AIDS FOR FIELD IDENTIFICATION OF PITCHER PLANT MOTHS OF THE GENUS *EXYRA* (LEPIDOPTERA: NOCTUIDAE)[1]

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ABSTRACT: Three species of *Exyra* live in the pitchers of carnivorous pitcher plants of the genus *Sarracenia*. *Exyra semicrocea* inhabits all species of *Sarracenia*, whereas *E. fax* is restricted to *S. purpurea*, and *E. ridingsii* is restricted to *S. flava*. All three species can be identified in the field, using macroscopic characters of the adult and larval stages, and by characteristics of feeding and life history. Each species occurs throughout the ranges of their host plants except that *E. semicrocea* does not occur in the northern portion of the range of *S. purpurea*.

The noctuid moths of the genus *Exyra* Grote are herbivores on the tissues of carnivorous pitcher plants of the genus *Sarracenia* (Sarraceniaceae). Three nominal species are recognized, *E. fax* (Grote), *E. ridingsii* (Riley), and *E. semicrocea* (Guenée). During our work with these species over the past twenty years, we have received many requests for identification, life history data, and conservation information. We therefore present the following material to assist other workers who may be interested in the group. We also attempt to clear up some confusion and inaccuracies present in the literature.

Two of the *Exyra* species, *E. fax* and *E. ridingsii*, are host specific (Jones 1935). The former occurs in association with *S. purpurea* and the latter with *S. flava*. *Exyra semicrocea* may be associated with any of the species, although it is less common in *S. psittacina* and *S. purpurea* than in the other species, and is not known to occur north of southeastern Virginia, where *S. purpurea* is the only pitcher plant species. Apparently, the ability of *E. semicrocea* to use *S. purpurea* as a host depends on the presence of other pitcher plant species to which it is better adapted. In general, the ranges of the various species coincide with the ranges of their host plants. (Detailed descriptions of the ranges are provided below.)

Among the moth species, *E. ridingsii* and *E. semicrocea* are very similar in many ways and appear to be a sister pair. They can easily be confused in the field. *Exyra fax,* called *E. rolandiana* Grote in much of the literature in the past century (see Lafontaine and Poole 1991), however, is very different from the other two species and morphologically may be more primitive, although Jones

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(1921) thought that the adult color pattern of the other two species was primitive. If *E. fax* is primitive, the genus would be assumed to have evolved when an ancestral noctuid began to use *S. purpurea* as a host plant.

Exyra semicrocea seems to be, in both morphology and behavior, the most variable of the three species. The epithets *hubbardiana* Dyar (1904) and *immaculata* Benjamin (Benjamin 1922, McDunnough 1938) were applied to color variants. Hodges (1983) listed these names as synonyms of *E. semicrocea*. We do not feel that these forms deserve taxonomic recognition because the variation appears to be continuous. Nor are they geographic variants as indicated by Forbes (1954). We have found all types at the same locality in the southeastern U. S., as did Benjamin (1922).

The life history of all three species is similar. Eggs are laid on the inner walls of the pitchers, just below the orifice. Larvae feed on tissues of the host plant, most commonly on the leaf tissue. In the spring, when the pitcher plants flower, larvae may occasionally be found feeding in the flower buds or flowers, and occasionally in very early fruits just after the petals have fallen. The latter condition occurs most commonly when weather conditions, or burning during the previous year, result in flowers being present for several days before new pitchers mature. *Exyra* larvae do not feed on or cause damage to the developing fruit in its later stages. The caterpillar commonly encountered in pitcher plant fruits is that of the olethreutine tortricid, *Endothenia hebesana* (= *E. daeckeana*) (Jones 1908, Hilton 1982, Folkerts 1992).

Feeding by larval *Exyra* spp. usually occurs within a protective, enclosed chamber created by larval activity. Interior tissues of the leaves are eaten, leaving the outer epidermis intact; tops of pitchers are closed by silken sheets or by wilting above a feeding groove that encircles the leaf; any holes present in leaves are webbed over with silk; drainage holes are often cut in pitchers, below the feeding chamber.

