
Biology and Importance of Two Eucharitid Parasites of *Wasmannia* and *Solenopsis*

John M. Heraty

Introduction

The biological control of pestiferous ants by means of self-sustaining and host-specific insect parasites is obviously desirable over almost any other control alternative. Chemical control of *Wasmannia auropunctata* (Roger) in the Galapagos Islands is not a desirable alternative because of the unique and fragile nature of the ecosystem. Pesticides can be effective in controlling *Solenopsis invicta* Buren and *S. richteri* Forel in the United States, but they have not been able to eradicate fire ants. Although chemicals can be useful for localized treatment, they cannot provide long term control and should not be used in non-agricultural habitats in which the diversity of other insect groups may be already under severe stress.

Unfortunately, ants present formidable defenses to most insect parasitoids and few groups have been able to adapt to ants as hosts. Except for Kistner's (1982) review of myrmecophilous *Diapriidae*, there has been little attention paid to the Hymenoptera that are true parasitoids of ants. Among such Hymenoptera, the *Eucharitidae* is by far the largest and most diverse group, with 42 genera and over 400 species distributed world-wide. The majority of species are included in two subfamilies, the *Oraseminae* and *Eucharitinae*, all of whose members are parasitoids of ant pupae.

Can *Eucharitidae* be considered for biological control? Johnson (1988) tried to address their potential for controlling ants but ended up raising more questions than answers. His major complaint was the "scarcity of

biological and systematic information for the eucharitids". In general, I must agree. Biological information exists for only 19 of the 42 recognized genera of *Eucharitidae*. However, through reclassification and grouping of species into monophyletic groups based on morphological analyses, there is enough information available to form predictions and identify certain taxa for more intensive study. Earlier lists of eucharitid genera and their ant hosts show little congruence, for example, species of *Myrmecia* (Myrmecinae) were listed as hosts for at least three genera of eucharitids (Wheeler and Wheeler 1937, Johnson 1988). However, recent taxonomic changes in *Eucharitidae* (Boucek 1988, Heraty 1990) have resulted in higher levels of congruence and the hosts of most eucharitid genera are clearly restricted to only one or a few closely related genera of ants (Heraty 1990); *Myrmecia* are now regarded as the host of only one genus, *Austeucharis*. Several reviews of the general biology of *Eucharitidae* have been published to which I would refer the interested reader (Clausen 1940a,b, 1941; Heraty and Darling 1984; Heraty 1990; Johnson 1988). In this chapter, I will focus on the biology of the genus *Orasema*, and, in particular, two species that are parasitoids of *W. auropunctata* and *S. invicta*.

Background

The genus *Orasema* is distributed worldwide throughout the tropical regions. In the Old World, 17 species are distributed among five species groups (Heraty 1990). In the New World, 80-100 species can be recognized, which extend north to southern Canada and south to central Argentina; these can be allocated to several species groups, none of which are shared between the Old and New World. Only 38 of the New World species have been described, and few of these can be recognized based on the original descriptions. I am currently revising these species and the predictions presented here are based on my initial efforts to group species into monophyletic groups.

The two species of *Orasema* known to attack *W. auropunctata* and *S. invicta* occur in two species groups (or possibly as distantly related species within one larger group). The first group (dealt with in this paper) includes the following species: *O. costaricensis* Wheeler and Wheeler, *O. minutissima* Howard, *O. smithi* Howard, and an undescribed species (*O. sp. C1*, nr *O. costaricensis*) from the southeastern United States, with *O. minutissima* and *O. smithi* considered as closely related, derived members; the second group includes *O. worcesteri* (Girault) and *O. xanthopus* (Cameron). *O. minutissima* is a parasite of *Wasmannia auropunctata* and *W. sigmoides* Mayr (Table 9.1). *O. xanthopus* is a parasite of species in the

Solenopsis saevissima-subcomplex of species (following Trager 1991), which includes *S. invicta*. Information on recognition, description of immature stages, and the taxonomic history of *O. xanthopus* is being prepared for separate publication.

TABLE 9.1 Host associations for species of *Orasema*. Names for ant species follow recent combinations in Kempf (1972), Smith (1979), and Trager (1991).

Parasite	Host Ant	Country
<i>O. argentina</i>	<i>Pheidole nitidula strobili</i> ³	Argentina
<i>O. assectator</i>	<i>Pheidole</i> sp. 1,7	India
<i>O. costaricensis</i>	<i>Pheidole flavens</i> ¹²	Costa Rica
<i>O. coloradensis</i>	<i>Solenopsis molesta</i> ¹¹	United States (CO)
	<i>Pheidole bicarinata</i> ¹¹	United States (CO)
	<i>Formica subnitens</i> ⁶	United States (ID)
	<i>Formica oreas comptula</i> ⁶	United States (ID)
<i>O. fraudulenta</i>	<i>Pheidole megacephala</i> ⁹	Ethiopia
<i>O. minuta</i> ^{2 [referred to as "minuta"]}	<i>Pheidole</i> nr <i>tetra</i> ⁵ [W]	United States (FL) ^{Mexico}
	<i>Tetramorium</i> sp. 5	United States (FL)
<i>O. minutissima</i>	<i>Wasmannia auropunctata</i> ^{2,15}	Cuba, Puerto Rico
	<i>Wasmannia sigmoides</i> ¹⁵ [S]	Puerto Rico
<i>O. rapo</i> [?]	<i>Eciton quadriglume</i> ⁵	Brazil
<i>O. sp.</i> [C1 nr <i>costaricensis</i>]	<i>Pheidole dentata</i> ^{5,10}	United States (FL)
<i>O. sixaolae</i>	<i>Solenopsis tenuis</i> ¹²	Costa Rica
<i>O. sp.</i>	<i>Pheidole</i> sp. 5 [W]	Solomon Islands
<i>O. sp.</i> [B1 nr <i>bakeri</i>]	<i>Solenopsis geminata</i> X <i>xyloni</i> ⁵ [T]	United States (TX)
<i>O. sp.</i> [B2 nr <i>bakeri</i>]	<i>Pheidole</i> nr <i>clementensis</i> ⁵ [W]	Mexico
	<i>Pheidole</i> nr <i>californica</i> ⁵ [W]	Mexico
	<i>Pheidole</i> sp. 5 [W]	Mexico
	<i>Tetramorium</i> sp. 5 [W]	Mexico
<i>O. susanae</i>	<i>Pheidole</i> nr <i>tetra</i> ⁵ [W]	Argentina
<i>O. tolteca</i>	<i>Pheidole hirtula</i> ⁸ [W]	Mexico
<i>O. valgius</i>	<i>Pheidole</i> sp. 4	Australia
<i>O. wheeleri</i>	<i>Pheidole ceres</i> ¹¹	United States (TX)
	<i>Pheidole sciophila</i> ¹¹	United States (TX)
	<i>Pheidole tepicana</i> ¹¹	United States (TX)
<i>O. worcesteri</i>	<i>Pheidole radoszkowskii</i> ⁵	Argentina
<i>O. xanthopus</i>	<i>Solenopsis invicta</i> ^{5,13,14}	Brazil
	<i>Solenopsis saevissima</i> -complex ¹³	Brazil, Uruguay

