A Survey of Hymenopteran Parasitoids of Forest Macrolepidoptera in the Central Appalachians

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ABSTRACT In 1995 and 1996, we conducted a study of the hymenopteran parasitoids of macrolepidopteran larvae in the George Washington National Forest (GWNF), Augusta County, Virginia, and the Monongahela National Forest (MNF), Pocahontas County, West Virginia. Macrolepidopteran larvae were collected from canopy foliage and from under canvas bands placed around tree boles. A total of 115 macrolepidopteran species and 5,235 individual larvae were reared. Forty-two percent (2,221) of the larvae were gypsy moth, *Lymantria dispar* (L.) (Lymantriidae). A total of 43 primary and seven secondary (hyperparasitoid) hymenopteran parasitoid species were reared from 46 macrolepidopteran species. Hymenopteran families represented included Ichneumonidae (23 species), Braconidae (19), Eulophidae (6), Perilampidae (1), and Trigonalidae (1). We reared 41 and 28 parasitoid species from the GWNF and the MNF, respectively, with 19 species reared from both forests. Many parasitoid species were collected infrequently, suggesting that they are relatively rare on the sampled hosts. The introduced species *Cotesia melanoscela* (Ratzeburg) (Braconidae), and *Euplectrus bicolor* (Swederus) (Eulophidae) were among the most commonly reared parasitoids, the latter reared from native hosts. The four most commonly reared native parasitoids were *Meteorus hyphantriae* Riley (Braconidae), *Microplitis* near *hyphantriae* (Ashmead) (Braconidae), *Aleiodes preclarus* Marsh & Shaw, and *Euplectrus maculiventris* (Westwood) (Eulophidae). A total of 53 new hymenopteran parasitoid-macrolepidopteran host records were documented. Results from this study will be used to evaluate long-term treatment effects of regional applications of *Bacillus thuringiensis kurstaki*, and the gypsy moth fungus *Entomophaga maimaiga* Humber, Shimazu & Soper on hymenopteran parasitoids of macrolepidopteran larvae.

KEY WORDS *Bacillus thuringiensis*, Appalachian Mountains, gypsy moth, host associations, Hymenoptera

PARASITOIDS PLAY AN IMPORTANT role in regulating native forest macrolepidoptera and are considered to be the most important natural enemies of many native macrolepidopteran species (LaSalle 1993, McCullough et al. 1999). Natural and human impacts on populations of either parasitoids or their hosts may create an imbalance in these self-regulating systems. Most research on parasitoids of native forest macrolepidoptera has focused on outbreak species such as *Alsophila pometaria* (Harris) (Geometridae), *Ennomos subsignarius* (Hübner), *Heterocampa guttivitta* (Walker) (Notodontidae), *Hyphantria cunea* Drury (Arctiidae), *Malacosoma americanum* (F.) (Lasiocampidae), *Malacosoma disstria* Hübner, and *Orgyia pseudotsugata* McDunnough (Lymantriidae) (Kulman 1965; Stehr and Cook 1968; Allen 1972; Morris 1972, 1976; Fedde et al. 1973; Anderson and Kaya 1976; Witter and Kulman 1979; Butler 1990; Parry 1995). A limited number of studies have addressed parasitoids of both outbreak and nonoutbreak forest macrolepidopteran species (Viereck 1916, Schaffner and Griswold 1934, Raizenne 1952, Wood and Butler 1991, Butler 1993, Whitfield et al. 1999).

With few exceptions, parasitoids of macrolepidoptera belong to the hymenopteran superfamilies Ichneumonoidea and Chalcidoidea, and the dipteran family Tachinidae (Askew 1971, Quicke 1997). North American hymenopteran and dipteran parasitoid host associations have been catalogued in the Krombein et al. (1979) taxonomic and Arnaud (1978) host-parasitoid catalogs, respectively. Krombein et al. (1979) included many previously unpublished associations, whereas Arnaud (1978) was based on previously published records. Recent large-scale rearings of forest macrolepidoptera by Butler (1993) documented 115 new host associations and our companion study by Strazanac et al. (2001), which reported 60 new tachinid host associations, indicate that we lack a considerable amount of knowledge in this area of forest ecology.

