

PARASITISM OF EASTERN LUBBER GRASSHOPPER BY  
*ANISIA SEROTINA* (DIPTERA: TACHINIDAE) IN FLORIDA

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The eastern lubber grasshopper, *Romalea microptera* Beauvois (= *guttata*; see Otte 1995) is a large romaleid grasshopper (adults = 2-12 g) that occurs sporadically throughout the southeastern USA, but in relatively high densities in the Everglades-Big Cypress area of south Florida (Rehn & Grant 1959, 1961). At this latitude, nymphs normally hatch from subterranean egg pods from January-April, eclose to adults from April-June, and oviposit from June-September. This grasshopper has been extensively studied due to its defensive attributes: they are gregarious, flightless, aposematically colored, expel an odorous secretion, and are toxic to birds and reptiles, but apparently not to most invertebrates (Jones et al. 1988, Whitman 1988, 1990, Whitman et al. 1991, 1992, Yosef & Whitman 1992, Hatle & Townsend 1996, Hatle & Spring 1998).

The New World tachinid genus *Anisia* (Subfamily: Goniinae; Tribe: Blondeliini) currently contains approximately 20 species (Wood 1985), which range from South America and the West Indies to southern Canada (Wulp 1890, Wood 1985). A few species are thought to parasitize Lepidoptera (Cole 1969, Arnaud 1978). However, *Anisia dampfi* (Aldrich 1927, Greene 1927) parasitizes various *Schistocerca* spp. grasshoppers in Central America (Greathead 1963, Arnaud 1978), *A. flaveola* (Coquillett) has been collected from a camel cricket in Florida (Chinn & Arnaud 1993), *A. gilvipes* (Coquillett) parasitizes crickets (Arnaud 1978), and *Tettigoniophaga vanini* Guimarães (?).

=*Anisia*) (Wood 1985) appears to attack katydids. A closely related genus, *Phasmopha*, apparently parasitizes walkingsticks (Patton 1958, Arnaud 1978, Wood 1985).

Very little is known about *Anisia serotina* (Reinhard). The species was originally described as *Stenoneura serotina* by Reinhard (1945), from specimens collected in Texas, and was noted as such by Stone, et al. (1965). The species was transferred to the genus *Anisia* by Wood in 1985. As far as we know, these purely taxonomic works are the only published references to *A. serotina*.

During 10 years of studying *R. microptera* prior to 1992, we observed very low levels (usually 0-2%) of tachinid parasitization in lubber grasshoppers from Georgia and Florida. However, during 1992-1996, adult lubber densities in the Copeland-Ochopee area of south Florida were extremely high (> 900/100 m<sup>2</sup> at Copeland in 1994) and estimated tachinid parasitization rates in this area ranged from 2 to 10%.

In 1997, we observed that adult *R. microptera* densities in SW Florida were reduced (est. maximum density = 8/100 m<sup>2</sup> at some sites) and lubbers were heavily infested with maggots of *A. serotina*. Between 26-V-1997 and 10-VI-1997, we collected 950 *R. microptera* (20 nymphs and 930 adults) from Copeland and Ochopee, FL and brought them to Illinois State University. Evidence of parasitization was first noted when maggots literally dropped from field-collected grasshoppers. Within one hour of collecting, numerous mature maggots were observed in the bottom of the collecting buckets. Approximately 5% of the grasshoppers appeared weak or moribund at the time of collecting. Many also exuded a black tar-like substance from the anus, suggesting pathogenic or parasitoid infection. In addition, field-collected grasshoppers suffered a high mortality rate; within one month, 491 (51.7%) of the 950 grasshoppers died. This contrasted with previous years (1992-1996) in which tachinid infestation levels at Copeland, FL were <10% and grasshopper survivorship was high. Dissections of 45 of the dead grasshoppers (20 males, 20 females, and 5 juveniles) on June 11, 1997 revealed that 62.2% were parasitized with from 1 to 30 maggots ( $\bar{x}$  = 9.18 maggots/infested grasshopper). Five of the parasitized grasshoppers were nymphs.