¹Das (1963); ²Gahan (1940); ³Gemignani (1933); ⁴Girault (1913); ⁵Heraty (1990); ⁶Johnson et al. (1986); ⁷Kerrich (1963); ⁸Mann (1914); ⁹Reichensperger (1913); ¹⁰Van Pelt (1950); ¹¹Wheeler (1907); ¹²Wheeler and Wheeler (1937); ¹³Williams and Whitcomb (1973); ¹⁴Wojcik et al. (1987); ¹⁵New Record. Single letters in brackets refer to identifier: S=R. Snelling; T=J. Trager; W=E. O. Wilson; parentheses refer to U.S. state where reared from host. *Orasema* species C1 and B1-2 are undescribed species.

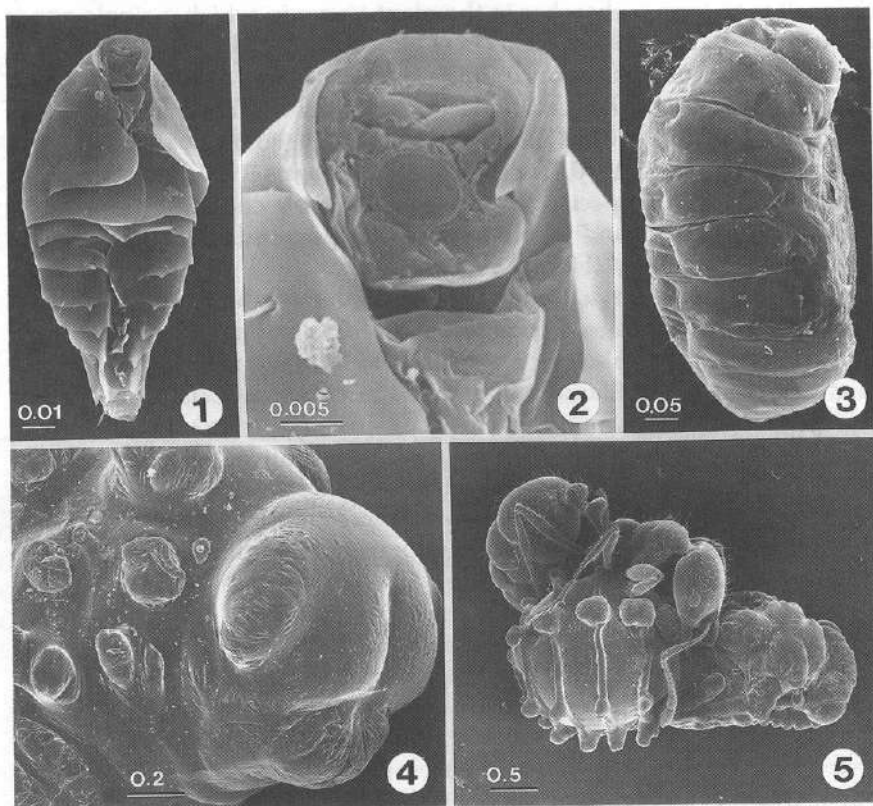
Biology of *Orasema*

Adults of *Eucharitidae* do not parasitize the host directly but instead deposit their eggs on or into plant tissue. Females of *Orasema* use their ovipositor to form a chamber in the plant tissue in which a single egg is deposited (Clausen 1940a, Johnson et al. 1986). Eggs are deposited into a wide variety of plants including leaves of tea (*Theaceae*), mango (*Anacardiaceae*), oak (*Fagaceae*) and olive (*Oleaceae*), involucre bracts of flower heads (of several families) and even young banana fingers (*Musaceae*) (Nicolini 1950, Tocchetto 1942, Roberts 1958, Johnson et al. 1986, Heraty 1990). Species are consistent in their choice of plant structure for oviposition, and within species groups trends in choice of plant structure are apparent (Heraty 1990).

The first-instar larva, termed a planidium (Figures 9.1, 9.2), must gain transport to the host brood. Larvae of *Eucharitinae* enter the colony by various means of phoretic attachment to foraging workers of the host ants (Clausen 1941). Planidia of *Orasema* are often associated with Thysanoptera or Homoptera as intermediate hosts (Das 1963, Clausen 1941, Beshear 1974, Wilson and Cooley 1972, Johnson et al. 1986, Heraty 1990). It is unknown whether these intermediate hosts serve as a temporary food source, or as an obligatory association in which ants collect the host as prey items and inadvertently transport planidia to the brood (Johnson et al. 1986, Heraty 1990).