Mention of trade names does not constitute endorsement by the U.S. Department of Agriculture.

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In efforts to slow the spread of gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), populations in the United States, aggressive spray programs have been implemented in many states. One of the most popular insecticides being used is *Bacillus thuringiensis kurstaki* (Btk), which is relatively specific to Lepidoptera (Boberschmidt et al. 1989, Sample et al. 1996). Through both direct and indirect nontarget effects, Btk can impact natural enemies of native macrolepidoptera, including parasitoids. Results of previous studies on the nontarget effects of Btk on parasitoids have varied, both among different parasitoid species and within different life stages of the same parasitoid (Reardon et al. 1979, Weseloh and Andreadis 1982, Andreadis et al. 1983, Wallner et al. 1983, Thoms and Watson 1986). The impacts that Btk may have on native parasitoids of macrolepidoptera in forest ecosystems can be evaluated only if adequate data on native parasitoid–macrolepidopteran host relationships are available.

In 1995 and 1996, we surveyed the parasitoid fauna of macrolepidoptera in two national forests on the southern leading edge of gypsy moth range expansion in the central Appalachians of Virginia and West Virginia. The main objective of this study was to obtain baseline information on both native macrolepidopteran and introduced gypsy moth parasitoids before treatment within a large-scale project designed to investigate the effects of multiple-year regional applications of Btk and the entomopathogenic fungus *Entomophaga maimaiga* Humber, Shimazu & Soper on nontarget arthropods. Here, we report the hymenopteran parasitoids reared from macrolepidopteran larvae collected during this 2-yr period. The dipteran parasitoids reared during this same study were reported by Strazanac et al. (2001).

Methods and Materials

This study was conducted in the George Washington National Forest (GWNF) in Augusta County, Virginia, and in the Monongahela National Forest (MNF) in Pocahontas County, West Virginia. The distance between the midpoints of study areas on each forest was ≈50 km. Detailed descriptions of the study sites are given in Butler and Strazanac (2000). The lower elevation GWNF plots had a large component of red oak species, *Quercus* (*Erythrobalanus*) spp., and hard pines, *Pinus* spp., whereas the more mesic MNF plots had large component of maples, *Acer* spp., and hickories, *Carya* spp. The study areas had abundant gypsy moth hosts and were estimated to be 2 yr away from their first significant gypsy moth infestations. Both forests had nine 200-ha plots and within each plot a 30-ha subplot was randomly established. Canvas bands (≈30-cm flap) were attached at breast height around six dominant or codominant trees representative of the area, at each of two sites within each 30-ha subplot. These two sites were arbitrarily located, with one site near a watershed and one site near a ridge when feasible. Five of the sample trees at each site were oak species and the sixth was a red maple, *Acer rubrum* (L.), or a hickory species. Macrolepidopteran larvae were removed from under the bands each week from early May to mid-August and placed in vials that were stored in coolers with ice packs until identifications were made in the laboratory.

Sampling of macrolepidoptera on foliage was conducted outside of the subplots but within the boundaries of each 200-ha plot to preserve the subplot integrity for other studies that were occurring simultaneously. Weekly, from early May to mid-August, five samples of foliage branch tips (≈30 cm in length) were pruned from the lower and mid-canopy with a pole pruner equipped with a plastic catch bag. Three samples were taken from oaks, either white oak, *Quercus alba* L., chestnut oak, *Quercus prinus* L., or members of the red oak species group. The fourth sample consisted of red maple and/or sugar maple, and the fifth sample consisted of mixed hickories [*Carya ovata* (Mill.), *Carya tomentosa* (Poir.), *Carya glabra* (Mill.), and *Carya cordiformis* (Wangenhi)]. Each oak and maple sample consisted of 21 branch tips, whereas samples of hickory, because of their large compound leaves, consisted of 15 branch tips. No more than two branch tips were taken per week from any individual tree. To avoid excessive damage to trees, pruning was alternated among nearby or adjacent areas each week.

