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Larval Host Plants of *Enodia anthedon*, *Satyrodes appalachia* and *S. eurydice* in Vermont, USA

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Larval host plants of *Enodia anthedon*, *Satyrodes appalachia* and *S. eurydice* in Vermont, USA

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Abstract: Field observation and captive rearing was used to clarify larval host plant use in *Enodia anthedon*, *Satyrodes appalachia* and *S. eurydice* in Vermont, USA. In nature *S. appalachia* larvae were found on *Carex lacustris*, *C. lupulina, C. gracillima* and *C. tuckermanii*. *E. anthedon* in nature was found to oviposit on grass and on *Carex lacustris*. Larvae of *E. anthedon* were found on *C. lacustris* and *C. lupulina*. In captivity, all but two *E. anthedon* larvae chose *Carex* over grass. Both *E. appalachia* and *E. anthedon* larvae thrived on a diet of *C. lacustris* and *C. lupulina* in captivity. Early instar captive larvae refused *C. sparganioides* but late instar captive larvae accepted said plant. Grass may be an acceptable alternate host for Vermont *S. eurydice*. Miscellaneous observations on early instars are reported.

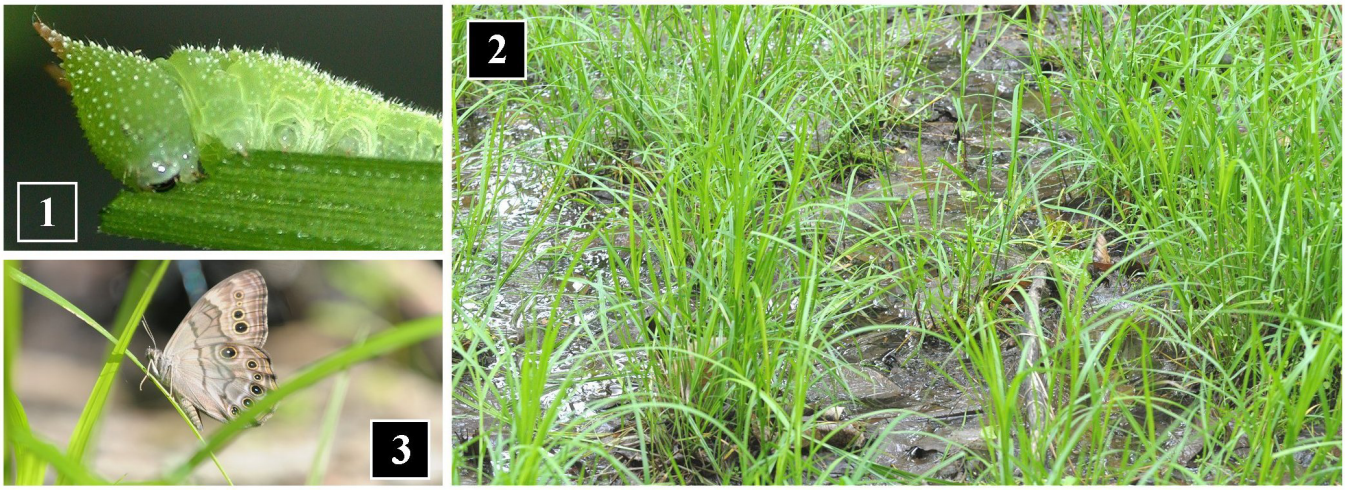
Additional key words: Lepidoptera, Nymphalidae, Satyridae, life cycle, habitat

