

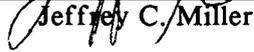
AN ABSTRACT OF THE THESIS OF

Kenneth J. West for the degree of Master of Science in Entomology presented on June 9, 1988.

Title: Biology and host relations of *Meteorus communis* (Cresson).

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Abstract approved:

 Jeffrey C. Miller

Fifteen species of Noctuidae (Lepidoptera) were collected in alfalfa and peppermint in western Oregon. Seven of these species were hosts for the braconid parasitoid *Meteorus communis*. The most frequently parasitized (percent) species were *Agrotis ipsilon* (35.3), *Dargida procincta* (15.0), and *Peridroma saucia* (6.9). Other species parasitized were *Autographa californica* (3.8) and three infrequently collected species, *Pseudaletia unipuncta* (20.0), *Amphipyra pyramidoides* (10.0) and *Xylena nupara* (5.0). Parasitism of *P. saucia*, *D. procincta* and *A. californica* was higher in alfalfa than in peppermint. Larvae of *M. communis* overwintered inside overwintering host larvae.

Six species of Noctuidae were studied in the laboratory as hosts for *M. communis* including *D. procincta*, *P. saucia*, *A. ipsilon* and *A. californica* which were hosts in the field, and *Mamestra configurata* and *Trichoplusia ni* which, although they occurred in the field, were not used as hosts. All six were found to be acceptable hosts in the laboratory but *M. configurata* and *T. ni* encapsulated most eggs and larvae of *M. communis*. Also, parasitoids able to complete development on *M. configurata* produced adults of significantly lighter dry weight than those produced by the other hosts. All hosts were heavily superparasitized under laboratory conditions.

Biology and Host Relations of *Meteorus communis* (Cresson)

by

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BIOLOGY AND HOST RELATIONS OF *METEORUS COMMUNIS* (CRESSON)

I. Introduction and literature review

A large number of factors influence the relative abundance of parasitoid species within a guild. Hosts found in different geographical areas may support very different guilds. Miller (unpublished data) has shown that fewer and different species of parasitoids utilized the alfalfa looper, *Autographa californica* (Speyer) in western Oregon than reported in southern California (Clancy 1969).

The abiotic environment of the host determined the abundance of *Apanteles circumscriptus* (Nees) and *Sympesis sericeicornis* (Nees), parasitoids of *Lithocolletes messaniella* Zeller (Delucchi 1958). He found that *A. circumscriptus* was most abundant when the host occurred in a prealpine habitat while *S. sericeicornis* was dominant on *L. messaniella* under Mediterranean conditions. Three introduced species of *Aphytis*, parasitoids of the red scale, sorted themselves out over geographical regions of southern California differing in temperature and humidity (DeBach and Sundby).

Environmental factors may interact with habitats disrupted by disturbance. At low temperatures, *A. medicaginis* (Muesebeck) did not complete development on *Colias philodice eurytheme* Boisduval in alfalfa before the crop was mowed (Allen & Smith 1958). The rate of recolonization of parasitoids following disturbances affects the observed abundance of individual species (Force 1974, Miller 1980). Early in recolonization *Tetrastichus* spp. is dominant in the *Rhopalomyia californica* Felt parasitoid guild. The next to last species to colonize new galls in a burned site became dominant over the course of a year with *Tetrastichus* becoming rare. Only three of

fourteen species of parasitoids of *Spodoptera praefica* (Grote) were commonly present in alfalfa fields due to frequent cuttings (disturbance) and subsequent recolonization (Miller 1980).

Biotic factors including fecundity (Price 1973), competitive ability (Force 1974), diapause (Force & Messenger 1974), and differences in the functional response of individual parasitoids to host densities (Weiss 1982), affect the dominance or rarity of individual species within a guild. The presence of alternative host species in the habitat or in adjacent habitats may determine the presence or absence of parasitoid species (McClure 1981). The observation of seasonal, low levels of parasitism of the alfalfa looper, *A. californica* by *M. communis* in alfalfa (Miller, unpublished data) prompted me to investigate the possibility that this species was using other hosts.

There are approximately 80 species of *Meteorus* in North America and the genus needs revision for the Nearctic region (Mason, pers. comm.). A few species of *Meteorus*, which are parasitoids of economically important insects, have been studied in detail. Simmonds (1947) described the egg and three larval stages of *Meteorus loxostegei* (= *campestris*) Viereck. The first instar is mandibulate with a well sclerotized head capsule which is shed at the molt to the second instar. First instars have a long caudal tail which decreases in length during the second instar and disappears in the third. The third instar chews through the integument of the host and spins a cocoon which is frequently suspended by a thread from the vegetation. These developmental stages, described by Simmonds (1947) also occur in *M. pulchricornis* (Wesmael) (Askari et al. 1977), *M. indagator* (Riley), *M. dimidiatus* (Cresson), (Balduff 1968), and *M. versicolor* Wesmael (Muesebeck 1918).

Interactions with hosts: The term "host regulation" was used by Vinson (1980) to describe the changes in host development and physiology associated with parasitism. A variety of host-parasitoid interactions have been described. The endoparasitoid *Cotesia congregata* (Say) molts from the first to the second instar in synchrony with the larval molt of its host *Manduca sexta* (Beckage & Riddiford 1983). The same synchrony

occurs when *Pieris rapae* (L.) is parasitized by *Cotesia glomerata* (L.) (Smith & Smilowitz 1976). Other effects of parasitism include the coincidence of parasitoid exit from the host with the host molt (Beckage & Templeton 1985) and the synchrony of host and parasitoid diapause (Schoonhoven 1962). First instar *M. loxostegei* overwinter inside their diapausing *Loxostege sticticalis* L. hosts and continue development only when the host breaks diapause (Simmonds 1947).