In the laboratory, macrolepidopteran larvae were removed from foliage and, with the canvas band specimens, identified to species. Native larvae were placed individually in rearing cups with foliage of the appropriate host food plant. When more than one individual of a species was collected in a foliage or canvas band sample, one-half were chosen at random for rearing. Gypsy moth larvae were reared only from canvas band samples. No more than 12 gypsy moth larvae per plot per week in 1995 and 24 in 1996 were selected for rearing on artificial wheat germ diet (Bio-Serv, Frenchtown, NJ) in rearing cups. Larvae were examined every other day for parasitoid emergence, and nongypsy moth larvae were given fresh foliage. Larvae that died were kept a minimum of 7 d to allow adequate time for parasitoid emergence. Parasitoid and macrolepidopteran pupae were placed in clean rearing cups containing Kimwipes (Kimberly-Clark Corp., Roswell, GA) moistened with Lexgard M (methylparaben, Inolex Corp., Philadelphia, PA). Adult parasitoids emerging from pupae or directly from host larvae were pinned and labeled. Microhymenoptera were preserved in vials containing 70% ethyl alcohol. Parasitoids and macrolepidopteran pupae requiring an overwintering period before eclosion were placed in clean cups on Kimwipes moistened with Lexgard M and given a 90-d cold period at 4°C. Adult parasitoids were sorted to family or superfamily (Chalcidoidea) and sent to specialists for identification. Adult moths eclosing from pupae were examined to verify larval identifications. Voucher specimens were deposited at the West Virginia University Arthropod Collection in Morgantown, WV. Hymenopteran parasitoid names follow Krombein et al. (1979) and Wharton et al. (1997). Macrolepidopteran species names used were from Hodges et al. (1983).

Table 1. Total number of reared macrolepidopteran larval individuals and species by family, and number of reared hymenopteran parasitoid species from 1995 to 1996 in George Washington National Forest and the Monongahela National Forest

Lepidoptera family	Total macrolepidopteran larvae reared		No. hymenopteran parasitoid species
	No. individuals	No. species	
Arctiidae	330	7	4
Geometridae	639	31	20
Hesperiidae	11	1	0
Lasiocampidae	82	2	0
Lycaenidae	21	2	1
Lymantriidae	2,239	4	4
Noctuidae	1,575	46	21
Notodontidae	240	13	6
Papilionidae	1	1	0
Saturniidae	84	6	2
Sphingidae	12	1	0
Thyatiridae	1	1	0

The potential novelty each parasitoid–host record generated in the current study was checked in Krombein et al. (1979). In addition, a literature search was conducted in October 2003 to locate any parasitoid–host records reported since 1979, including Agricola, Agris, BA, CABI, TREECD, and ZooRecord. Literature searches were made using all generic names and synonyms of the reared hymenopteran parasitoids. We also performed searches using the terms "host associations" and "host records" combined with the family names of the reared parasitoids.

Results and Discussion

A total of 5,235 macrolepidopteran larvae were reared; 3,014 of these consisted of native macrolepidoptera, and 2,221 larvae were *L. dispar*. Larvae comprised 115 species (114 native species), representing 12 lepidopteran families (Table 1). Most of the reared species were Noctuidae (40% of total species) and Geometridae (27%). Eighty-nine macrolepidopteran species were reared from the GWNF, 94 species from the MNF, and representatives of 68 of these species were reared from both forests. Parasitized larvae represented 45 species and seven families (Table 1).