Initially, the planidium parasitizes the ant larva. In *Orasema*, the parasite larva burrows just under the host cuticle and begins feeding. Upon pupation of the host, the first-instar larva becomes external and resumes feeding in the ventral region of the thorax. First-instar larvae can undergo almost a 1000-fold increase in size before molting to the next instar (Figure 9.3). Further development takes place on the host pupa. *Orasema* larvae often do not consume all of the host and the remains of these deformed host pupae have been termed phthisergates, phthisaners or phthisogynes based on sex and caste of the host (Wheeler 1907). Separation of these three forms is difficult and usually unnecessary, and application of the single term phthisergates to all pupae deformed in this manner is appropriate. Pupation and emergence of adults takes place within the nest. Mature larvae and pupae of *Orasema* have a very characteristic shape, and possess series of swollen pustules or warts (Figures 9.4, 9.5). Cuticular hydrocarbons of immature stages, and probably adults within the nest, mimic those of the host brood (Vander Meer et al. 1989), so that the parasitoids are generally well treated by the ants. Ants have been known to protect immature stages, assist in eclosion, and feed adults within the nest (Wheeler 1907, Williams 1980, Wojcik 1989). These "factors" appear to break down

FIGURES 9.1-5. *Orasema xanthopus*. 1-3, first-instar larva: 1. habitus of unfed larva; 2. mouthparts; 3. fully distended larva in external feeding phase, tergites dorsal and separated; 4. anterior region of third-instar larva; 5. worker of *Solenopsis* sp. clasping pupa. Scale in mm.



within a few days after eclosion and adults are recognized by their host as either refuse to be ejected from the colony or as an invader and attacked (personal observations). Adults must leave the nest to mate and deposit eggs (Heraty 1990).

Are Orasema host specific?

Recent taxonomic changes (Boucek 1988, Heraty 1990) have shown that associations between *Eucharitidae* and their ant hosts are relatively congruent. Species of *Oraseminae* are almost exclusively parasitoids of *Myrmicinae*, and *Eucharitinae* are parasitoids of *Formicinae*, *Myrmeciinae* and *Ponerinae* (Heraty 1990). Among New World species of *Orasema*, the

majority of records are from various species of *Pheidole*, *Solenopsis*, *Wasmannia*, and *Tetramorium* (all *Myrmicinae*), with uncommon records from *Formica* (*Formicinae*) and *Eciton* (*Ecitoninae*) (Table 9.1). All of the Old World host records for *Orasema* are from species of *Pheidole*. Because species of *Pheidole* are the only known host for species of the closely related genus *Orasemorpha*, *Pheidole* is the probable ancestral host for *Orasema*.

Accurate host information exists for 20 species of *Orasema* (Table 9.1). Four of the species have been reared from more than one species of ant host. Of these four species, two have been reared from different ant genera and one has been reared from two different subfamilies (Table 9.1). In some cases, the actual number of host associations may be fewer. *O. coloradensis* Wheeler was reared from species of *Pheidole* and *Solenopsis* (both *Myrmicinae*), and *Formica* (*Formicinae*) (Table 9.2). Wheeler (1907) acknowledged that the *Solenopsis molesta* (Say), which were the host of *O. coloradensis*, were living in cleptobiosis with *Formica ciliata* Mayr, and the parasitoids may have originally come from the *Formica* colony. Even so, *O. coloradensis* belongs to a distinct species group that is distantly related to the species groups being discussed here. Of the two species groups in question, species of *Orasema* have been reared from *Myrmicinae* only.

Because the number of accurate host associations are few, it is still difficult to assess the degree of host specificity. In south Texas, *Orasema* sp. [B1, near *bakeri* Ashmead] was reared from colonies of *S. geminata* X *xyloxi* (hybrid species, cf. Trager 1991). Females deposited their eggs in large numbers on *Acacia* shrubs (*Leguminosae*) that were less than four

TABLE 9.2 Rates of parasitism calculated for a single colony of *P. dentata* attacked by *Orasema* sp. [C1] in Huntsville State Park, Texas.

Unparasitized <i>Pheidole</i>		Parasitized <i>Pheidole</i>	
Larvae	32	<i>Orasema</i> planidia	16
Pupae	204	<i>Orasema</i> larvae	5
		<i>Orasema</i> pupae	17
		<u>Phthiserigates</u>	<u>234</u>
Total	236	Total	272
Parasitism based on larvae, pupae and phthiserigates (272/508)		53.5%	
Parasitism excluding phthiserigates (38/274)		13.8%	
Parasitism based on ant larvae and immatures of <i>Orasema</i> (38/70)		54.2%	
Parasitism based on mature larvae and pupae (22/258)		8.5%	

meters from parasitized colonies, and yet colonies of *S. invicta* within the same distance from the plant host were unparasitized. In the laboratory, planidia of this *Orasema* sp. were induced to burrow into larvae of *Solenopsis* and survived on the host for over a month, but pupation of the host did not occur, and development could not proceed. Therefore, an unknown factor, possibly host foraging strategy, may result in differential parasitism of hosts in the field.

Pest or parasite?