Developing *Meteorus* larvae caused the growth of host larvae to stop in several different species. Larvae of the spruce budworm parasitized by *M. trachynotus* Viereck remained in the larval stage while unparasitized hosts pupated and moths emerged (McGugan 1955). Larvae of the wax moth ceased feeding 3 to 5 days after parasitism by *M. pulchricornis* while unparasitized larvae continued to feed and grow (Askari et al. 1977). Soybean looper, *Pseudoplusia includens* (Walker), larvae stopped feeding 6 to 8 days after parasitism by *M. autographae* and total foliage consumption was reduced significantly. Coop & Berry (1986) noted significant differences in growth and foliage consumption between *M. communis* parasitized and unparasitized *P. saucia* larvae.

Little published information is available for *M. communis*. Coop (1987), and Coop and Berry (1986) reported a reduction in foliage consumption by parasitized larvae of *Peridroma saucia* and Howard (1897) mentions *M. communis* as a parasite of *Malacosoma americanum* (F.). Burbutis and Stewart (1979) collected large numbers of *M. communis* and 5 other *Meteorus* species at light traps. No information is available on *M. communis* life cycle, habitat specificity, host range, or parasitoid-host interactions.

My objectives for this study were to 1) determine what species of noctuid larvae in peppermint and alfalfa were hosts for *M. communis* in the field, 2) determine if there were any differences in the development of *M. communis* reared on different host species, and 3) determine why certain species were not used as hosts despite occurring in large numbers in the same fields.

II. Patterns of host exploitation by *Meteorus communis* (Cresson)

Abstract

The parasitoid *Meteorus communis* was reared from seven of fifteen species of noctuids collected in peppermint and alfalfa. Parasitism of these species consistently involved the second through penultimate instars. The most frequently parasitized species (%) were *Agrotis ipsilon* (35.3), *Dargida procincta* (15.0), and *Peridroma saucia* (6.9). Parasitism of *P. saucia*, *A. ipsilon*, and *Autographa californica* (3.8) by *M. communis* are new host records. Also parasitized were the less common, *Pseudaletia unipuncta* (20.0), *Amphipyra pyramidoides* (10.0) and *Xylena nupara* (5.0). Percent parasitism by *M. communis* was significantly higher in alfalfa than in peppermint. Three or four overlapping generations of *M. communis* may occur per year in western Oregon. Larvae of *M. communis* overwinter inside the host larva.

Introduction

The biology of only a few species of *Meteorus* Haliday (Braconidae) has been described. In general, species of *Meteorus* are solitary or gregarious parasitoids of larval Coleoptera and Lepidoptera and many are polyphagous. Typically, development proceeds through three instars (Simmonds 1947, Balduf 1968, Askari et al. 1977). The third instar larva exits the host and spins a cocoon which characteristically dangles by a thread from the vegetation. Larvae of *M. communis* overwinter inside the host larvae (Simmonds 1947, Balduf 1968, Shaw 1981, West and Miller 1988).

One of the parasitoids most frequently reared from noctuid larvae collected on peppermint and alfalfa in western Oregon is *Meteorus communis* (Miller unpublished data, Coop 1987). Known hosts for *M. communis* include the noctuids *Amphipyra pyramidoides* Guenée, *Dargida procincta* (Grote), *Eupsilia sedus* (Guenée), *Lithophane bethunei* (G. and R.), *L. laticineae* Grote, *Orthosia hibisci* (Guenée), *O. revicta* (Morrison), *Pseudaletia unipuncta* (Howorth), the lymantriid *Malacosoma americanum* (F.) and the tortricid *Grapholitha* sp. (Krombein et al. 1979). We found no published information on the biology of *M. communis*. Here we report the patterns of host utilization by *M. communis* on peppermint and alfalfa in the Willamette Valley of Oregon.

Materials and Methods

We monitored the relative abundance of immature Lepidoptera by species and age class in alfalfa and peppermint to determine the factors influencing the relative abundance of *M. communis* throughout the growing season. Study plots to assess the parasitism of noctuid larvae were established in peppermint and alfalfa near Corvallis, Benton County, Oregon. Four peppermint fields and three alfalfa fields were sampled during 1984. The original four plus three additional peppermint fields and two of the three original alfalfa fields were sampled during 1985.

Sampling was conducted and standardized as follows. A series of 25 sweeps in a 120° arc with a standard (38 cm diameter) sweep net were taken. Sweeps were started at the edge of a field and taken 1m apart progressing into the field. This process was repeated moving laterally 3m until a total of 250 sweeps were taken or 250 noctuid larvae had been collected. This pattern was altered in the case of damp foliage (the number of sweeps per transect reduced to ten) or if the density of noctuid larvae was extremely low (number of sweeps increased to 500). Weekly sampling was initiated in early July during 1984 and mid-June during 1985, when larvae were present in both crops, and continued until peppermint harvest (ca. August 10) or until the final cut in alfalfa (ca. September 15). Samples were taken on a monthly basis during the winter of 1984-1985 on alfalfa regrowth. None of the peppermint fields had sufficient winter growth to facilitate sampling.

Larvae were placed in plastic cups (473 ml) while in the field, and returned to the lab where individual larvae were placed into 30 ml cups, provisioned with cubes of artificial diet (BioServ #928L2, Cabbage Looper Diet) and sealed with paper insert lids. Diet was changed at least every two days. The species and instar of each noctuid was recorded at time of collection. Larvae were reared in the lab at a constant temperature of 24 (\pm 2)°C and observed daily for parasitoid emergence. The time it took *M. communis* to exit from hosts in the lab was correlated to the host instar at the time of collection by regression analysis. Cadavers of hosts from which *M. communis* had exited

were dissected within 12 hours for evidence of superparasitism.