From these larvae, 50 hymenopteran parasitoid species were reared to adults, including 43 primary and seven secondary parasitoids (i.e., hyperparasitoid) species (Table 2). We reared 41 and 28 parasitoid species from the GWNF and the MNF, respectively, with 19 of these documented for both forests. Thirty-three and 26 parasitoid species were reared in 1995 and 1996, respectively, with only 10 species reared in both years. Hosts from foliage samples produced 36 parasitoid species, whereas hosts from canvas band flaps produced 20, with seven species collected by both sampling methods.

Native Hymenopteran Parasitoids. Including all hymenopteran and dipteran parasitoids, i.e., both those that did and did not eclose to adults, and parasitic nematodes, 15.6% of the native macrolepidopteran larvae were parasitized, with 6.6% by Hymenoptera, 6.4% by Tachinidae, 2.0% unidentified insects (most likely Hymenoptera or Tachinidae), and 0.5% by nematodes. For those larvae parasitized by primary hymenopteran parasitoids, based on adult parasitoid identifications and recognizable pupae or cocoons, 54% were parasitized by braconids, 29% by ichneumonids, 14% by eulophids, and 3% by other Chalcidoidea. The level of parasitism fluctuated during the sampling periods, with the highest levels for both years occurring in larvae collected in late May to early June, and again throughout July. During both years, parasitism rates tended to be lowest in mid- to late June. In general, parasitism rates reflected caterpillar abundance (Fig. 1). Exceptions to this occurred at the end of each sampling season in August, when a few caterpillar species became very abundant.

Adult hymenopteran parasitoids were not produced from 69 of the macrolepidopteran species reared during this study, likely explained by the low number of larvae collected and reared. For example, of the species not yielding adult hymenopteran parasitoids, 44 (64%) were represented by five or fewer specimens.

Combined parasitism rates on both forests for the 15 most commonly reared native macrolepidopteran species ranged from 0 to 15.6% (Table 3). *Itame pustularia* (Guenée) (Geometridae), a species that feeds only on maple species (McGuffin 1972), had the highest combined parasitism rate, and parasitism rates were consistent between forests (Table 3). Interestingly, *I. pustularia* also had the largest number of hymenopteran parasitoid species (seven primary, one secondary) reared from it (Table 2). Apparently, hymenopteran parasitoids play a significant role in the ecology of *I. pustularia*. *Itame pustularia* larvae were abundant through most of the collecting season, with larvae reared from all 4 mo (Butler and Strazanac 2000). This species is univoltine but the population itself is not synchronized, resulting in overlapping larval instars (Prentice 1963, Wagner et al. 1997). The presence of larvae in the field for this length of time would allow many opportunities for parasitism. Parasitism rates for many species varied between forests, possibly reflecting differences in predator/prey population cycles. For example, *Polia latex* (Gn.) (Noctuidae), *Nadata gibbosa* (J.E. Smith) (Notodontidae), and *Alsophila pometaria* (Harris) (Geometridae) parasitism rates were much higher on the MNF compared with the GWNF (Table 3). In contrast, *Besma quercivoraria* (Guenée) (Geometridae) parasitism was much higher on the GWNF (Table 3).

Malacosoma americanum (F.) (Lasiocampidae) was the only species of the 15 most commonly reared macrolepidopteran species from which no hymenopteran parasitoids were reared (Table 3). However, *M. americanum* was heavily parasitized by tachinids (42%) (Strazanac et al. 2001), and several hymenopteran parasitoids have been reported from larvae of this species (Kulman 1965, Witter and Kulman 1972, Krombein et al. 1979).