Pupation takes place within pitchers. Pupae are either suspended by silk or found within accumulated frass at the bottom of pitchers. Drainage holes are often made before pupation. Adults occur in the pitchers clinging to the inner walls. They are among the few insects that can successfully crawl on the inner surface of a pitcher. Rymal (1980) studied some of the adaptations of *E. semicrocea* for this unique type of locomotion. Adults may be seen flying at dusk and are sometimes taken at light, although they are not as attracted to light as are many moths (Benjamin 1922). Most of these are males, females seeming to stay in or near the pitchers. Mating occurs in the pitchers (Rymal 1980).

Rymal and Folkerts (1982) discussed the significance of pitcher plant insects, including *Exyra* spp., in the conservation of the plants. However, little has been written about the conservation status of the insects. All species of *Exyra* are declining in abundance, although none currently appear threatened with extinction. The major factor causing decline is destruction and alteration of pitcher plant habitats (Folkerts 1977, 1982, 1990, 1991). The major loss of diversity among the moths may be related to the extinction of *Exyra* popula-

tions associated with disjunct *Sarracenia* populations, notably *S. oreophila*, *S. rubra* subsp. *alabamensis* and *S. rubra* subsp. *jonesi.* Additionally, we have noticed a significant decline in southern populations of *E. fax* in the past two decades. Although definitive data are difficult to obtain, we feel that two introduced species, the imported red fire ant (*Solenopsis richteri* Forel) and the nine banded armadillo (*Dasypus novemcinctus* L.) may be involved. Larvae of *E. fax* are relatively easy for fire ants to locate because the pitchers of *S. purpurea* are decumbent and short. We have seen columns of fire ants removing prey from pitchers in which the water had dried down. Armadillos are common in pitcher plant habitats throughout much of the southeast. Pitchers of *S. purpurea* damaged by armadillo chewing are frequently encountered. Pitchers of other species are also sometimes torn by armadillos, seemingly in attempts to locate sarcophagid larvae that inhabit the prey mass.

Although adults and larvae of all three species vary, identification is relatively easy if several characters are examined. The features we use in the following keys and descriptions are those readily seen by the naked eye and a few easily visible with a hand lens. For those who wish additional features, the genitalia of both sexes of all three species have been pictured by Lafontaine and Poole (1991). Color pictures of adults may be found in Holland (1920) and in Lafontaine and Poole (1991), who depicted some of the variations. Black and white photographs of adults of all species, showing much of the variation, may be found in Jones (1921). Lafontaine and Poole (1991) pictured the larva of *E. fax*. Jones (1907, 1921) provided sketches of all larval instars and pupae of all species. He also included photographs of the eggs but not at a size that allows the distinguishing features to be seen.

Key to adults of the species of *Exyra*

1. Prothoracic notum covered with orange to maroon scales; fore wings with ivory, orange and maroon mottling on a black background or with wavy, horizontal bars of ivory, orange and black, varying to entirely grayish black, sometimes with an orange distal fringe; hind wings entirely grey to black; found in *Sarracenia purpurea* almost exclusively, adults occasionally in *S. flava* ..... *Exyra fax* (formerly called *E. rolandiana*).

1'. Prothoracic notum covered with black scales; fore wings patterned with areas of ivory and areas of black, or entirely ivory to light yellow; hind wings entirely black, entirely ivory, or black and ivory ..... 2.

2. Basal half of fore wings entirely ivory to light yellow; distal half entirely black or black with one wavy-edged ivory band; hind wings entirely grey to black; with wings at rest, most appear to have three distinct colored areas (black pronotum, light base of the forewings, black distal portions of forewings); occasionally fore and hind wings entirely ivory to light yellow; found in all *Sarracenia* species ..... *Exyra semicrocea.*

2'. Basal half of fore wings ivory to light yellow with one wavy edged, black transverse band; distal half black with at least one wavy-edged ivory bar; occasionally black bands are widened and fused

such that forewings are nearly black with traces of ivory; hind wings with wavy, horizontal black and ivory bars, varying to almost entirely black; with wings at rest, appear to have alternating horizontal bands of black and ivory; found exclusively in *S. flava* ..... *Exyra ridingsii.*

Key to the larvae of the species of *Exyra*

Note: There seems to be no precisely appropriate term for the laterally projecting unsclerotized lobes present on the thorax and abdomen in larvae of two of the species. Although Jones (1921), the most notable student of the genus, called them lappets, a reviewer pointed out that this term is usually reserved for more flattened projections that function to disguise the outline of resting larvae. "Pinaculum" was used by Lafontaine and Poole (1991), but refers to a sclerotized area around the base of one or more setae (Stehr 1987). "Chalaza" and "scolus" might be applicable but also refer to sclerotized structures (Stehr 1987). Rather than coin a new term, we follow the usage of Jones (1921), Forbes (1954) and others and use "lappet," although we acknowledge the possible ambiguity.