Results and Discussion

A total of 5197 noctuid larvae representing 15 different species were collected (table II.1). Seven species were parasitized by *M. communis*. Parasitism of *A. ipsilon* (35.3%), *P. saucia* (6.9%), and *A. californica* (3.8%) are new host records. Also parasitized were *P. unipuncta* (20%), *D. procincta* (15%), *A. pyramidoides* (10%), and *Xylena nupara* Lintner (5%). Additionally, we recovered *M. communis* from winter collections of *D. procincta* (10.8%) and *A. californica* (6.0 %) in alfalfa. Of those species not parasitized, only *M. configurata* was collected in sufficient numbers to suggest that it is not a suitable host species. It is possible that parasitism of some of the other species may occur but insufficient numbers of larvae were collected during this study. For example, *T. ni* was readily accepted and suitable for *M. communis* in laboratory tests (West, 1988).

Larvae of three noctuid species were parasitized by *M. communis* in both peppermint and alfalfa (table II.2). Most often, *M. communis* was associated with *P. saucia*, *D. procincta*, and *A. californica* in alfalfa and peppermint. The most frequently parasitized species, *A. ipsilon*, was extremely rare in mint.

The relative abundance of *M. communis* and the three hosts common to both crops is given in figure 1. The peak in host abundance during July was due to the presence of *P. saucia*, *A. californica*, and *D. procincta* in alfalfa and *P. saucia* and *A. californica* in peppermint. The increase in abundance of hosts was followed by a similar increase in *M. communis* parasitized hosts in alfalfa while in peppermint no such response was observed.

In any analysis of host-parasitoid relationship it is important to determine the host stages used by the parasitoid for development. It is possible to infer the instar that *M. communis* oviposits into in the field from a combination of field and laboratory data (Fig. 2). All but the first and last instars of each noctuid species received eggs from *M. communis*. The number of days required for *M. communis* to exit hosts (*D. procincta*, *A. californica*, and *P. saucia*) in the lab was longer for those exiting younger hosts

presumably because they had more recently received *M. communis* eggs. The number of days required for *M. communis* to exit (at $24 \pm 2^\circ\text{C}$) after field collection was ($\bar{x} \pm \text{sd}$) 10.2 ± 1.8 , $n=19$ for second instars, 8.1 ± 2.2 , $n=42$ for third instars and 6.8 ± 2.4 , $n=44$ for fourth instars (*M. communis* exited from 2 of 105 fifth instars which required 4 and 8 days). This compares to the ten day developmental time we observed in our lab culture (oviposition to exit, reared on *P. saucia* third instars). These data suggest that hosts are typically parasitized as second instars in the field.

Neither host species nor instar had an effect on the sex ratio of *M. communis*, which was 1:1, throughout the year. I did not detect superparasitism in field collected hosts (based on host dissections, $n=110$). No hyperparasitoids were reared from *M. communis* emerging in the lab ($n > 500$), but two field collected *M. communis* pupae yielded a species of Mesochorinae (Ichneumonidae) indicating that hyperparasitism occurs in the pupal stage.

A larger percentage of susceptible hosts (second through penultimate instars) were parasitized in alfalfa than in peppermint (all species pooled, table II.2). Overall parasitism was higher in alfalfa. Ten hosts parasitized by *M. communis* were collected per thousand sweeps in alfalfa versus only two per thousand sweeps in peppermint. This difference was consistent both years and may be a result of: 1) durational stability of the habitat, 2) host availability in the agroecosystems, 3) nutritional affects on the development and allelochemical affects on behavior caused by the host plants, 4) differences in the use of insecticides. The influence of each of these variables requires experimental examination but may be considered as follows: 1) peppermint foliage is present only part of the year (June - early August) while alfalfa foliage is present throughout the year. 2) Although *A. ipsilon*, *A. pyramidoides*, and *P. unipuncta* did not occur in peppermint, proportionately more larvae of *D. procincta* and *P. saucia* were parasitized when they occurred in alfalfa than when they occurred in peppermint (table II.2). 3) there was no difference in the ability of *M. communis* to develop in hosts fed peppermint versus alfalfa in the laboratory (West and Miller 1988). Also, development

times for *M. communis* reared from *P. saucia* fed mint foliage (Coop and Berry 1986) were not significantly different from times observed with an alfalfa or artificial diet (West 1988). 4) insecticides were used on all but one peppermint field while no alfalfa fields were treated.

Conclusions

The results of my investigation demonstrated that *M. communis* is abundant throughout the growing season, is more common in alfalfa than in peppermint, and is capable of exploiting a large number of noctuid hosts, some of economic importance. Further investigations should address the role of cultural practices and the impact of insecticide treatments to further determine what influences parasitism by *M. communis* in these habitats. Data from these studies will be useful in investigations on the structure and dynamics of parasitoid guilds and the potential of using biological control in these crops.

Table II.1. Numbers and species of noctuid larvae collected in peppermint (m) and alfalfa (a) and parasitism of those species by *M. communis* (*M. c.*), (+) parasitized, (-) not parasitized.

Species	Crop	Number	<i>M. c.</i>
<i>Autographa californica</i>	a,m	1997	+
<i>Peridroma saucia</i>	a,m	1203	+
<i>Mamestra configurata</i>	a,m	853	-
<i>Dargida procincta</i>	a,m	564	+
<i>Agrotis ipsilon</i>	a	312	+
<i>Xestia adela</i>	a,m	92	-
<i>Amphipyra pyramidoides</i>	a	48	+
<i>Leucania farcta</i>	a	44	-
<i>Trichoplusia ni</i>	a,m	40	-
<i>Xylena nupara</i>	a,m	23	+
<i>Pseudaletia unipuncta</i>	a	10	+
<i>Heliothis phloxiphaga</i>	a,m	8	-
<i>Heliothis zea</i>	a	1	-
<i>Scotogramma trifolii</i>	a	1	-
<i>Spodoptera praefica</i>	a	1	-

Table II.2. *Meteorus communis* parasitism of field collected noctuid larvae collected from peppermint and alfalfa in western Oregon during 1984-1985.

