Station Site. Site Inspection Report.* Tallahassee, Mactec Engineering and Consulting, Inc. 101 pp. https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/6636.

Molina, T. F., Di Mare, R. 2017. Defensive froth in Arctiidae species (Lepidoptera) in the Rio Grande Sul State, Brazil. *EntomoBrasilis* 10(3): 248-250.

New, T. R. 2014. *Lepidoptera and Conservation*. Oxford, John Wiley & Sons, Ltd. 280 pp.

North America Butterfly Association (NABA). Miami Blue Chapter. 2021. *Rare or Endangered Butterflies*. https://miamiblue.org/rare-or-endangered-butterflies/. Accessed 11 January 2021.

Possley, J., Duncan, J., Klein, J., Maguire, J. 2018. *Miami-Dade County's Management Plan for the Richmond Pine Rocklands, 2nd Ed.* Prepared by Fairchild Tropical Botanic Garden for Miami-Dade County, Department of Parks, Recreation and Open Spaces and Zoo Miami. https://fairchildgarden.org/wp-content/uploads/2020/04/2018-RICHMOND-PLAN-2ND-ED-FINAL_1.pdf

Saastamoinen, M., Ikonen, S., Wong, S. C., Lehtonen, R., Hanski, I. 2013. Plastic larval development in a butterfly has complex environmental and genetic causes and consequences for population dynamics. *Journal of Animal Ecology* 82(3): 529-539.

Sea Level Rise Work Group. 2015. *Unified Sea Level Rise Projection. Final Report.* Southeast Florida Climate Compact Steering Committee. 37 pp. https://southeastfloridaclimatecompact.org/wp-content/uploads/2015/10/2015-Compact-Unified-Sea-Level-Rise-Projection.pdf

Thomas, P., Boyer, D., Oehler, D., Silver, S., Perrotti, L. 2018. *Headstarting as a Conservation Strategy for Threatened and Endangered Species*, pp. 91-111. *In*: Kaufman, A. B., Bashaw, M. J., Maple, T. L. (Eds.), *Scientific Foundations of Zoos and Aquariums*: *Their role in conservaton and research*. Cambridge, Cambridge University Press.