1. Laterally projecting lappets (conical projections from the lateral portions of segments) on mesothoracic, metathoracic and first four abdominal segments; integument from red to brown with white or whitish intersegmental areas ..... 2.

1'. Laterally projecting lappets absent; integument red to reddish brown with whitish intersegmental areas..... *Exyra fax* (formerly called *E. rolandiana*).

2. Abdominal lappets blunt apically, entirely covered with minute black hairs, a long terminal hair (L1) projecting from each; thoracic lappets pointed, less than half the length of the abdominal lappets, covered with shorter hairs; integument bright red with white intersegmental areas, occasionally varying to a duller brownish red with dull white intersegmental areas; head capsule marked with wavy black bands on an ivory background ..... *Exyra semicrocea*

2'. Thoracic and abdominal lappets sharply pointed, with long terminal hairs (L_1), partially covered by minute hairs between which the smooth integument can be easily seen (appearing almost smooth in gross aspect); thoracic lappets nearly as large as abdominal lappets, metathoracic lappets more than half the length of the first abdominal lappets; integument varying from bright red and white to reddish brown with brownish white intersegmental areas; head capsule marked with wavy, dark-brown bands on a brown background ..... *Exyra ridingsii*

Key to feeding sign and other evidence of *Exyra* activity in pitcher plants

(Although identification of the species of *Exyra* is sometimes difficult without specimens, it is often possible, using several characters, to distinguish the signs of *E. semicrocea* feeding from that of the other two species when sign is found in *S. flava* or *S. purpurea.*)

1. In *S. flava*; evidence of 1st instar larvae feeding in the vertical groove of the pitcher throat in the form of silk and frass capsule covering the larvae or remaining in pitcher throat after larvae have departed; pupae or pupal exuviae in smooth, oval chambers within the frass near the bottom of pitchers; most damaged pitchers closed by a silken sheet near the orifice, or up to several centimeters below, several silken sheets often present in same pitcher; usually only immature pitchers closed by wilting; drainage holes usually present in pitchers with pupae, but rarely present in pitchers occupied by larvae ..... *Exyra ridingsii*

1'. In any *Sarracenia* species; no evidence of 1st instar larvae feeding in pitcher throat; pupae or pupal exuviae suspended by silk above the frass, only occasionally within the frass; damaged pitchers closed by wilting or by silken sheets near the orifice; drainage holes may be present in pitchers with pupae or larvae. 2

2. In *S. purpurea*; drainage holes nearly always present near the base of occupied pitchers; pitcher orifice often covered with a sheet of silk that frequently contains frass; usually only one encircling feeding groove present . . . . . *Exyra fax*

2'. In any *Sarracenia* species; drainage holes usually present only in pitchers containing pupae; sheets of silk covering pitcher orifices only occasionally contain frass; several encircling feeding grooves often present . . . . . *Exyra semicrocea*

ADDITIONAL NOTES

Exyra fax

Eggs are dull, yellowish-white, and laid separately, several per pitcher, on the interior walls. Usually this species overwinters as 3rd instar larvae in small amounts of frass in narrow bottom portions of dry pitchers. Overwintering pitchers are closed, usually by wilting and silk, and have drainage holes. Pupae are suspended from a sheet of silk within pitchers that are usually closed by silk or wilting. Occasionally pupation occurs within frass. In the southeastern U. S., adults occasionally rest in pitchers of *S. flava*.

We have found no evidence that the larvae "tie the top of the pitcher closed with silk" as indicated by Lafontaine and Poole (1991). Although hibernacula usually do not contain water, overwintering larvae can withstand freezing temperatures and can survive being frozen in ice. Jones (1921) hypothesized that the reddish coloration of the adult was an adaptation for crypsis on the often reddish-purple pitchers.

The period of activity of this species begins in late March at sites along the Gulf Coast. Several generations per year occur in the southerly areas of the range. In the more northerly portions of the range, activity may not begin until late June and only one generation may occur in a season (Brower and Brower 1970).