Host	Year	Alfalfa		Peppermint	
		No. ^a	% para ^b	No. ^a	% para ^b
<i>Peridroma saucia</i>	1984	25	8	330	2
	1985	310	12	167	6
<i>Dargida procincta</i>	1984	104	12	17	0
	1985	256	18	44	5
<i>Agrotis ipsilon</i>	1984	286	36	1	0
	1985	15	27	1	0
<i>Autographa californica</i>	1984	317	3	226	3
	1985	423	6	380	2

^a susceptible stages only (instars II-V, II-IV for *A. californica*)

^b determined by rearing.

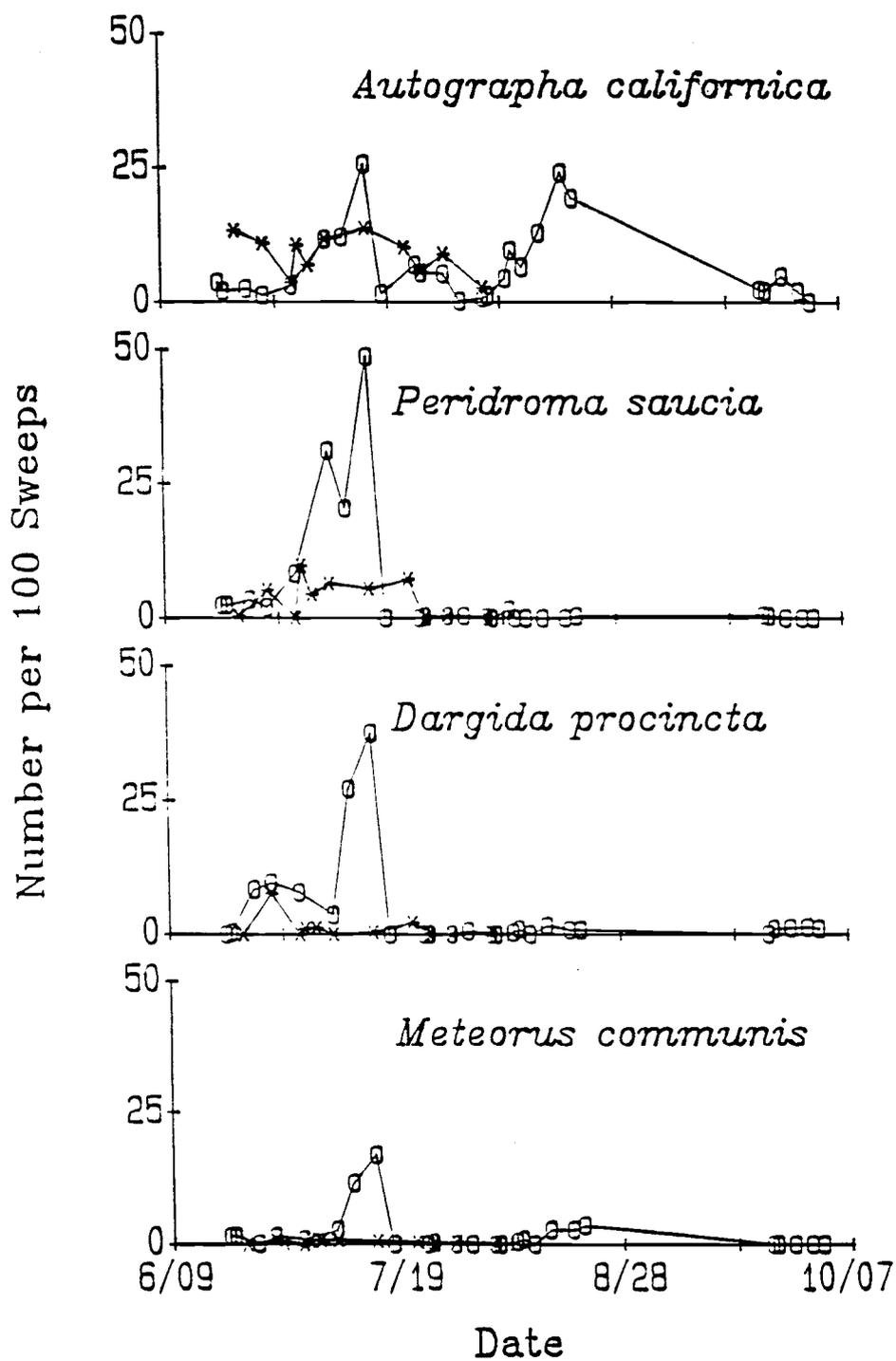


Fig. II.1. Seasonal abundance (per 100 sweeps) of *Meteorus communis* and three of its principal hosts in peppermint and alfalfa during 1985. Peppermint (*) Alfalfa (o)