INTRODUCTION

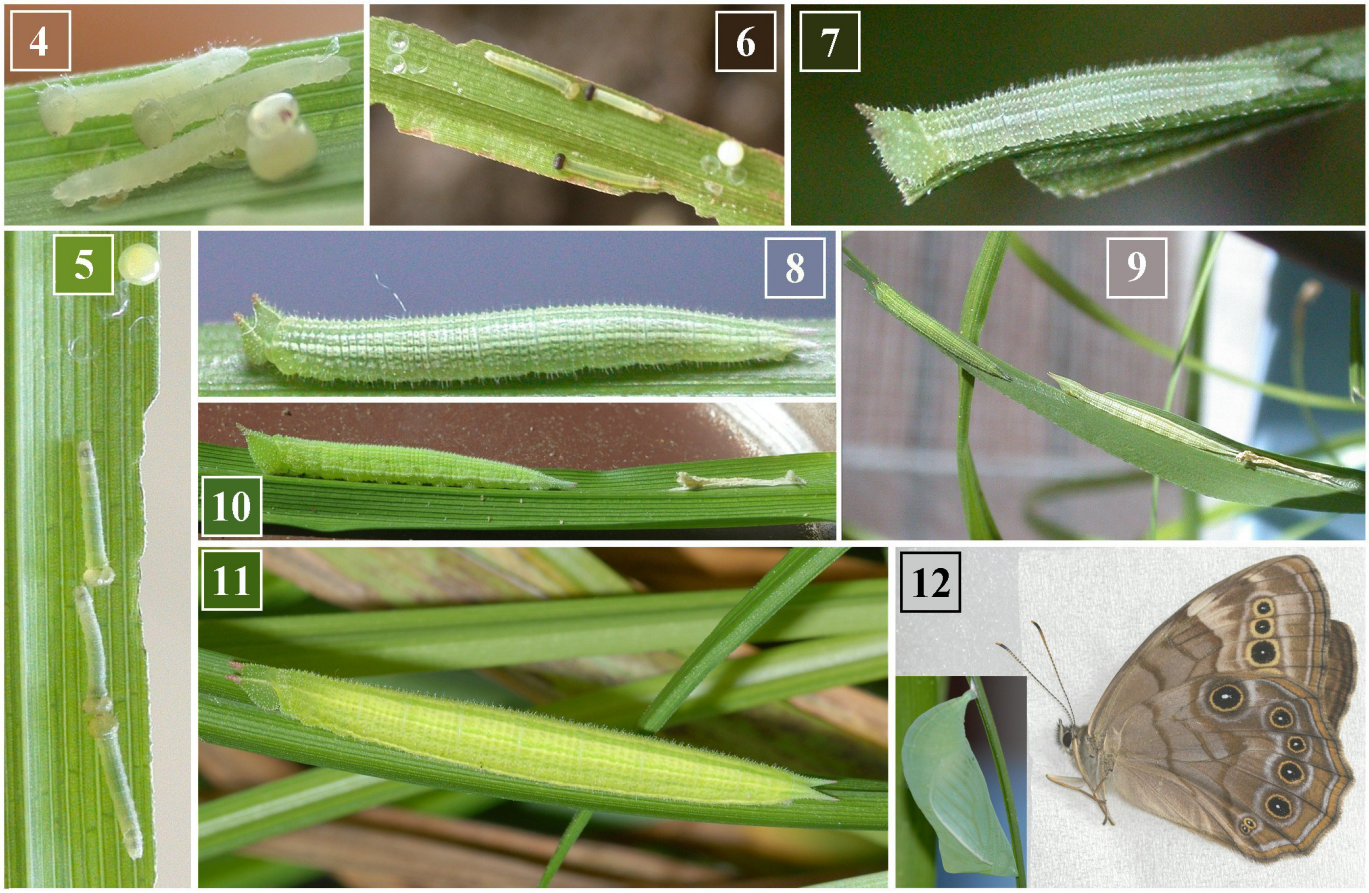
Various grass species and *Carex* sedges are listed respectively as host plants for *Enodia anthedon* and *Satyrodes appalachia* by many authors, including Howe (1975). Scott (1986) wrote: [*anthedon*] "Hostplants grasses" and [*appalachia*] "Larvae refused grasses in the lab." Handfield (1999) lists eight grasses for *E. anthedon*, and *Carex* for *S. appalachia leeuwi*. Nielsen (1999) and Douglas & Douglas (2005) similarly list various species of grasses for *anthedon* vs. sedges for *appalachia*. O'Donnell, et al. (2007) list grass (*Dactylis glomerata*) for *anthedon*, and sedges (incl. *Carex stricta*) for *appalachia*. Allen (1997) wrote: "Grasses are the primary host for [*anthedon*]"and "Third instar larvae from the last brood overwinter in a rolled grass blade tied together with silk." Allen describes *appalachia* as overwintering in a similar way, but adds, "In West Virginia the Appalachian Brown also uses grasses as hosts."