Table 2. Summary data for adult hymenopteran parasitoids reared from macrolepidopteran larvae collected weekly from May through August in 1995 and 1996 in GWNF and MNF

Parasitoids sorted by family and subfamily along with associated hosts	Total no. parasitized larvae by forest		Parasitoid status[a]	First and last collection dates[b]
	GWNF	MNF		
Braconidae				
Rogadinae				
Aleiodes gastritor Thunberg				
Alsophila pometaria (Harr.) (Geo.)[c]	1	0	N	23 May
Aleiodes sp.[d]				
Itame pustularia (Gn.) (Geo.)	1	0	N	15 Aug
Melanolophia canadaria (Gn.) (Geo.)	0	1	N	11 Jun
Halysidota tessellaris (J.E. Smith) (Arc.)	1	0	N	13 Aug
Aleiodes preclarus Marsh and Shaw				
Hypoprepia fucosa Hbn. (Arc.)	2	4	R	22 May–1 July
Braconinae				
Bracon near[e] *xanthonotus* Ashmead				
Phoberia atomaris Hbn. (Noc.)	0	1	N	10 June
Microgastrinae				
Cotesia near *cyaniridis* (Riley)				
Abagrotis alternata (Grt.) (Noc.)	0	1	N	27 May
Cotesia near *delicata* (Howard)				
Lithophane antennata (Wlk.) (Noc.)	0	1	N	20 June
Cotesia near *hyphantriae* (Riley)				
Polia latex (Gn.) (Noc.)	0	1	N	4 July
Morrisonia confusa (Noc.) (Hbn.)	1	0	R	4 June
Cotesia melanoscela (Ratzeburg)[f]				
Lymantria dispar (L.) (Lym.)[f]	56	45	R	20 May–3 July
Cotesia murtfeldtae (Ashmead)				
Plagodis alcoolaria (Gn.) (Geo.)	1	0	N	20 June
Cotesia phobetri Rohwer				
Halysidota tessellaris (J.E. Smith) (Arc.)	0	2	R	13 Aug.
Diolcogaster facetosa (Weed)				
Bomolocha baltimoralis (Gn.) (Noc.)	0	1	N	18 July
Parallelia bistriaris Hbn. (Noc.)	0	1	N	16 July
Polia latex (Gn.) (Noc.)	1	0	R	25 July
Diolcogaster schizurae (Muesebeck)				
Lochmaeus manteo Doubleday (Not.)	1	0	R	1 Aug.
Glyptapanteles compressus (Muesebeck)				
Besma quercivoraria (Gn.) (Geo.)	1	0	N	2 July
Hypoprepia fucosa Hbn. (Arc.)	0	4	R	1 July–22 July
Microplitis near *hyphantriae* (Ashmead)				
Amphipyra pyramidoides Gn. (Noc.)	1	2	R	30 May–20 June
Cosmla calami (Harv.) (Noc.)	2	0	R	14 May
Eupsilia n. sp. (Noc.)[g]	0	1	N	30 May
Morrisonia confusa (Hbn.) (Noc.)	1	0	R	23 July
Orthosia rubescens (Wlk.) (Noc.)	1	0	N	14 May
Polia latex (Gn.) (Noc.)	0	2	R	25 July–6 Aug.
Microplitis laticinctus Muesebeck				
Epiglea decliva (Grt.) (Noc.)	1	0	N	22 May
Protapantales paleacritae (Riley)				
Nadata gibbosa (J.E. Smith) (Not.)	1	0	N	6 Aug.
Homolobinae				
Homolobus truncator (Say) [*Zele mellea* (Cresson)]				
Besma quercivoraria (Gn.) (Geo.)	2	0	N	13 June
Lambdina fiscellaria (Gn.) (Geo.)	2	0	N	13 June–19 June
Lambdina fervidaria (G. & R.) (Geo.)	1	0	N	8 Aug.
Meteorinae				
Meteorus hyphantriae Riley				
Acronicta ovala Grt. (Noc.)	10	4	R	9 July–13 Aug.
Meteorus sp.				
Phoberia atomaris Hbn. (Noc.)	2	0	N	29 May–3 June
Achatia distincta Hbn. (Noc.)	1	0	N	27 June
Ichneumonidae				
Anomalinae				
Aphanistes heinrichi Hopper				
Melanolophia canadaria (Gn.) (Geo.)	0	1	R	23 July
Achatia distincta Hbn. (Noc.)	1	0	N	10 July
Erigorgus xanthopsis (Ashmead)				
Orthosia rubescens (Wlk.) (Noc.)	1	0	N	3 June