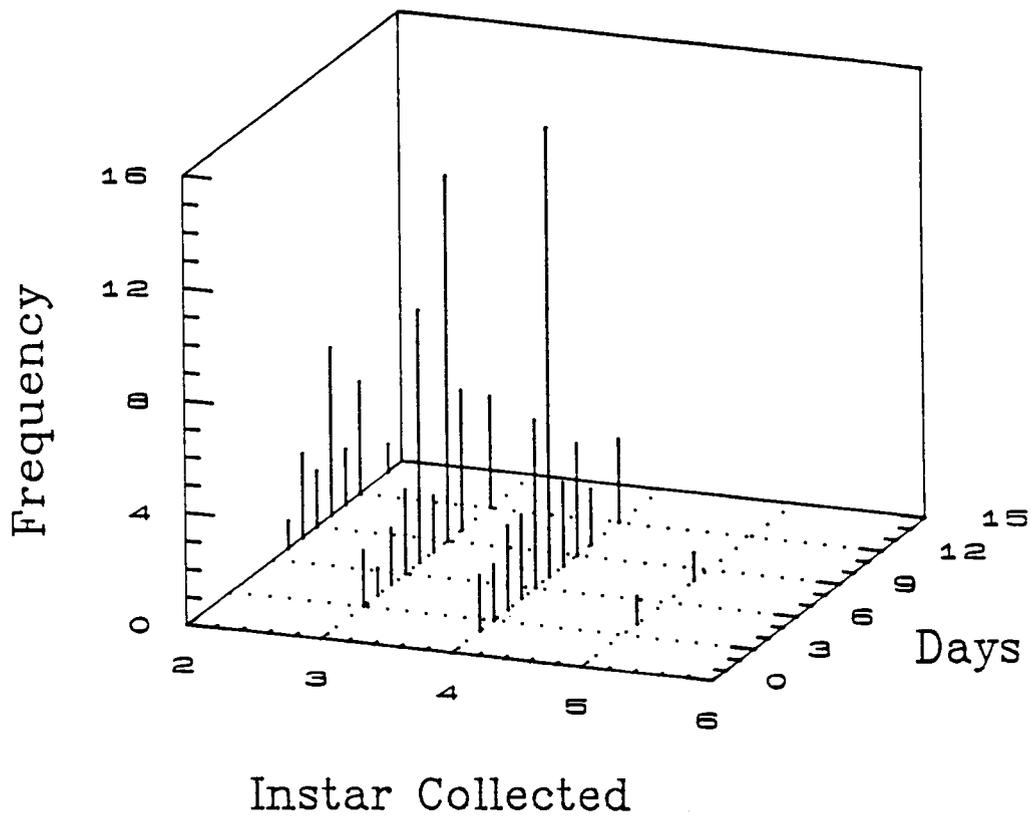


Fig. II.2. Relationship between the number of days required for *Meteorus communis* to exit from a host after collection and the instar of that host at the time of collection. (regression $r^2 = .22$, $y = 12.97 - 1.545x$).

III. Suitability of five species of Noctuidae as hosts for *Meteorus communis*

Abstract

Six species of Noctuidae found in alfalfa and peppermint in western Oregon including *Dargida procincta* (Grote), *Peridroma saucia* (Hübner), *Agrotis ipsilon* (Hufnagel), *Autographa californica* (Speyer), *Mamestra configurata* Walker, and *Trichoplusia ni* (Hübner) were studied as hosts for *Meteorus communis* (Cresson) (Hymenoptera, Braconidae). All were found to be acceptable and suitable in the laboratory but *M. configurata* and *T. ni* encapsulated parasitoid eggs and larvae. This may explain why these two species are not parasitized in the field. Parasitoids developing on *M. configurata* produced adults of significantly lighter dry weights than those produced by the other hosts. All species were heavily superparasitized and this may explain the difference in laboratory and field observations.

Introduction

Generalist parasitoids may encounter a number of different potential hosts in any given habitat. Qualitative differences in the acceptability and suitability of each host will determine patterns of parasitism (Miller and West 1987). The acceptability and suitability of each host will vary with a variety of factors including 1) the developmental stage or age of the host (Vinson and Iwantsch 1980), 2) the experience and age of the ovipositing parasitoid (Arthur 1981, Mackauer 1983, Blumberg and DeBach 1981), 3) the ability of the host's immune system to eliminate the parasitoid once present (Blumberg 1977, Salt and Van den Bosch 1967), and 4) whether or not the host was super- or multiparasitized (Salt 1937, Salt and Van den Bosch 1967).

Meteorus communis (Cresson) is a native, solitary, larval endoparasitoid of lepidopterous larvae, primarily Noctuidae (Krombein et al. 1979, West and Miller 1988). It is multivoltine and capable of completing four overlapping generations in western Oregon. The three instars take 10 days to complete development (L14:D10, 25±1°C, West and Miller, unpub.). The first instar is mandibulate and actively eliminates supernumerary conspecifics (pers. obs.) and presumably, larvae of other parasitoid species as well. The third instar exits the host and spins a cocoon which it suspends by a thread. The pupal stage lasts 4 days (L14:D10, 25±1°C) and emerging adults mate immediately (pers. obs.).

This species is an important part of the parasitoid guild of noctuid larvae found in agricultural crops in western Oregon (Coop & Berry 1986, Coop 1987, West & Miller 1989). Up to 40 percent of the noctuid larvae collected in peppermint and alfalfa were parasitized by *M. communis*, however, certain species were never parasitized despite being present in large numbers (West and Miller 1989). This observation coupled with a lack of published information on the host relationships of *M. communis* prompted this study.

Research on host range, host suitability, and fitness characteristics of development on different hosts will contribute to understanding the role of *M. communis* in the

natural regulation of noctuid populations. Here, I report certain aspects of the biology of *M. communis* on different host species including: 1) host range, 2) aspects of development on different hosts, 3) adult body size, and 4) fate of parasitoid eggs or larvae.

Materials and Methods

General Laboratory experiments to study host acceptance and suitability were conducted in controlled environment chambers at $25 \pm 1^\circ\text{C}$, 35-55% r.h., and L14:D10.