Species of *Orasema* are interesting in that they may be considered as both a beneficial parasitoid of economically important ants, or as an economic pest that causes injury to plant tissue. The pest status of eucharitids has been documented for three species, *O. aenea* Gahan, *O. assectator* Kerrich and *O. costaricensis*. In India, *O. assectator* deposits its eggs into incisions in the leaf tissue of tea bushes. The incisions are formed by the ovipositor and secondary fungal infections of the incisions cause "sewing leaf blight" (Das 1963, Kerrich 1963). The extent of damage to tea has not been documented since the initial report, and it could have been an isolated phenomenon. In South America, *Orasema* have earned the common name "bicho costureiro" or seamstress insect for their characteristic oviposition marks on leaves of various plants (Tocchetto 1942). In Argentina, in a case similar to the Indian species, *O. aenea* was identified as a transmitter of the bacterium, *Pseudomonas savastanol* (E. Smith), that caused tubercular infections on leaves of olive (Nicolini 1950). *O. costaricensis* was also reported as causing "brown spot" on young banana fingers in Costa Rica as a result of their oviposition punctures (Tocchetto 1942, Roberts 1958, Evans 1966). Wojcik (1990) mistakenly reported that insecticidal baits were used to control *Orasema* in banana plantations, when in fact populations of *Orasema* and its host, *Pheidole*, increased as a result of baits applied against *Solenopsis* (Wojcik, pers. comm.). Because of their intermediate association with thrips, it is possible that *Orasema* was a secondary pest of bananas. With the presence of thrips acting as an oviposition attractant for *Orasema* (P. Hansen, University of Costa Rica, personal communication). There have been no further reports on the pest status of any of these species and they are probably very minor pests.

Is there a potential for an introduced species of *Orasema* becoming a pest in the Galapagos Islands or in the United States? *Orasema costaricensis* is already present on the island of Santa Cruz in the Galapagos and is relatively common in Ecuador, but it has not been reported as a pest in either location. *Orasema* sp. [C1] may be the most closely related species to *O. costaricensis* and, along with another undescribed

species, is common throughout the gulf coast region of the United States. Again, these two species have not been reported as pests. Thus, species which are most likely to be damaging have never been observed causing economic problems. Even when oviposition punctures are extremely dense on leaves or stems and the plant tissue becomes heavily scarified, recovery is apparently rapid and older leaf tissue shows almost no signs of damage (Heraty 1990).

Orasema minutissima has been collected from *Gynerium sagittatum* (Aubl.) Beauv. (Poaceae) and *Chamissoa altissima* (Jacq.) H.B.K. (Amaranthaceae) in Jamaica, but the oviposition habits of *O. minutissima* and *O. xanthopus* are unknown. Among species that are considered closely related, oviposition has been observed for *O. aenea* into leaves of *Iliaceae*, *Ranunculaceae*, *Polygonaceae*, *Passifloraceae* and *Bignoniaceae* (Parker 1942, Tocchetto 1942, Heraty 1990), for *O. costaricensis* into leaves of *Anacardiaceae* (mango) and fruit of *Musaceae* (banana) (Heraty and Darling 1984, Heraty 1990), and for *O. sp.* [C1] into leaves of *Fagaceae* and *Myricaceae* (Heraty 1990). Oviposition into leaves versus involucre bracts of undeveloped flower buds is ancestral and could be the plant structure of choice for all members of this group.

Host mortality

Under some conditions, some species of *Orasema* can be common and obviously have an impact on the host species but, as pointed out by Johnson (1988), there are few studies on the impact of Eucharitidae on the host. One study on *Pseudometagea schwarzii* (Ashmead) (Eucharitinae) in Ontario suggested they parasitize only the relatively unimportant overwintering brood (Ayre 1962). However, species of *Orasema* can undergo several generations per year, and comparisons cannot be made with a univoltine, temperate species. There are certain difficulties that need to be overcome in assessing mortality caused by eucharitids. In particular, the continual turnover of immature stages in an ant colony make it difficult to assess the rate of parasitism. A single colony of *P. dentata* Mayr had a total of 508 immature stages, of which 272 showed signs of parasitism by *O. sp.* [C1] (Table 9.2). The rate of parasitism can exceed 50%, if based on all larvae, pupae and phthysergates (53.8%) or only on larval host and immature *Orasema* (54.2%). However, if ant pupae are included, or only phthysergates excluded, the rate of parasitism drops dramatically (8.5 and 13.8%, respectively). The range of larval stages from planidia to pupae, and an additional 27 adults also found in the nest, indicate continual immigration and emigration of *Orasema* into or from the nest. Attempts to "freeze" a moment in time to assess the true rate of parasitism will continue to be difficult.

Orasema xanthopus was found in 38.7% of 1502 colonies of *S. invicta* that were collected in the Mato Grosso and Mato Grosso do Sul provinces of Brazil (Wojcik 1988). Numbers of mature larvae, pupae and adults averaged 17.5 per nest, but one nest contained 598 *O. xanthopus* (Wojcik et al. 1987). In total, 7225 specimens of *Orasema* were collected, representing 80.5% of all insect parasites or nest inquilines (Wojcik et al. 1987). There is no information on parasitism rates of species of *Wasmannia* by *O. minutissima*.

