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Authors: Wells, Carrie N., Spencer, Lori, and Simons, Don

Source: The Journal of the Lepidopterists' Society, 65(1) : 51-53

Published By: The Lepidopterists' Society

URL: <https://doi.org/10.18473/lepi.v65i1.a5>

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REPRODUCTIVE BEHAVIOR OF *SPEYERIA DIANA* (NYMPHALIDAE) IN ARKANSAS**Additional key words:** Diana fritillary, threatened butterfly, reproductive biology, mating behavior, great spangled fritillary

The Diana fritillary, *Speyeria diana* (Cramer 1775) (Nymphalidae), is considered a rare species across most of its range (Rudolph *et al.* 2006; Campbell *et al.* 2007). The North Carolina and Arkansas Heritage Programs currently list *S. diana* as an imperiled species of special concern (rank S2/S3) due to its rapid decline over the past two decades; it is also included on the Xerces Society Red List of Pollinator Insects (Vaughan & Shepard 2005; Howard & Legrand 2009). The conservation network, NatureServe, assigns *S. diana* a Global Status of G3/G4, which describes the species as very rare or local throughout its range, found locally in a restricted range (21 to 100 occurrences), and threatened throughout its range (NatureServe 2008). Because of its rapid disappearance across portions of its former distribution, *S. diana* may soon become a candidate for listing under the Endangered Species Act of the United States (Federal Register 1991, Vol.56, no. 225, pp. 58, 831). Currently, *S. diana* is not protected through any special conservation status, although it appears to be declining across certain portions of its distribution (Carlton & Nobles 1996; Moran & Baldrige 2002; Cech & Tudor 2005; Wells unpublished).

Our goal here is to describe the reproductive behavior of *S. diana* observed during two separate occasions in Mount Magazine State Park, Arkansas, in the summer of 2007. We are aware of only two published accounts of this species mating in the wild, one from Missouri in 1853 (Strecker 1900), and the other more recently from Bath County, Virginia (Cohen & Cohen 1991).

Bionomics. The Diana fritillary is univoltine, producing one generation per year. Adult males emerge and take flight in late May, typically several weeks before females (Allen 1997; Cech & Tudor 2005). Males patrol along the edge of forest habitat, and have an active and mobile lifestyle. While males begin to die off in late July, females persist somewhat cryptically into early October (Opler & Krizek 1984; Adams & Finkelstein 2006). Females are believed to be longer lived than the males, and are often found resting quietly in the cover of forest for much of the day, nectaring or ovipositing on the forest floor (Klots 1951; Spencer 2006).

In general, *S. diana* inhabits moist cove forests and deep woodland areas near streams. Adult Diana fritillaries are often found in open areas feeding on tall, high-quality nectar sources such as milkweeds, butterfly bushes or large fall composites (Moran & Baldrige 2002; Spencer 2006; Baltosser 2007; Ross 2008). Violets (*Viola*, Violaceae) are the only larval host plants used by *Speyeria*. Each female Diana fritillary can lay thousands of eggs singly on ground litter during the month of September in the vicinity of violets (Allen 1997; Cech & Tudor 2005). The hatched larvae immediately burrow deep into the leaf litter of the forest floor where they overwinter until the following spring.

Historical observations. According to natural historical accounts, the orange and black *S. diana* male was first noted when the type specimen of this species was initially described by the Dutch naturalist Pieter Cramer near Jamestown, Virginia (Cramer & Stoll 1777; Klots 1951). These coastal populations of *S. diana* have since been extirpated since the 1950s (Scott 1986; Howard & Legrand 2009). In August 1864, the prominent 19th century lepidopterist, William Henry Edwards, was the first to formally describe natural populations of the iridescent blue-green female *S. diana*, then *Argynnis diana*, in Kanawha, West Virginia (Edwards 1864). Holland (1883) captured and pinned what he believed at the time to be the “first specimen of the female *Argynnis diana* ever put upon an insect pin”



FIG. 1 *Speyeria diana*, the Diana fritillary, was observed mating on two occasions during summer 2007 in Mount Magazine, Logan County, Arkansas. The female (on left) is an iridescent blue and black, while the smaller male (on right) has bright orange and black coloration.

sometime between 1858 and 1861 in Salem, North Carolina. However, a note published by the renowned entomologist, Herman Strecker, dated 9 March 1900 describes what is likely the actual earliest described female *S. diana* held in the collection of a Baltimore collector and lepidopterist, J.P. Wild. In this note, Strecker described what was defined taxonomically at that time as a female of *Argynnis diana* captured in copula with a male in Missouri around 1853 (Strecker 1900). Upon inspection of the Strecker collection, most of which is now held at the Field Museum of Natural History in Chicago, Illinois; however, we were not able to find any copulating pair of Diana fritillaries. In fact, we found no *S. diana* specimens from Missouri in the entire Strecker collection. We welcome any knowledge of the whereabouts of the aforementioned Strecker specimens, as well as any other historical accounts of mating in *S. diana*.

Field observations. We observed two copulating pairs of Diana fritillaries on 9 and 23 June 2007 in Mount Magazine State Park, Logan County, Arkansas (Fig. 1). Mount Magazine State Park is one of Arkansas' newest state parks, and is managed by Arkansas State Parks through a special partnership with the US Forest Service. The Park conserves 904 hectares of mountain habitat, including Arkansas' highest point at 840m, and is surrounded by more than 4,500 hectares of mixed, moist deciduous forest in Ozark National Forest. The US Forest Service designates 14 invertebrate species found in Mount Magazine as endemic, rare, sensitive or threatened, including *S. diana* (Ross 1998).