Hosts All host larvae used in experiments were the F_1 progeny of field collected material. Hosts were collected in peppermint and alfalfa fields in western Oregon, and included *Dargida procincta* (Grote), *Peridroma saucia* (Hübner), *Agrotis ipsilon* (Hufnagel), *Mamestra configurata* Walker, *Autographa californica* (Speyer), and *Trichoplusia ni* (Hübner). Larvae were brought into the laboratory and reared on cabbage looper diet (*T. ni*), BioServ # 928L2. Moths were placed in sleeve cages for mating and oviposition. Cages were provisioned with a saturated honey-water solution and were sprayed daily with water to increase humidity. Paper towels were folded and hung or stood vertically to provide a substrate for oviposition. Host eggs were collected every 24 hours after oviposition began and newly hatched larvae were reared on artificial diet until the desired stages were obtained.

Parasitoids All parasitoids used in experiments were the F_1 progeny of adults obtained from field collected hosts in order to avoid laboratory effects such as inbreeding or conditioning. Larval *M. communis* emerging from host larvae were held for pupation and adult emergence. Adults were placed in sleeve cages within 12 hours of emergence and allowed to mate. Mating occurs in the first half hour when males and virgin females are placed together (pers. obs.). Parasitoids were removed from the sleeve cage and placed in jars with hosts (described below) when 24-72 hours old. All exposures to parasitoids were conducted in narrow mouth, one quart canning jars laid sideways. The jars were provisioned with a saturated honey-water solution, cubes of artificial diet and hosts. Fine mesh netting with a small hole for insertion of parasitoids was placed over the opening and held in place with a lid ring. After insertion of parasitoids the hole was sealed with a cork. Host larvae were exposed to parasitoids for 24 hours.

Experimental Design Four of the six host species, *D. procincta*, *P. saucia*, *A. ipsilon*, and *M. configurata* usually develop through six instars and the semi-loopers, *T. ni* and *A.*

californica develop through five instars. Previous studies (West and Miller 1989) have shown that *M. communis* will not parasitize the first or last instar of a host. Therefore, second through fifth instars of the first four species were exposed to parasitism and second through fourth instars of the semi-loopers were used in this study.

Host to parasitoid ratio for all experiments was 8.5:1 (100/12). One hundred individuals of each host instar used were selected randomly from the lab culture and exposed to *M. communis* for each trial. All cohorts of larvae were used within 12 hours of molting to the desired stage. Second and third instar larvae were placed 50 per jar and each jar received 6 female *M. communis*, two jars constituted a trial. Fourth and fifth instar larvae were placed only 25 per jar to avoid cannibalism. Only three female parasitoids were placed in each jar in this case so that four jars constituted a trial. Parasitoids and hosts were distributed randomly in each trial.

Half of the larvae were randomly assigned to groups for rearing and half for dissection after exposure. Larvae were frozen five days after parasitism for later dissection. Five days was chosen to allow any host immune reaction to occur and become apparent. The numbers of parasitoid eggs and larvae per host were recorded upon dissection. Also, the numbers of encapsulated or phagocytized larvae per host were noted. Hosts and instars were considered "accepted" by *M. communis* if eggs or larvae were found in dissected hosts and "suitable" only if parasitoids could be successfully reared from living hosts. The time to exit from the host, sex ratio and the dry weight (mg) of adult parasitoids was recorded. Individuals not successfully completing development to the adult stage were not included in the analyses. Adult parasitoids were dried for 72 hours at 45°C prior to weighing.

Results and Discussion

Larvae of *M. configurata*, *P. saucia*, *D. procincta*, *T. ni*, and *A. ipsilon* were accepted by *M. communis* (table III.1). All of these species were considered suitable hosts for *M. communis* in the laboratory because at least some parasitoid adults were obtained. West & Miller (1988) reared *M. communis* from field collected *P. saucia*, *A. californica*, *D. procincta*, and *A. ipsilon* but never from *T. ni* or *M. configurata*. Reasons for the difference in field and laboratory observations are considered in the discussion of each host-*M. communis* interaction which follows.

Peridroma saucia. The second through the fourth instars of *P. saucia* were heavily parasitized (accepted) by *M. communis* (table III.1). Many individuals were superparasitized with as many as nine eggs deposited in a single host larva. The 24 hour period of exposure to parasitism may be responsible for the superparasitism observed in this study, however, similar levels of superparasitism occurred with *Meteorus pulchricornis* (Wesmael), which deposited 7-8 eggs per host larva during six hour exposures (Askari et al. 1977).

The high level of superparasitism I observed in the lab does not occur in the field. Dissections of cadavers of field collected hosts from which *M. communis* had emerged (n=110) showed no evidence of superparasitism, however, it is possible that parasitoid larval remains may be encysted in the cuticle and cast by the host at the time of a molt. Cuticular encystment (Arthur and Ewen 1975) is readily observable in *T. ni* and may remove the record of superparasitism from field collected material. Ovipositing females will frequently probe a single host several times in the laboratory but are not depositing eggs each time (pers. obs.). No *M. communis* larvae were found inside fifth instar *P. saucia* upon dissection, but three fifth instar larvae produced *M. communis* males in one of the reared groups indicating a low degree of acceptability and suitability of this instar. These data indicate that second through fourth instar *P. saucia* were acceptable and suitable for development of *M. communis*, and that fifth instar larvae were marginally suitable. West & Miller (1988) reported that parasitism of fifths in the field

is uncommon. Clearly, *M. communis* can parasitize fifth instar *P. saucia* although the parasitoids had some difficulty ovipositing due to a vigorous behavioral defense by the host which included regurgitating crop contents and biting at the parasitoid. This pattern occurred with late instar *Loxostege sticticalis* L. which were "too strong" for *Meteorus loxostegei* Viereck (Simmonds 1947). Also, in the field, fifth instar *P. saucia* move off the foliage to the ground (Coop 1987) where they may be less likely to be encountered by *M. communis*. Coop and Berry (1986) observed a six fold decrease in parasitism of larvae which reach the fifth instar.