METHODS

I searched for ovipositing females and larvae in natural habitats during 2007, 2008, 2009 and 2010. I searched the range of habitats used by *E. anthedon* and *S. appalachia* in the Grand Isle area. Larvae were raised, in containers, in locations receiving partial sunlight – somewhat imitating wooded habitat. A screened narrow porch on the west side of the house provided partial late afternoon sunlight; the duration of which was limited by trees to the west. Indoor locations were used when high winds were thrashing the sedges and when close monitoring of larvae was desired (also in cold months!): windows provided partial direct morning and afternoon light, with only a distant 60w bulb extending light hours throughout each evening.

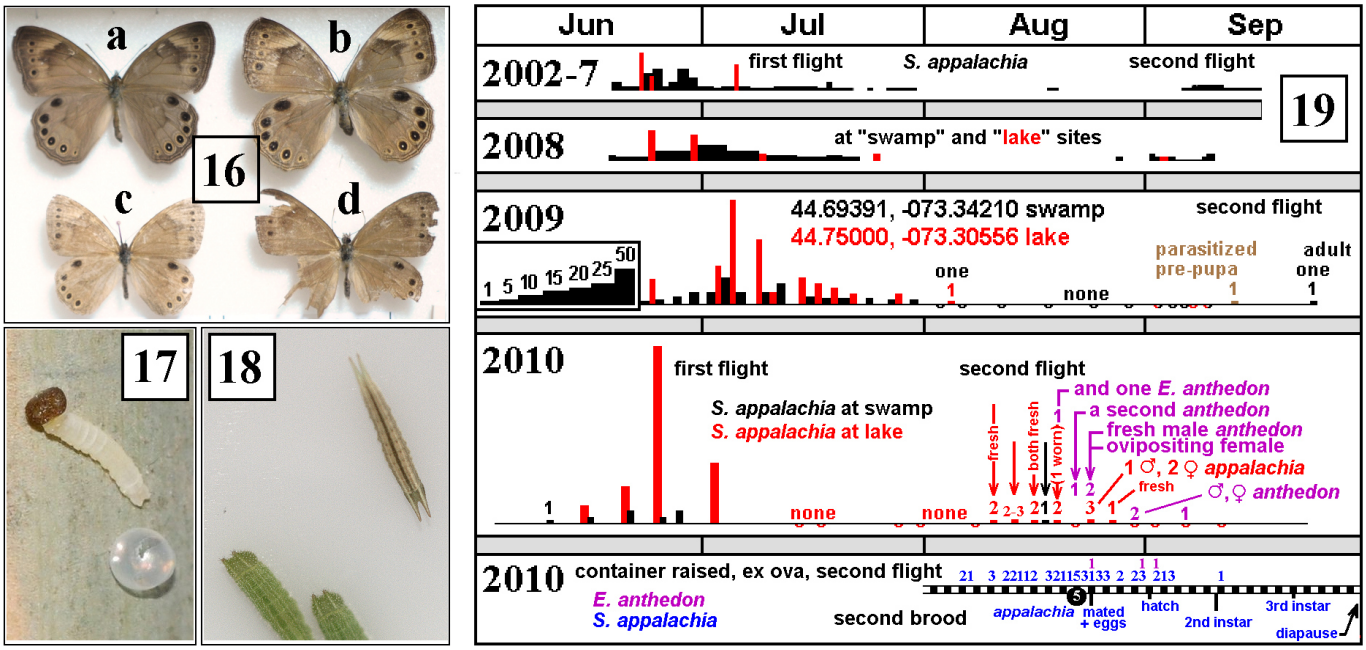


Figures 1-3. Host – *Carex* sedges. Fig. 1. 31-May-2009, small sixth-instar *E. anthedon* larva eating container-grown sedge. Fig. 2. 30-Jun-2009: Typical habitat at the swamp, a 1.75 acre (0.71 hectare) vernal pool. Fig. 3. *E. anthedon* male at swamp.