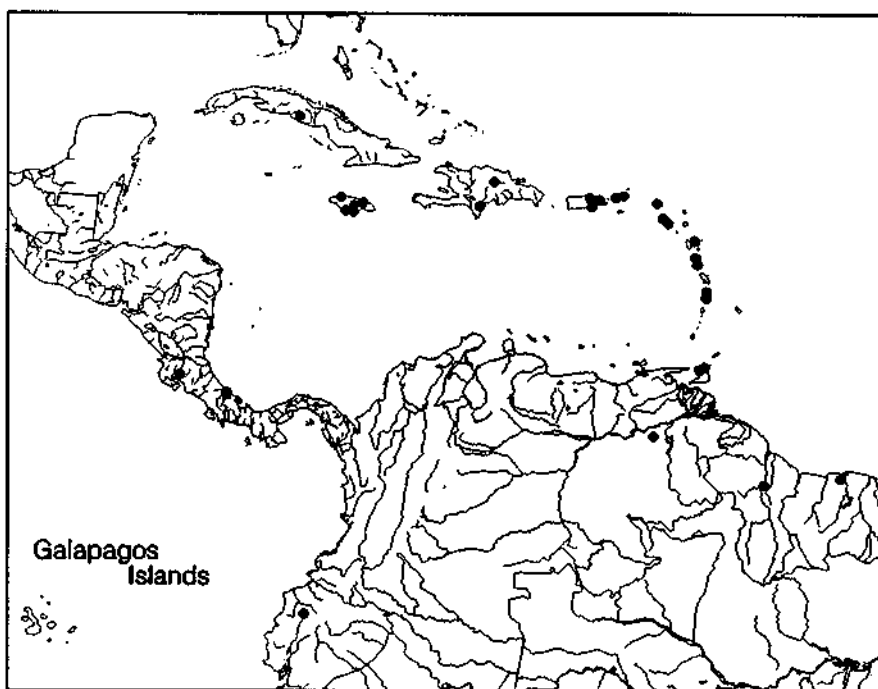
The number of host immatures consumed by an *Orasema* larva is an important consideration for parasite effectiveness. Because of the relatively constant size of the parasite larva and the variable size of the host larva, Wojcik (1989, 1990) hypothesized that *O. xanthopus* needs more than one host pupa to complete its development. In my study of *O. sp.* [C1] from Huntsville, Texas, mature ant larvae with internal planidia were relatively constant in size (1.82 ± 0.09 mm long, 0.84 ± 0.04 mm broad, $n=10$). Mature larvae of *O. sp.* [C1] were almost equal in size to parasitized host larvae (1.80 ± 0.10 mm long, 0.88 ± 0.06 mm broad, $n=10$) and were not significantly different in length (Student's *t*, $P < 0.05$). Parasitized larvae were always much larger in size than pupae of minor workers of *P. dentata*, suggesting that parasitoid larvae are either selecting for larvae of major workers or somehow affecting the development of host larvae. Growth of the host may be affected by feeding of the internal first-instar of species of *Orasema*. Additionally, deformation of ant pupae is dramatic and is apparent as soon as the first instar becomes external. If mature larvae fed on more than one host, parasitoid larvae would be associated with undeformed ant pupae; this has not been observed. Thus, it seems unlikely that a single *Orasema* parasitoid feeds on more than one host pupa.

Distribution

The present distribution of *O. minutissima* and *O. xanthopus* can offer insights into their ability for dispersal to or establishment in new areas, as well as possible host associations. *Orasema minutissima* is widespread in the Greater and Lesser Antilles and is known from sporadic collections in Costa Rica and northern South America (Figure 9.6).

Notably, a series of specimens was collected in Ecuador at about the same latitude as the Galapagos Islands. However, the dispersal abilities of this species may be limited. Although the host ant is known from south Florida and the Bahamas, *O. minutissima* is unknown from either location. It is not known whether this absence is due to poorer dispersal capabilities of this species (less than its host), or if these areas are beyond the northern limits of the parasitoid. Adults of *O. minutissima* have been

Figure 9.6. Distribution of *Orasema minutissima*.

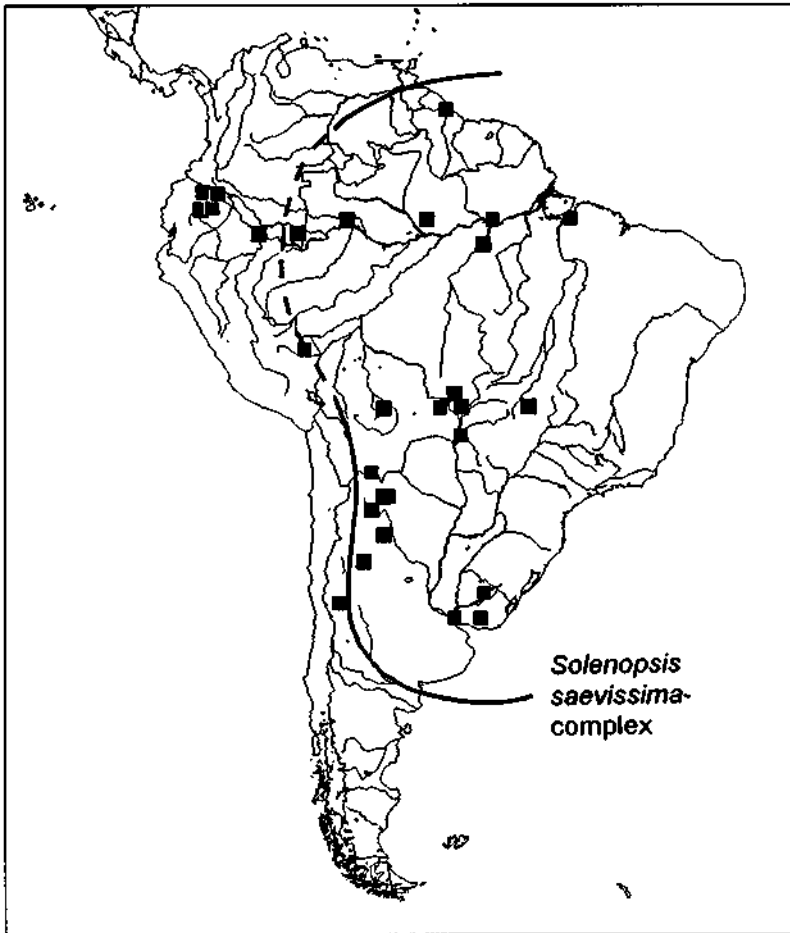


collected from elevations ranging from sea level to 1200 meters, and habitat types recorded from label data are rainforests, coffee plantations, and citrus groves. *W. auropunctata* occupies a wide variety of habitats from dry open areas to heavily shaded areas (Creighton 1950). Further collections of *O. minutissima* are necessary to observe how well it can adapt to the same ecological conditions.