Exyra ridingsii

Eggs are dusty white, laid separately, one to several per pitcher, on the interior walls, one to a few centimeters below the orifice. Jones (1921) stated that the eggs were cryptic when pitchers were encrusted with dried nectar. This species may overwinter as 2nd, 3rd or 4th instar larvae in the lower portions of senesced pitchers. Larvae may become active during warm winter periods but rarely feed because green tissue is seldom present in the senesced pitchers of *S. flava*. Pupae of this species may be distinguished by a conspicuous anterior protuberance, which was figured by Jones (1921).

Activity begins in late March or early April at sites in northern Florida. In

northerly portions of the range in North Carolina and Virginia, adults may not be seen until early May. At all sites, two or more generations may occur per year.

Exyra semicrocea

Eggs are dull, yellowish white, laid separately, one to several per pitcher, on the interior walls, one to a few centimeters below the orifice. First instar larvae almost always girdle pitchers with a feeding groove. This species overwinters as 2nd, 3rd or 4th instar larvae, usually near the bottoms of pitchers. Larvae may become active and feed during warm winter periods. Migration to a new, undamaged pitcher usually takes place before pupation.

This species exhibits considerable variation in its behavioral patterns. Jones (1921) stated that it altered its behavior to suit each particular host plant. However, we have found essentially all variations in behavior in populations within a single host species, *S. leucophylla.* We have not observed the tough, thick, button-like wad of silk and chewed fragments that Jones (1921) reported this species to use in closing pitchers of *S. psittacina.* We have found larvae of this species feeding on *S. psittacina* during the winter when the leaves of other host species present were partially or completely senescent.

Forbes stated, of the genus, that color variation in the moths was related to the flower color of the host species. This is not true, since yellow morphs of *E. semicrocea* feed on both red- and yellow-flowered *Sarracenia* species. Jones (1907) felt that moths of this species were not as variable as *E. ridingsii.* We, like Lafontaine and Poole (1991), find it to be the most variable of the genus.

Activity begins in mid March at sites in central Florida where the moth uses *Sarracenia minor* as a host plant. In northerly areas of the range, activity may not begin until mid May.

DISTRIBUTION AND ABUNDANCE

No complete range maps for the species have been published. The maps and range information in Lafontaine and Poole (1991) only represent the localities of examined material and are, for the most part, incomplete.

Exyra fax (Figure 1a)

Range: Throughout the range of the host plant, *S. purpurea*, as far as is known. From northeastern British Columbia, across Canada to Labrador, south throughout the boreal peatland area to Minnesota and northeastern Illinois east to Pennsylvania, south along the Atlantic Coastal Plain, extending into the mountains of the Carolinas, to east central Georgia (most of Georgia lacks the host plant), from southwestern Georgia west though southern Alabama and the Florida Panhandle and historically to eastern Louisiana (no populations of the host plant are currently known to exist in Louisiana).

Abundance: In the northerly portions of the range, the moth is present in the majority of host plant populations. However, in the southern portion of the range, where *S. purpurea* occurs sympatrically and often syntopically with other *Sarracenia* species, *E. fax* is not abundant, many populations of the host plant not harboring the species. This may be the result of competition with *E. semicrocea.*

Exyra ridingsii (Figure lb)

Range: Throughout the range of the host plant, *S. flava.* From southeastern Virginia south along the Atlantic Coastal Plain to northern peninsular Florida, west through the Florida Panhandle to southwestern Alabama. A disjunct population in the mountains of the Carolinas.

Abundance: Relatively abundant throughout its range, but absent from many host plant populations where *S. flava* is syntopic with other species of *Sarracenia.* Populations of this species have been known to be displaced by populations of *E. semicrocea, i.e.,* sites which once harbored only *E. ridingsii* species now support only *E. semicrocea.*

Exyra semicrocea (Figure 1c)

Range: Throughout the ranges of all *Sarracenia* species except in northern areas where *S. purpurea* is the only host species present. From southeastern Virginia south along the Atlantic Coastal Plain to central peninsular Florida (where *S. minor* is the only host plant), west to southeastern Louisiana. Disjunct in western Louisiana and east-central Texas (where *S. alata* is the only host plant). Disjunct populations in central Alabama, northeastern Alabama, north-central Georgia and adjacent North Carolina, and the mountains of the Carolinas (these in disjunct populations of *S. oreophila, S. rubra alabamensis* and *S. rubra jonesi).* The locality depicted by Lafontaine and Poole (1991) on the Mississippi River in the vicinity of Baton Rouge, Louisiana, is almost certainly incorrect. Pitcher plants of the genus *Sarracenia* do not occur on the alluvial soils of the Mississippi River floodplain. Thus, the absence of a host plant precludes the existence of an *Exyra* population in the area.