To determine infestation levels in living grasshoppers, we isolated 50 adult males and 50 adult females into individual 1-L containers with solid bottoms that trapped all emerging maggots. Lubbers were fed daily and maintained in the laboratory at 24-30°C. Grasshoppers were isolated on June 13, 1997 (approximately 3 days after the last removal of insects from the field) and maintained for 48 days, during which we recorded all emerging maggots. At the end of the isolation period, we dissected and examined all surviving grasshoppers for maggots (grasshoppers that died during the experiment were immediately dissected). We obtained the total parasitoid load for each lubber by summing the number of maggots that emerged and the number of maggots found during the dissection. The results (Table 1) show that significantly more females were infested (92%; 46/50) than males (72%; 36/50,  $X^2$  = 6.78, df = 1,  $p$  < 0.05). The number of maggots per grasshopper ranged from 0 to 63 and averaged 7.0 ± 3.3 (SE) (n = 100). There was a strong trend, but no significant difference in the mean number of parasitoids in adult males ( $\bar{x}$  = 5.1 ± 1.4 (SE), n = 50) vs. adult females ( $\bar{x}$  = 8.9 ± 1.5 (SE), n = 50,  $t$  = 1.81, df = 98,  $p$  > 0.05). Similarly, when only parasitized grasshoppers were compared, there was no significant difference in the mean number of maggots in males ( $\bar{x}$  = 7.1 ± 1.8 (SE), n = 36) versus females ( $\bar{x}$  = 9.7 ± 1.6 (SE), n = 46,  $t$  = 1.04, df = 80,  $p$  > 0.05).

In 1998, we returned twice to south Florida to survey lubber populations for tachinid infestation. We found both lubber and tachinid populations greatly reduced from previous years. Maximum adult lubber densities in the Copeland-Ochopee area were < 0.6/100 m<sup>2</sup> (approximately 1.0% of 1996 levels and 0.07% of 1994 levels).

Between 9-V-98 and 28-V-1998, we collected and dissected 52 lubbers (4 nymphs, 25 adult males, and 23 adult females) from an area extending from Everglades City

to Immokalee to Shark Valley, FL. We found only one maggot in a single adult male collected 15 miles N of Copeland, FL (Table 1).

Between 27-VII-1998 and 5-VIII-1998, we conducted a second survey and dissected 114 adult lubbers (84 males and 30 females) from an area extending from Copeland, to the Anhinga Trail, to Flamingo Key. Seven lubbers (3 females & 4 males) were infested with *A. serotina* maggots (Table 1). Three females contained 7, 22, and 35 maggots, whereas each of the four males contained a single maggot. Five of the parasitized lubbers were collected 10-14 miles N of Copeland, one male from Ochopee, and one male from the Anhinga Trail in the Everglades National Park. Summing all 1998 dissections across south Florida shows that 8/166 (4.8%) of dissected lubbers were infested with *A. serotina* maggots. The 1998 parasitization rate for just the Copeland-Ochopee area (Copeland, Ochopee, and 15 mi. N of Copeland) was 7.6% (7/92) (Table 1).

This is the first published host record for *A. serotina* and the first record of its occurrence in Florida. In addition, this is the first recorded parasitization in *R. microptera*. Indeed, neither Patton (1958), Rees (1973), Arnaud (1978), nor Fry (1987) mention either species. However, the US National Museum in Washington, D.C. contains *A. serotina* specimens reared from *R. microptera* in June 1966 from Hendry Co. and Lake Placid, FL (N. Woodley, pers. comm.).

We believe that our observed 1997 infestation rate (82%) is the highest ever observed for tachinids parasitizing grasshoppers. However, this probably represents a low estimate, because we did not isolate our grasshoppers until June 13, when many maggots may have already matured and emerged from their hosts. Our observations of 8.6 maggots per infested grasshopper with one male containing 63 maggots is also quite high, and surpasses Leonide's (1961) record of 62 tachinid (*Ceracia mucronifera* Rondani) maggots in a single *Anacridium aegyptium* L. grasshopper. Mature *A. serotina* maggots weigh ca. 0.038 g each. Hence, the mass of 63 mature *A. serotina* maggots is about 2.39 g or 72% of the mass of a mature Copeland-area male lubber (roughly 3.30g). Askew (1971) states that Tachinidae are almost without exception solitary endoparasitoids and it is unusual for more than one larva to survive in a single host. This is clearly not the case for tachinids attacking grasshoppers (Arnaud & Rentz 1965, Johnson et al. 1996).