Orasema xanthopus is widespread in South America (Figure 9.7). If the host is indeed restricted to species in the *Solenopsis saevissima*-subcomplex, then collections are indicative of a widespread distribution that is directly comparable to its hosts (Wilson 1952, cf. fig. 1; Buren 1972; Buren et al. 1974). The *S. saevissima*-subcomplex has been divided into nine species that are predominant in certain regions: *S. interrupta* Santschi in western Argentina, *S. richteri* in southeastern Brazil to east-central Argentina, *S. invicta* in southern Brazil to north-central Argentina, and *S. saevissima* F. Smith in Amazonia and southeastern Brazil (Trager 1991). Although the distribution of these ants may overlap, the occurrence of *O. xanthopus* over the entire range (Figure 9.7) suggests that it may not be

specific to any one species within this sub-complex of *Solenopsis*. However, collections of *S. richteri* in Argentina were parasitized by two other species of *Orasema* and not by *O. xanthopus* (Wojcik and Heraty, unpublished).

Figure 9.7. Distribution of *Orasema xanthopus* (solid square). Line delimits distribution of the *Solenopsis saevissima*-complex according to Wilson (1952).



The distribution of *S. invicta* and *S. richteri* in the United States occurs between 26° and 36° north of the equator. The same latitudinal range in the southern hemisphere includes populations of *O. xanthopus* in Argentina and Uruguay (Figure 9.7). So far, the biology of *O. xanthopus* has been studied only in the Mato Grosso region of Brazil, which is the type locality for *S. invicta*; this location occurs much closer to the equator than any of the North American populations. Mato Grosso populations were sampled from disturbed cerrado, pantanal and Campo Limpo vegetation zones (Wojcik, pers. comm.). Habitat types for other South American populations are unknown.

Conclusions

Can, or should, *Orasema* be considered for the biological control of species of *Wasmannia* or *Solenopsis*? Leaving aside the philosophical problems associated with introducing any organism for biological control, I believe that species of *Orasema* do have potential as biological control agents and deserve more study. I have tried to address some of the major issues associated with host-ant and host-plant specificity, effect on host populations, distribution, habitat and their potential for being pests. There are obvious gaps in our knowledge of these groups that need to be addressed, but these could be overcome through study of *O. minutissima* and *O. xanthopus* in their native habitat and areas of relevant distribution.

The Galapagos Islands are unique not only for their flora and fauna, but also for their historical importance in the development of current evolutionary theory. Organisms that were introduced recently threaten the existence of endemic species and considerable effort has been expended to control plant and vertebrate invaders. However, introduced insects, such as *W. auropunctata* and *Polistes versicolor versicolor* (Oliver), present new problems that need to be addressed in order to protect this fragile ecosystem. The establishment of these insects in the Galapagos Islands, without their complement of natural enemies, has allowed their populations to explode and will result in a continued decline in the diversity among all groups of organisms. Biological control, through the introduction of carefully evaluated insect parasitoids, can be used against introduced species without having adverse effects on native organisms. Similar arguments for the biological control of *S. invicta* and *S. richteri* in North America can be made, but there is not the same sense of urgency as is needed to protect the fauna of the Galapagos Islands.

The introduction of *O. minutissima* to the Galapagos Islands for the control of *W. auropunctata* has the greatest potential for success based on the following qualities:

1. The range of habitat types occupied by *O. minutissima* is limited. Present information suggests its distribution is restricted to moist, shaded habitats (citrus, coffee, rain forest), but this information is based on few collections. *Wasmannia* occurs in high densities and in a variety of habitats in the Galapagos Islands. If *O. minutissima* occurs in the Caribbean in habitats equivalent to the "transition forest" of the Galapagos Islands, then it has the highest potential to be effective.
2. *Orasema minutissima* parasitizes at least two species of *Wasmannia* but is not known to parasitize any other ant genus. The host of its most closely related species, *O. smithi*, is unknown, but is likely to be *Pheidole*. It is possible that *O. minutissima* may parasitize the endemic Galapagos species, *P. williamsi* Wheeler, but this may be a host of *O. costaricensis* which already occurs in the Galapagos Islands. Other *Myrmicinae*, the most likely alternate hosts, are not endemic to the Galapagos Islands. Therefore, there are no other endemic ant species known from the Galapagos Islands that would be parasitized by species of *Orasema*. *W. auropunctata* is already having devastating effects on the native ant fauna (Clark et al. 1982) and other insects (personal observations), and *O. minutissima*, which is only known to attack *Wasmannia*, is not likely to be damaging to other ant species.
3. The two plant genera, *Gynerium* and *Chamissoa*, that are possible oviposition hosts for *O. minutissima*, are not found on the Galapagos Islands. However, their respective plant families, *Poaceae* and *Amaranthaceae*, are represented by several other genera. It is important to know the particular plant structure that is preferred for oviposition by this species in order to evaluate the presence of similar plant forms on the Galapagos Islands. Because *O. costaricensis* has been implicated as a pest of bananas and *O. minutissima* belong to the same species group, *O. minutissima* needs to be evaluated in its native habitat to determine any potential problems caused by its oviposition. However, *O. costaricensis* is already present in the Galapagos Islands and is not a reported pest.
4. *Orasema minutissima* is common on islands such as in the Lesser Antilles (Figure 9.6) which are comparable in size to the Galapagos Islands. In addition, its presence on the western slopes of the Andes in Ecuador indicates that there is no problem of intro-

ducing a new parasite back to the mainland after establishment on the islands.

If *O. minutissima* is imported, the Galapagos Islands offer a unique opportunity for observing the establishment of a biological control agent. *W. auropunctata* is widely distributed and often extremely abundant; if ecological conditions for the host and parasite can be matched, establishment should be relatively certain. Perhaps more importantly, the islands of the Galapagos Archipelago, by the nature of their size, distribution and variable habitats, could be treated as independent experimental units for use in evaluating the spread and effectiveness of an introduced parasitoid. If successful and effective, *O. minutissima* could be used to assess the feasibility of future studies on *O. xanthopus* for control of *Solenopsis* in North America.