Figures 4-12. Life cycle of *E. anthedon*. Fig. 4. *E. anthedon* larvae hatching. Fig. 5. Recently hatched *E. anthedon* larvae after first meals of sedge. Fig. 6. First-instar larvae: *E. anthedon* (one) & *S. appalachia* (two), 19-Jul-2009. Fig. 7. Second-instar *E. anthedon*. Fig. 8. Third-instar *E. anthedon*. Fig. 9. Fourth-instars: *E. anthedon* (left) & *S. appalachia* (right), on grass, 26-Aug-2009. Fig. 10. Sixth-instar *E. anthedon*, after molt from fifth-instar as collected on *Carex* sedge, 4-Jun-2009. Fig. 11. Late sixth-instar *E. anthedon*. Fig. 12. *E. anthedon* female, ex-pupa 30-Jun-2009.

Figures 13-15. *S. appalachia*. Fig. 13. Female (54.5mm), ex-ovum Jul-2008; ex-pupa 12-Jun-2009. Fig. 14. Various-aged *S. appalachia* larvae and molted head capsules illustrating the often prominent dark line extending from the base of the horns to the eyes. Fig. 15. Male (D/V), ex-larva collected at swamp, ex-pupa 24-Jun-09.



Figures 16-19. *S. appalachia*. Fig. 16a. Male, ex-pupa 26-Aug-2008; from ovum laid 30-Jun or 01-Jul-2008. Fig. 16b. Female, netted at swamp 02-Sep-08. Fig. 16c. Male, netted at lake site 03-Sep-08. Fig. 16d. Male, from swamp 05-Sep-08. Fig. 17. Newly hatched larva 01-Sep-10, from unassisted pairing of second-flight *appalachia*. Fig. 18. A third-instar *appalachia* larva (upper right), from the second flight, in diapause mid-Oct-2010 to Apr-2011; and two first-flight diapausing *E. anthedon* larvae (lower left). Fig. 19. Phenograms illustrating partial second flight of *appalachia*.

RESULTS AND DISCUSSION

Field Observations

At a woodland swamp, I located ca. 20 post-diapause *S. appalachia* larva during May-June 2007, 18 post-diapause larvae in 2008, and 38 in 2009. While most larva were feeding on *C. lacustris* (Willd) and C. lupulina (Muhl. ex Willd), a few were found on *C. gracillima* (Schwein), and one fed successfully on a fourth sedge species, *C. tuckermanii* (Dewey), an observation repeated in 2010. One of three first-instar *S. appalachia* larva found July 2007 was feeding on grass, an unexpected host, as were two ex-ova larvae raised at home and two of >20 larva observed in the woodland swamp Aug.-Sept. 2009.

Grass might also be an acceptable alternate host for Vermont *S. eurydice* – one of which laid an egg on grass in an all-grass habitat on July 5, 2007.

An *E. anthedon* was observed ovipositing on grass, the expected host, in the woodland near the swamp on July 27, 2008. However, in the same swamp, on Sept. 25, I collected three small *anthedon* larvae from *Carex* sedges in two locations. These three larvae were stored over winter in my refrigerator, along with two dozen *appalachia* larvae. Due to mold encroachment, some larvae were prematurely transferred to container sedge in late January, too early for extended larval survival – and in late-February, when newly released *appalachia* larvae shortly resumed robust growth. However, the two surviving *anthedon* larvae soon died – only one eating but one meal on Mar. 4, 2009. Room temperature was 14°C (57°F).