The length of time for development from oviposition to the exit of the parasitoid from *P. saucia* is given in table III.2. Both males and females developed faster when third or fourth instar hosts were parasitized. Also, *M. communis* emerging from *P. saucia* parasitized as fourth instars were significantly larger than those reared from earlier instars (table III.3).

A single incidence of encapsulation of a first instar *M. communis* was observed in a dissection of a second instar *P. saucia* (n=136). No other host immune response was observed in cases where parasitoid larvae were present in this host. Supernumerary *M. communis* larvae that were wounded or killed in physical combat with others were usually encapsulated.

Mamestra configurata. Second and third instar *M. configurata* were parasitized by *M. communis* in the laboratory (table III.1). Five males and two females were reared from second instars (n=135). The males were significantly smaller than those reared from second instar *P. saucia* (p=0.037, t-test) (the females were smaller but statistical analyses were not conducted with only two cases). Also, the developmental time (days) from parasitism to exit from the host was significantly longer (p<0.001) for *M. communis* males reared from second instar *M. configurata* (\bar{x} =16.2, se=.83, n=5) than from second instar *P. saucia* (\bar{x} =12.04, se=.33, n=14). No *M. communis* were reared from third (n=96) or fourth instars (n=50).

Four cases of encapsulation were observed (n=140) five days post exposure in

second instar *M. configurata*. The first instar *M. communis* that were not encapsulated were the size of newly hatched larvae (pers. obs.) rather than ready to molt to the second instar as was the case when *P. saucia* was the host. Mortality of exposed larvae was high (50%) in two of three replicates of the reared treatments while none occurred in the culture from which these cohorts were drawn.

The successful parasitism of *M. configurata* in the laboratory was surprising because there was no evidence of parasitism of field collected larvae. Searching *M. communis* may avoid ovipositing in *M. configurata* altogether in the field although there is no evidence of this in the laboratory. The unusually high mortality of *M. configurata* larvae exposed to *M. communis* may explain why I was unable to rear it from field collected individuals. Larvae of *M. configurata* may be parasitized by *M. communis* in the field, but these individuals die, preventing their detection. A similar situation exists with *Bracon hebetor* (Say), an ectoparasitoid of noctuids. A "hypersensitivity" to the parasitoid occurred when *Spodoptera littoralis* Boisduval was the host and nearly all parasitized hosts died and yielded no parasitoid progeny (Gerling & Rotary 1973). Another possibility is that the ability of *M. configurata* to encapsulate *M. communis* is overcome when the host is heavily superparasitized.

It is possible that *M. communis* may be able to overcome the defensive reactions of some normally unsuitable species by placing more than one egg in a single host. There is some evidence that the immune system of some hosts can be circumvented in this way (Salt and Van den Bosch 1967). Also, some hosts may only be able to successfully encapsulate a single parasitoid egg (Bakker et al. 1985) Thus, it may be advantageous for the original female or a conspecific to superparasitize and this may be the strategy used by *M. communis* to overcome host defenses. Also, it is possible that this is merely a laboratory artifact. Waage (1986) reported increased numbers of eggs were laid per host over time when *Trichogramma evanescens* Westwood were confined in the laboratory. Whether this is the case with *M. communis* remains to be tested.

Trichoplusia ni. Second through fourth instar *T. ni* were parasitized in the lab by

M. communis but only 16 *M. communis* were reared from 235 exposed larvae. Developmental times of males and females from the different instars were not significantly different and were pooled for comparison to *P. saucia*. The developmental time (days) from host exposure to parasitoid exit from the host was not significantly different from times with *P. saucia* as the host ($p = .43$), ($\bar{x} = 10.24$ and 10.54 respectively). The adult parasitoids exiting *T. ni* were heavier than those exiting *P. saucia* ($p = .043$). Several of the host larvae which ultimately pupated showed signs of having eliminated *M. communis* by cuticular encystment. Only 8 of 100 third instars were found to be parasitized when dissected, half had encapsulated first instars of the parasitoid. Three fourth instars were parasitized, but all *M. communis* larvae had been encapsulated including two in one host. None of four parasitized second instar *T. ni* showed any sign of encapsulation.

If *M. communis* is not encapsulated *T. ni* provides a favorable environment for larval development. The combination of rapid development and large size indicates good fitness of progeny developing in this host. The lack of encapsulation in second instars suggests that this capability may improve with age. As with *M. configurata*, encapsulation might be overcome by supernumerary parasitism. If superparasitism allows *M. communis* to circumvent encapsulation then it would clearly be advantageous.

Agrotis ipsilon. Larvae of *A. ipsilon* were available briefly during the fall of 1984. I reared large numbers of *M. communis* from field collected second through sixth instars but was only able to obtain a small lab culture of this host. Parasitism of second and fourth instars was 9.4 and 22.9 percent as determined by dissections of host larvae (table III.1.). Only one *M. communis*, a male, was reared from *A. ipsilon* in the lab. No evidence of any host immune reactions were observed in dissected host larvae.

Dargida procincta. Although *D. procincta* is readily collected in the field, I was only able to rear small numbers of *D. procincta* because of low rates of oviposition in the lab (individual moths laid only 7 or 8 eggs). Second instars of this species were readily parasitized by *M. communis*, however, it took significantly longer ($p < 0.001$) for the

parasitoids to exit this host (21.5 days vs. 12.0 days) than when *P. saucia* was the host. Mean dry weights (mg) of *M. communis* adults were less when reared from *D. procincta* second instars (0.69 ± 0.02 , vs. 0.60 ± 0.06 , $p=0.053$) than from *P. saucia* second instars.