Admittedly, we still do not have a tremendous amount of information on species of *Oreasema*. There are only 38 names available for the 80-100 species that I have recognized, and at the moment very few of the named species can be identified without comparison to type material. Of these same 100 species, we have sporadic biological information for only 18. This does not mean that we cannot make valid inferences on hosts, behavior and patterns of distribution. If taxa can be placed into hierarchical, monophyletic groups that reflect their phylogeny, then it is easier to make predictions regarding host specificity, habitat preference, or other biological attributes. Museum collections, and revisionary studies based upon them, also provide information on host, habitat and distribution that are not otherwise made available through the literature. Here, information from both aspects is combined to summarize biological information for the genus *Oreasema* and to focus attention on two species that may be useful for biological control of pest ants.

Acknowledgments

I would like to thank J. M. Cumming and J. T. Huber (Biological Resources Division, Agriculture Canada, Ottawa), D. P. Wojcik (Medical and Veterinary Entomology Research Laboratory, Gainesville, FL), and Laura Heraty for their comments and criticisms. Immature stages of *Oreasema* associated with *Solenopsis* and *Wasmannia* were made available by D. Wojcik and D. P. Jouvenaz (MAVERL) and Roy Snelling (Los Angeles County Museum, Los Angeles, CA), respectively. Voucher specimens of *O. xanthopus* and undescribed species were deposited in the Canadian National Collection of Insects, Ottawa. This work was supported by a National Sciences and Engineering Research Council of Canada postdoctoral fellowship to the author.

Resumen

El *Eucharitidae* es uno de los grupos más exitosos en la parasitización de los estados inmaduros de hormigas. Los adultos depositan sus huevos en el tejido de la planta, lejos de su hospero, y el primer instar larvario penetra la colonia dado su comportamiento forético. La larva del eucharitido parasita la larva del hospedero, pero completa su desarrollo en la pupa. El empupamiento y emergencia de los parasitoides ocurre dentro de la colonia. La relación con los hospederos está altamente correlacionada: especies de *Oraseminae* son casi todas parasitoides de *Myrmicinae*, y las especies de *Eucharitinae* son casi todas parasitoides de *Formicinae* y *Ponerinae*. Las especies de *Orasema* son parasitoides de *Pheidole*, *Solenopsis*, *Wasmannia* y *Tetramorium*. *Orasema minutissima* es un parasitoide de *Wasmannia auropunctata*, y *O. xanthopus* es un parasitoide de *Solenopsis invicta*. Se discute en este capítulo los problemas asociados con estos parasitoides como agentes de control biológico en las islas Galápagos y en Norte América.

La información biológica está limitada solamente a unas pocas especies de *Orasema*, pero las relaciones filogenéticas pueden ser utilizadas para hacer predicciones concernientes a su comportamiento y su especificidad a ciertas plantas y hormigas. Las especies de *Orasema* pueden ser plagas debido a problemas asociados con la perforación de la planta durante la oviposición, pero las especies que causan estos problemas están presentes en las áreas de interés y no han sido reportadas como plaga. *Orasema minutissima* y *O. xanthopus* pertenecen a especies grupo dentro *Orasema* los cuales son solamente parasitoides de especies relacionadas de *Wasmannia* o *Solenopsis*. Se presenta evidencia que únicamente un solo individuo de *Orasema* se desarrolla por pupa del huésped. Se han efectuado unos estudios limitados en la tasa de parasitismo, pero bajo ciertas condiciones, las especies de *Orasema* pueden ser comunes y efectivas. Tanto *O. minutissima* y *O. xanthopus* pueden tener potencial como agentes de control biológico. Se sugiere que *O. minutissima* debe ser usado para control biológico de *W. auropunctata* en las islas Galápagos. Resultados de una liberación en una o varias de las islas pueden ser usados como un enfoque experimental para determinar el trabajo futuro en *O. xanthopus*.

References

- Ayre, G. L. 1962. *Pseudometagea schwarzii* (Ashm.) (Eucharitidae: Hymenoptera), a parasite of *Lasius neoniger* Emery (Formicidae: Hymenoptera). *Canadian J. Zool.* 40: 157-164.