Subsequent searches of the woodland swamp, May 30 to June 14, 2009, revealed ten post-diapause sedge-eating *anthedon* larvae. Another was found on June 4, 2009, in a lakeside wet woodland 10k (5.4 miles) away. Two larvae were monitored at the swamp; the other nine were collected, the smallest of which died; it appeared to be deformed, or possibly was injured when collected. Another larva escaped from its container. Although two of the larvae had been feeding on a fine-leaf grass, they were situated in sparse vegetation where they had initially eaten sedge. The two undoubtedly would have returned to sedge – the available grass was insufficient to provide many meals. When collected and offered a choice of sedge or the same grass species, the two larvae chose sedge. These seven surviving container-bound larvae successfully matured on the sedge diet; the first two emerged from their pupae on June 25, the same day that the first flight of *anthedon* (n = 4) was observed. The two uncollected larvae also pupated successfully on their host sedges.

From early Sept. through Oct. 5, 2009, twelve pre-diapause *anthedon* larvae were found eating sedge at the swamp - some of these larvae were found again in May of 2010.

The two woodland study sites (44.75000N, -073.30556W and 44.69391N, -073.34210W) for *E. anthedon* were chosen for the presence of colonies of *S. appalachia* with which the *anthedon* associated. The nearby drier site, a former pasture reverting to shrubs, was at 44.69548N, -073.34010W. Observed flight numbers in 2009 for *anthedon* were low, perhaps related to frequent rainy weather; the flight seemed to be delayed a week or two. However, the one-day maximum of 120-140 *appalachia* was higher at the lake site than numbers observed in previous years - in 2010, an early first flight peaked at 250. The lake site is dominated by young ash (*Fraxinus pennsylvanica*) and elm (*Ulmus americana*) with a dense carpet of sedge. The woodland swamp is a 1.75 acre (0.71 hectare) vernal pool shaded by red maples (*Acer rubrum*), and surrounded by other mature trees and patchy forest-floor vegetation.

An interesting observation was made: At the dry upland site, up to 15 male *anthedon* clustered together on shrubbery, instead of engaging in territorial aerial pursuit as observed in the two wet habitats. A few years previously, I had observed similar communal behavior at the lake site. These Vermont sites fall within the "contact zone" of *E. a. anthedon* and *E. a. borealis* – taxa showing behavioral differences (Grkovich & Pavulaan, 2003).

Captive Rearing

In 2009, I collected five female *E. anthedon*, and a few female *S. appalachia* to obtain ova. Two of the *anthedon* were collected from the woodland swamp, two from the lakeside woodland (one was ovipositing on sedge), and the fifth from a nearby dry upland habitat. I later noted no discernible differences among the *anthedon* larvae.

Of >65 *E. anthedon* and *S. appalachia* eggs, most were deposited on sedge (it being the dominant plant in each container), one egg on grass, one on twine, and several inside the plastic cap of a support stake and on the sides of the Rubbermaid® containers.

Larvae were free to chose between sedge and grass – all but two of the *anthedon* larvae opting for sedge. By late-Aug., three *anthedon* larvae were feeding on grass – two having moved from sedge onto grass, while one of the previous two had abandoned the grass. On Sept. 8, four were on grass, but some of the *anthedon* were already idle, in diapause, as were most of the *appalachia* larvae sharing the containers. Two of the *S. appalachia* larvae were also feeding on grass. One quit its grass diet for sedge in mid-Aug; the second *appalachia* remained on grass, molting to a

normal straw-colored 4th instar in late-Aug. All *appalachia* (n = 45-50) entered diapause as 4th instar larvae by Sept. 14, while six *anthedon* were still feeding. Larvae of both species ate at any hour of the day, the daytime feeding being especially noticeable with the *appalachia*. Conversely, Cech and Tudor (2005) wrote, "[*appalachia*] Caterpillars feed at night, hiding near hostplant base by day."