We observed *S. diana* copulation for a duration of 4hrs on 9 June 2007, and for 2hrs on 23 June 2007, between 1200 hrs and 1700hrs. In general, nymphalids are known to mate for durations of thirty minutes to over 5hrs (Brower *et al.* 1965; Miller & Clench 1968; Pliske & Eisner 1969). We observed dozens pairs of *S. cybele* mating in the same vicinity, and at the same time, as *S. diana*. The mating behaviors of *S. diana* appear to be highly similar to that of the widespread great spangled fritillary, *S. cybele*, lending observational support to hypotheses relating *S. diana* and *S. cybele* as probable sister species (Hammond 1978; Baltosser 2007; Dunsford 2009).

We witnessed carrying pair behavior in *S. diana* during copulation, which is rarely observed in nature. During both of our observations, the female Diana fritillary alighted, carrying the limp male high into the branches of the forest after several hours of copulation. The only other published description we have found of *S. diana* mating behavior was Cohen & Cohen (1991), who also reported the *S. diana* female carrying the male in Bath County, Virginia. The carrying pair behavior we

observed in *S. diana* is consistent with that displayed by other butterflies in the genus *Speyeria*, where females frequently carry their male partners during mating (Shields & Emmel 1973).

The habitats where we encountered mating pairs of *S. diana* and *S. cybele* were open fields that contained a rich mix of high quality nectar plants bordered by dense forest. We noted the following plant species present where *S. diana* and *S. cybele* pairs were mating: coreopsis (*Coreopsis lanceolata*), purple coneflower (*Echinacea purpurea*), butterfly weed (*Asclepias tuberosa*), bee balm (*Monarda* spp.), yarrow (*Achillea millefolium*), ironweed (*Vernonia* spp.), thistle (*Cirsium* spp.), and goldenrod (*Solidago* spp.). During both of our observations, the female *S. diana* nectared on purple cone flower throughout copulation (Fig. 1), while the males did not ever feed. It has previously been suggested that *Speyeria* butterflies may confine their activities to particular types of nectar-producing flowers, specifically those that provide the highest quality of energy-packed sugars (Ross 2003; Rudolph *et al.* 2006). Future investigation that quantifies nectar quality across a wide variety of *S. diana* habitats would be very useful in examining relationships between *S. diana* reproductive behavior and floral composition.

While our field observations are limited in scope, they provide important insight into the copulation, mating time, and carrying pair behavior of a threatened North American butterfly that is rarely seen mating in nature. Future investigation should focus on quantifying specific habitat requirements for *S. diana*, including the documentation of larval and nectar plant associations across this species' entire distribution to better inform future conservation efforts.

ACKNOWLEDGEMENTS

We would like to thank our colleagues for ongoing discussion on this topic, including Dr. William Baltosser (University of Arkansas, Little Rock, AR), and Eric Smith (Caldwell Community College and Technical Institute, Boone, NC). We are grateful to Dr. Peter Adler and the anonymous reviewers who offered helpful comments that improved this note.

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CARRIE N. WELLS, *Clemson University, Department of Biological Sciences, 132 Long Hall, Clemson, South Carolina; email: carrieu@g.clemson.edu*, LORI SPENCER & DON SIMONS, *Mount Magazine State Park, 16878 Highway 309 South, Paris, Arkansas, 72855*.

Received for publication 14 February, revised and accepted 5 July 2010.

Journal of the Lepidopterists' Society
65(1), 2011, 53–57

A NEW RECORD OF THE FRUIT PIERCING MOTH *ORAESIA EXCAVATA* (BUTLER) (EREBIDAE: CALPINAE: CALPINI) FOR HAWAII AND THE UNITED STATES

Additional key words: Asia, Pacific, peach, pear, orchard pest, Menispermaceae

In November 2009, an exotic fruit piercing moth was collected at an elevation of 1125 m in Kula, Maui, Hawaii by W. G. King, and the specimen was submitted with his insect collection for an introductory entomology course at the University of Hawaii. Soon thereafter, the species was independently collected by the authors and others from other localities on the islands of Maui, Kauai, Oahu, and Hawaii (C. Campora, B. Kumashiro, C. Jacobsen pers. comm.), and tentatively identified as *Oraesia excavata* (Butler) (Erebidae: Calpinae: Calpini), which was confirmed by M. Pogue (2010). To our knowledge, this is the first record of establishment of *O. excavata* outside of Asia, and certainly the first record of establishment in the USA. Widespread surveys have not taken place, so the full extent of the invasion within Hawaii remains unknown. However, the species has been collected from widely dispersed sites on the islands of Kauai, Oahu, Maui, and Hawaii, and eradication is not considered a possibility.

The large moth is quite distinctive, with a scalloped trailing edge of the forewings, unusual porrect palpi,

and orange head and ventral surface of the body and legs (Fig. 1), which easily distinguish it from other species present in Hawaii. Antennae of males are pectinate, while those of females are simple. When resting with folded wings, the moth somewhat resembles a dead leaf with a scalloped dorsal edge, and the beaklike palpi are noticeable (Fig. 2).

Because we observed only a few eggs and larvae, and none were successfully reared completely from egg to adult, we are unsure of the number of instars, duration of life cycle, and extent of color variation. We successfully reared one field-caught caterpillar to adulthood (Fig. 2), confirming the association between caterpillars and adults. Six eggs were laid in the laboratory by a female caught by S. Montgomery *et al.* at Kokee, Kauai. These were roughly spherical (diameter about 0.80 mm), light brown with dark brown splotches, and loosely adhered to a substrate within the collecting container (Fig. 3). Newly hatched larvae (Fig. 4, body length 3.2 mm, head capsule width 0.45 mm) are uniformly grey with black tubercles and setae. Intermediate instars (Figs. 5 and 6) are very dark