I was unable to culture *A. californica* in the laboratory due to a nuclear-polyhedrosis virus. I found *M. communis* larvae in *A. californica* larvae that were diseased and West & Miller (1988) reported its suitability as a host in the field.

Conclusions

In general, parasitoids take longer to complete development when the host is in the first or second instar (Puttler 1961, Smilowitz and Iwantsch 1973, Vinson and Barras 1970). This was the case with *P. saucia* as *M. communis* development was 1.5 to 2 days slower on second instars than third, fourth or fifth instars ($p < 0.01$). Whether host developmental time or some minimum quantity of food resources needed by the developing parasitoid, is more important in determining the nature of this host parasitoid relationship requires further study.

The significantly longer time *M. communis* takes to exit *D. procincta* may be due to the host's slow developmental rate. Jubb and Watson (1971) suggested that the host developmental rate may affect that of the parasitoid. *D. procincta* takes approximately ten weeks to complete a generation at 25°C as compared to four weeks for *T. ni*, and six weeks for *P. saucia* (pers. obs.). Also, more time may be necessary for sufficient resources to accumulate for the parasitoid when *D. procincta* is parasitized as a second instar. A delay in the development of the parasitoid may prevent premature utilization of the host when resources are insufficient to produce fit offspring (Jowyk and Smilowitz 1978).

Laboratory studies of individual parasitoids provide important information on host parasitoid relationships. When compared with field studies these data provide important information on the potential of parasitoid species for classical biological or integrated pest management programs. The ability of *M. communis* to parasitize several instars of different species of noctuids in alfalfa and peppermint indicates that it is an important member of the guild of natural enemies of noctuid moths in western Oregon. Given the importance of the Noctuidae as pest species, the role of parasitoids such as *M. communis* in regulating host densities is extremely important.

Table III.1. Percent acceptance of noctuid larvae by *Meteorus communis* in the lab (based on dissections of larvae (n)).

Host Species	Host Instar			
	2nd	3rd	4th	5th
<i>Peridroma saucia</i>	35.3(136)	61.3(142)	67.6(139)	0.0(100)
<i>Trichoplusia ni</i>	8.3(48)	14.1(99)	5.7(88)	0.0(100)
<i>Mamestra configurata</i>	25.7(140)	2.2(45)	0.0(50)	*
<i>Agrotis ipsilon</i>	9.4(32)	0.0(31)	22.9(35)	*
<i>Dargida procincta</i>	40.8(98)	*	*	*

* Larvae not available

Table III.2. Days from exposure of *Peridroma saucia* to exit of larval *M. communis* (14L:10D, 25°C), (\bar{x} , se, (n)), p values are for significance between male and female wasps. Time to exit from third and fourth instar hosts was significantly shorter than from second instars (FPLSD $p < 0.01$).

Parasitoid development (days)					
Host instar	males		females		p
II	12.0	0.33 (14)	12.6	0.46 (10)	.361
III	10.0	0.16 (24)	10.9	0.59 (8)	.049
IV	9.5	0.12 (20)	9.9	0.16 (16)	.063

Table III.3. Dry weight (mg) of adult *M. communis* reared from three instars of *Peridroma saucia* in the laboratory (\bar{x} , se (n)). Females were significantly larger than males for all instars ($p < 0.005$).

Host instar	Parasitoid weight	
	Males ¹	Females ²
II	0.69, 0.06 (14)	0.81, 0.05 (10)
III	0.65, 0.08 (24)	0.78, 0.12 (8)
IV	0.77, 0.17 (20)	1.04, 0.15 (16)
V	0.93, 0.06 (3) ³	

¹ Parasitoids exiting fourth instars significantly larger than thirds ($p = .004$).

² Parasitoids exiting fourth instars significantly larger than seconds and thirds ($p < .01$, FPLSD).

³ Only 3 of 98 were successfully reared, (a female did not successfully exit the pupa and is not included).

IV. Conclusions

The results presented in this thesis are a contribution to the understanding of host-parasitoid relationships, and add to the knowledge base required for successful implementation of biological control.

Studies of parasitoid foraging behavior have described the steps involved in host finding (Arthur 1981, Vinson 1981). Doult (1959) broke the parasitoid foraging behavior into three steps: habitat location, host location and host selection. This partitioning of foraging behavior has served as a model for many studies of parasitoid behavior.

The noctuid parasitoid *M. communis* occurs in row and forage crops and appears to be habitat specific (*sensu* Vinson 1976). Extensive sampling of Lepidoptera in forest and other habitats (Miller & Scaccia, unpublished) has failed to detect any *M. communis*. Most of the noctuid species commonly occurring in the peppermint and alfalfa habitats were acceptable to *M. communis* suggesting that habitat may be the level at which *M. communis* selects hosts. This aspect of *M. communis* biology would be important in any consideration of this species use as a biological control agent.

The lack of parasitism of *M. configurata* in spite of its abundance in the field and acceptability in the laboratory has implications for foraging theory. If the superparasitism in the laboratory allowed *M. communis* to overcome the defense mechanisms of *M. configurata* then perhaps it may occur in the field. This may permit a parasitoid to overcome temporary shortages of more suitable hosts, a characteristic desirable in a biological control agent.

Identification of these types of characteristics in individual species of parasitoids will greatly enhance our ability to conduct biological control and integrated pest management. Further investigation of the role of superparasitism, additional alternative hosts and climatic tolerances are necessary to evaluate the potential of *M. communis* for biological control of a particular pest.

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