- Beshear, R. J. 1974. A chalcidoid planidium on thrips larvae in Georgia. *J. Georgia Entomol. Soc.* 9: 265-266.
- Boucek, Z. 1988. Australasian Chalcidoidea (Hymenoptera). C.A.B. International, Wallingford.
- Buren, W. F. 1972. Revisionary studies on the taxonomy of the imported fire ants. *J. Georgia Entomol. Soc.* 7: 1-26.
- Buren, W. F., G. E. Allen, W. H. Whitcomb, F. E. Lennartz and R. N. Williams. Zoogeography of the imported fire ants. *J. New York Entomol. Soc.* 82: 113-124.
- Clark, D. B., C. Guayasamín, O. Pazmiño, C. Donoso, and Y. Pérez de Villacís. 1982. The tramp ant, *Wasmannia auropunctata*: autecology and effects on ant diversity and distribution on Santa Cruz Island, Galapagos. *Biotropica* 14: 196-207.
- Clausen, C. P. 1940a. The immature stages of the Eucharidae (Hymenoptera). *Proc. Entomol. Soc. Washington*, 42: 161-170.
- . 1940b. The oviposition habits of the Eucharidae (Hymenoptera). *J. Washington Acad. Sci.* 30: 504-516.
- . 1941. The habits of the Eucharidae. *Psyche* 48: 57-69.
- Creighton, W. S. 1950. The ants of North America. *Bull. Mus. Comp. Zool.* 104: 1-585, plates 1-57.
- Das, G. M. 1963. Preliminary studies on the biology of *Orasema assectator* Kerrich (Hymenoptera: Eucharitidae) parasitic on *Pheidole* and causing damage to leaves of tea in Assam. *Bull. Entomol. Res.* 54: 393-398.
- Evans, H. E. 1966. *Life on a Little Known Planet*. Dell, New York.
- Gahan, A. B. 1940. A contribution to the knowledge of Eucharidae (Hymenoptera: Chalcidoidea). *Proc. U.S. Nat'l Mus.* 88: 425-458.
- Gemignani, E. V. 1933. La familia Eucharidae (Hym. Chalcidoidea) en la republica Argentina. *Ann. Mus. Nac. Hist. Nat. Buenos Aires* 37: 277-294.
- Girault, A. A. 1913. New genera and species of chalcidoid Hymenoptera in the South Australian Museum, Adelaide. *Trans. Roy. Soc. S. Australia* 37: 67-115.
- Heraty, J. M. 1990. Classification and evolution of the Oraseminae (Hymenoptera: Eucharitidae). Unpub. Ph.D. thesis, Texas A&M Univ. [Dissert. Abstr. Int. B 52: 632].
- Heraty, J. M. and D. C. Darling. 1984. Comparative morphology of the planidial larvae of Eucharitidae and Perilampidae (Hymenoptera: Chalcidoidea). *Syst. Entomol.* 9: 309-328.
- Johnson, D. W. 1988. Eucharitidae (Hymenoptera: Chalcidoidea): biology and potential for biological control. *Florida Entomol.* 71: 528-537.
- Johnson, J. B., T. D. Miller, J. M. Heraty and F. W. Merickel. 1986. Observations on the biology of two species of *Orasema* (Hymenoptera: Eucharitidae). *Proc. Entomol. Soc. Washington* 88: 542-549.
- Kempf, W. W. 1972. Catálogo Abreviado das Formigas da Regiao Neotropical (Hymenoptera: Formicidae). *Studia Entomol.* 15: 3-344.
- Kerrich, G. J. 1963. Descriptions of two species of Eucharitidae damaging tea, with comparative notes on other species (Hymenoptera: Chalcidoidea). *Bull. Entomol. Res.* 54: 365-371.
- Kistner, D. H. 1982. The social insect's bestiary. Pp. 1-244. In: H.R. Hermann [ed.]. *Social Insects*, Vol 3. Academic Press, New York.
- Mann, W. M. 1914. Some myrmecophilous insects from Mexico. *Psyche* 21: 171-184.

- Nicolini, J. C. 1950. La avispa costurera y la tuberculosis del olivo. *Rev. Agron., Porto Alegre* 14: 20.
- Parker, H. L. 1942. Oviposition habits and early stages of *Orasema* sp. *Proc. Entomol. Soc. Washington* 44: 142-145.
- Reichensperger, A. 1913. Zur Kenntnis von Myrmecophilen aus Abessinien. I. *Zool. Jahrb. Syst.* 35: 185-218.
- Roberts, F. S. 1958. Insects affecting banana production in Central America. *Proc. X Intern. Congr. Entomol.* 3: 411-415.
- Smith, D. R. 1979. Family Formicidae. Pp. 1323-1468. In: Krombein, K.V., P.D. Hurd, D.R. Smith, and B.D. Burks [eds.]. *Catalog of Hymenoptera in America North of Mexico, Vol. 2.* Smithsonian Inst. Press, Washington.
- Tocchetto, A. 1942. Bicho costuriero. *Rev. Agron., Porto Alegre* 6: 587-588.
- Trager, J. C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae: Myrmicinae). *J. New York Entomol. Soc.* 99: 141-198.
- Van Pelt, A. F. 1950. *Orasema* in nest of *Pheidole dentata* Mayr (Hymenoptera: Formicidae). *Entomol. News* 41: 161-163.
- Vander Meer, R. K., D. P. Jouvenaz and D. P. Wojcik. 1989. Chemical mimicry in a parasitoid (Hymenoptera: Eucharitidae) of fire ants (Hymenoptera: Formicidae). *J. Chem. Ecol.* 15: 2247-2261.
- Wheeler, G. C. and E. W. Wheeler. 1937. New hymenopterous parasites of ants (Chalcidoidea: Eucharitidae). *Ann. Entomol. Soc. Amer.* 30: 163-173, plates 1, 2.
- Wheeler, W. M. 1907. The polymorphism of ants with an account of some singular abnormalities due to parasitism. *Bull. Amer. Mus. Nat. Hist.* 23: 1-100.
- Williams, R. N. 1980. Insect natural enemies of fire ants in South America with several new records. *Proc. Tall Timbers Conf. Ecol. Anim. Cont. Habitat Manage.* 7: 123-134.
- Williams, R. N. and W. H. Whitcomb. 1973. Parasites of fire ants in South America. *Proc. Tall Timbers Conf. Ecol. Anim. Cont. Habitat Manage.* 5: 49-59.
- Wilson, E. O. 1952. O complexo *Solenopsis saevissima* na America do Sul (Hymenoptera: Formicidae). *Mem. Inst. Oswaldo Cruz* 50: 49-59. (Eng. ver., Pp. 60-68).
- Wilson, T. H. and T. A. Cooley. 1972. A chalcidoid planidium and an entomophilic nematode associated with the western flower thrips. *Ann. Entomol. Soc. Amer.* 65: 414-418.
- Wojcik, D. P. 1988. Survey for biocontrol agents in Brazil—a final report, with comments on preliminary research in Argentina. *Proc. Imported Fire Ant Conf.* 50-62.
- _____. 1989. Behavioral interactions between ants and their parasites. *Florida Entomol.* 72: 43-51.
- _____. 1990. Behavioral interactions of fire ants and their parasites, predators and inquilines. Pp. 329-344. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied Myrmecology, A World Perspective.* Westview Press, Boulder, CO.
- Wojcik, D. P., D. P. Jouvenaz, W. A. Banks and A. C. Pereira. 1987. Biological control agents of fire ants in Brasil. Pp. 627-628. In: J. Eder and H. Rembold [eds.]. *Chemistry and Biology of Social Insects.* Verlag J. Peperny, München.