Whereas most authors state that larval diapause occurs with the third or fourth instar, Layberry, et al. (1998) wrote, "[*anthedon*] larvae overwinter in the first instar." Watching and measuring each *anthedon* larva, I attempted to confirm that every larva molted from third to fourth instar prior to diapause, and am confident that all larvae did. By Sept. 14, the six ex-ova *anthedon* larvae still eating sedge (five) and grass (one) had reached their maximum instar length: 18.5-19mm. The two smallest of the five larvae collected from the swamp molted to fourth instar on Sept. 13 and 17. The lack of frost in September ensured that all larvae had time to enter the fourth instar. In most years, the surrounding Lake Champlain buffers Grand Isle from early frost. The average first frosts normally arrive in mid-Oct.

In all years, none of the diapausing larvae, *anthedon* or *appalachia*, made any attempt to create a shelter of rolled leaves as reported by Allen (1997), although in 2008 some *appalachia* did hide under dried deciduous leaves, rather than stay on sedge stems and leaves. I did notice that occasionally a cut section of refrigerated sedge leaf, while drying, by chance would partially curl around the attached larva – the larva's silk track having no influence on the direction of the curl. It was also noted that *anthedon* (and *appalachia*) larval length shrinks during diapause.

When *appalachia* larvae resumed growth in springtime, they required two more molts prior to pupation. In 2008, the one container-raised *appalachia* larva that skipped diapause, apparently did skip one late larval instar; I saw no evidence of the missing (and necessarily short-timed) molt. In 2009, one exceptional *appalachia* larva unexpectedly molted to a large, boldly-striped SEVENTH-instar, but the ensuing pupa was slightly deformed and eclosion failed..

From my limited observations of May-June anthedon larvae, I noted only two molts occurring post-diapause – a total of six larval instars (final max. length 41-43.5mm) – the same sequence as the local *appalachia*. Again in early 2010, the same two post-diapause molts were observed for *anthedon* larvae which had survived fourth-instar diapause in my refrigerator, and which successfully eclosed as adults, after feeding on sedge. Additionally, in 2010, a warm year in which *appalachia* and *anthedon* had early (mid-August) second flights, I obtained some ova from a first flight *anthedon* female, as well as from some *appalachia*. Three of nine surviving *anthedon* larvae skipped diapause, eclosing in late August and early September.

Although the majority (50) of my first-brood *appalachia* larvae also skipped diapause in 2010, twenty-two entered diapause at fourth-instar as I had anticipated. However, from a mated pair of the second-flight *appalachia*, six of the seven ex-ova larvae entered diapause earlier, at third-instar; only one underwent one more molt.

Both species were again raised on *C. lacustris* and/or *lupulina*, with access to a very limited amount of grass in one of the four containers of sedge. Larvae of both species were observed eating sedge and grass, with no apparent preference. Also present in two of the containers were *C. sparganioides* (Muhl. ex Willd) and an unidentified common wide-leaf sedge. Both of the latter sedges were refused by early-instar larvae, thus unlikely to be utilized in the wild – although both, especially the *sparganioides*, were accepted by late-instar larvae.

Phenotypically, my *anthedon* larvae match published descriptions. However, larvae of this Vermont population of *appalachia leeuwi* differ slightly from descriptions – the black stripe on the Vermont *leeuwi* head-capsule horns typically extends beyond the base of the horns to the eyes (the stripe may vary in intensity, but is often very bold). Cardé, et al. (1970) and other authors indicate that for *appalachia*, unlike *S. eurydice*, the dark stripes stop at the base of the horns.

CONCLUSION

Although sedges are not currently listed as host plants for *E. anthedon*, *Carex* species are accepted by, and may be the preferred host of, this northern New England population of *anthedon*. Oviposition by *anthedon* on *C. lacustris*, and

on a grass species, was observed, and larvae were found feeding on *C. lacustris* and *C. lupulina*. *E. anthedon* larvae raised from ova thrived on a diet of *C. lacustris* and *C. lupulina*. Host sedges for larvae of *S. appalachia* in Grand Isle include *C. gracillima*, *C. lacustris*, *C. lupulina* and *C. tuckermanii*.

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