This high level of parasitism is interesting because *R. microptera* is chemically defended and is unpalatable to many vertebrate predators (Jones et al. 1988, Whitman 1988, 1990, Whitman et al. 1991, 1992, Yosef & Whitman 1992). However, evidence suggests that some invertebrate predators are not deterred by lubber toxins (Whitman 1988, 1990). Indeed, many chemically defended arthropods are associated with specialized parasitoids or predators that have overcome their host's defenses (Reichstein et al. 1968, Askew 1971, Rothschild et al. 1973, Chapman & Page 1979, Eisner et al. 1980, Barbosa et al. 1986).

Our observations suggest an extremely dynamic host-parasitoid relationship between *R. microptera* and *A. serotina*. Although grasshopper-parasitoid populations often fluctuate widely in space and time (Prescott 1960, Greathead 1966, Farrow 1982, Chapman et al. 1986, Capinera 1987, Joern & Gaines 1990), our observed one-year (1997-1998) change in parasitization rate from 82% to 7.6% for the Copeland area is impressive. Just as striking, is the >99.9% reduction in lubber densities at Copeland, FL between 1994-1998. We do not know what drives these population fluctuations. Possibly, high lubber densities in the five years prior to 1997 may have allowed the tachinid population to build. Alternatively, weather may have contributed to the 1998 population crashes of both species. During 1997-98, south Florida experienced an unusually wet winter followed by a long spring drought, thought to have been influenced by an El Niño effect (NOAA 1997, 1998). Finally, alternative hosts may influence *Romalea-Ani-*

TABLE 1. PRESENCE OF *ANISIA SEROTINA* MAGGOTS IN LUBBER GRASSHOPPERS IN SOUTH FLORIDA IN 1997 AND 1998.

Date	Location	n Dissected			n Parasitized			% Parasitized		
		♂	♀	Total	♂	♀	Total	♂	♀	Total
VI-1997	Copeland-Ochopee	50	50	100	36	46	82	72	92	82
VI-1990	5 mi W Immokalee	3	2	5	0	0	0	0	0	0
	12-15 mi N copeland	11	4	15	1	0	1	9	0	7
	Copeland	1	4	5	0	0	0	0	0	0
	Ochopee	12	8	20	0	0	0	0	0	0
	16 mi W Shark Valley	1	3	4	0	0	0	0	0	0
	Shark Valley	0	3	3	0	0	0	0	0	0
VIII-1998	12-15 mi N Copeland	17	9	26	2	3	5	12	33	19
	Copeland	1	0	1	0	0	0	0	0	0
	Ochopee	20	5	25	1	0	1	5	0	4
	Shark Valley (EGNP)	14	8	22	0	0	0	0	0	0
	Anhinga Trail (EGNP)	18	3	21	1	0	1	6	0	5
	1-5 mi N Paurotis Pond (EGNP)	14	5	19	0	0	0	0	0	0
Total 1998		112	54	166	5	3	8	4	6	5

*sia* population dynamics. During our studies, *A. serotina* exhibited no diapause at room temperature (mature maggots pupated and eclosed in as few as 6 days). This suggests that *A. serotina* is multivoltine in south Florida, and may undergo numerous generations during a single lubber season (March-September). If *A. serotina* are active during the winter, when lubbers presumably are not available, they would need to utilize other hosts. Hence, tachinid densities in spring (when lubbers hatch) might depend on tachinid densities in winter, which in turn may depend on alternative hosts.

In any event, *Romalea-Anisia* interactions warrant further examination. *Anisia* may have potential as a biological control agent, not only for lubbers, which are minor garden and agricultural pests (Watson 1941, Griffiths & Thompson 1952), but also for more damaging Orthoptera.

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## SUMMARY

In 1997, 92% of female and 72% of male eastern lubber grasshoppers, *Romalea microptera Beauvois*, in southwest Florida were infested with maggots of the tachinid parasitoid *Anisia serotina* (Reinhard) ( $X = 8.6$  maggots/infested grasshopper). In 1998, densities of both host and parasitoid were greatly reduced.

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