Abundance: Usually present in higher inherent abundance than the other *Exyra* species. At many sites in the southeastern U. S. where host plants of the other species occur, this is the only species present. It seems to attain very high population levels in *S. leucophylla* and *S. alata.* It is not as commonly encountered in *S. psittacina* and *S. purpurea* as in the other host species. Populations of this species are known to have been displaced from *S. flava* by *E. ridingsii.*

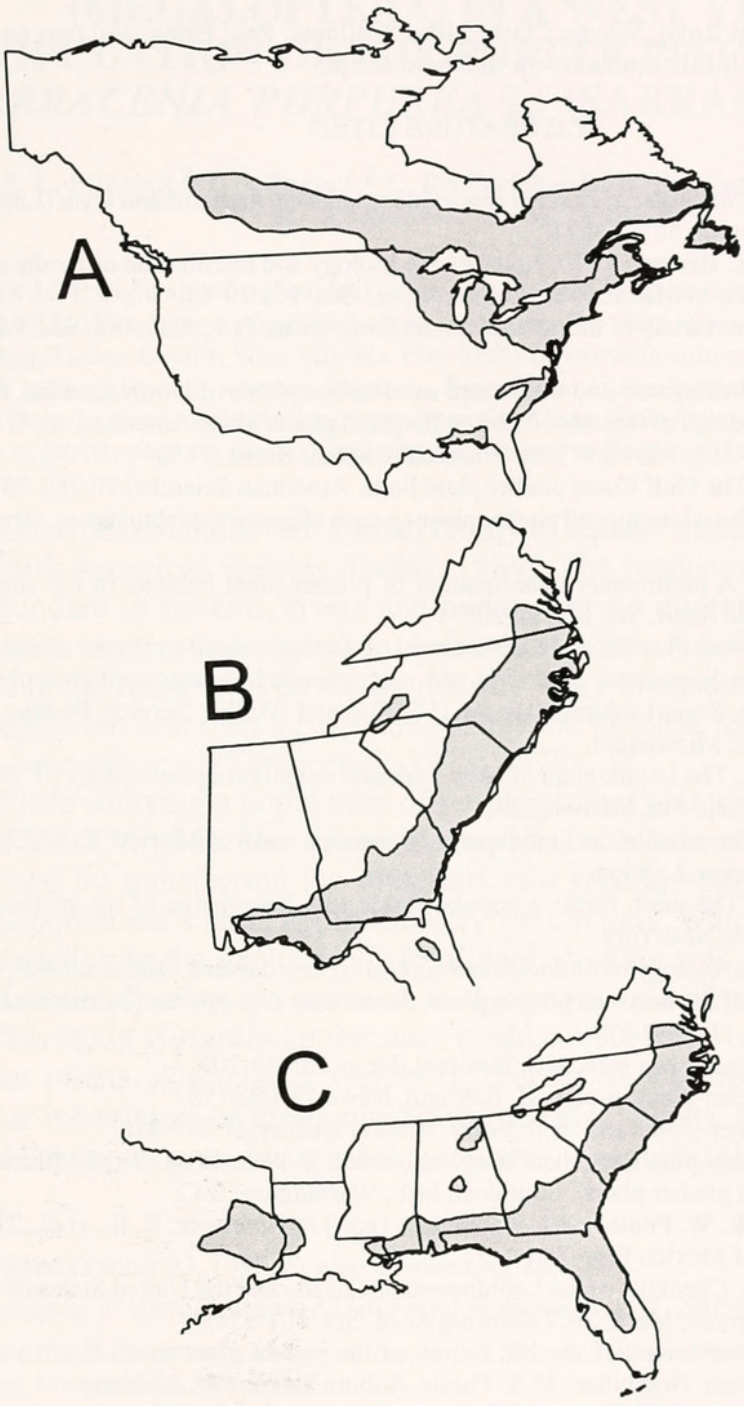

Fig. 1. Geographic ranges of *Exyra* species. A. *E. fax*. B. *E. ridingsii*. C. *E. semicrocea*.

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