Table 2. Continued

Parasitoids sorted by family and subfamily along with associated hosts	Total no. parasitized larvae by forest		Parasitoid status[a]	First and last collection dates[b]
	GWNF	MNF		
Therion near n. sp.[g]				
Catocala micronympha Gn. (Noc.)	1	0	N	22 May
Catocala amica (Hbn.) (Noc.)	2	0	N	19 June
Campopleginae				
Casinaria forcipata Walley				
Itame pustularia (Gn.) (Geo.)	1	0	R	30 May
Casinaria geometrae geometrae Walley				
Melanolophia canadaria (Gn.) (Geo.)	1	0	N	30 May
Casinaria limenitidis (Howard)				
Itame pustularia (Gn.) (Geo.)	1	0	N	21 May
Dusona deceptor (Walley)				
Itame pustularia (Gn.) (Geo.)	2	0	R	30 May–20 June
Dusona ellopiae Walley				
Lambdina fervidaria (Hbn.) (Geo.)	1	0	N	8 July
Dusona quebecensis (Walley)				
Itame pustularia (Gn.) (Geo.)	1	0	N	13 June
Hyposoter annulipes (Cresson)				
Copipanolis styracis (Gn.) (Noc.)	0	1	N	28 May
Lithophane antennata (Wlk.) (Noc.)	1	0	N	4 June
Polia latex (Gn.) (Noc.)	0	2	N	1 Aug.–13 Aug.
Hyposoter fugitivus (Say)				
Anisota senatoria (J.E. Smith) (Sat.)	1	0	R	13 Aug.
Anisota virginiensis (Drury) (Sat.)	1	0	R	30 July
Satyrium falacer (Godt.) (Lyc.)	1	0	N	22 May
Hyposoter fuscitarsis (Viereck)				
Anavitrinella pampinaria (Gn.) (Geo.)	1	0	N	30 May
Erannis tiliaria (Harr.) (Geo.)	0	1	R	23 May
Ennomus subsignaria (Hbn.) (Geo.)	0	1	N	6 June
Phoberia atomaris Hbn. (Noc.)	1	0	N	29 May
Hyposoter rubiginosus Cushman				
Dasychira basiflava (Pack.) (Lym.)	0	1	R	5 June
Phobocampe geometrae (Ashmead)				
Erannis tiliaria (Harr.) (Geo.)	1	0	R	7 May
Phigalea titea (Cram.) (Geo.)	0	1	R	28 May
Phobocampe pallida (Cushman)				
Heterocampa guttivitta (Wlk.) (Not.)	1	0	R	16 July
Lochmaeus manteo Doubleday (Not.)	0	1	N	15 Aug.
Phobocampe n. sp.[g]				
Besma quercivoraria (Gn.) (Geo.)	0	1	N	16 July
Lambdina fervidaria (Hbn.) (Geo.)	0	1	N	30 July
Metopiinae				
Trieces dentatus Townes				
Cyclophora packardi (Prout) (Geo.)	1	0	N	13 Aug.
Cryptinae				
Gelis tenellus (Say)				
Dryocampa rubicunda (F.) (Sat.)	0	1	2°	15 Aug.
Gelis sp.				
Lymantria dispar (L.) (Lym.)[f]	2	0	2°	19 June
Isdromas lycaenae (Howard)				
Amphipyra pyramidoides Gn. (Noc.)	0	1	2°	20 June
Ichneumoninae				
Platylabus near *sexmaculatae* Heinrich				
Protoboarmia porcelaria (Gn.) (Geo.)	1	0	N	6 June
Mesochorinae				
Mesochorus discitergus (Say)				
Lymantria dispar (L.) (Lym.)	1	0	2°	12 June
Mesochorus uniformis Cresson				
Itame pustularia (Gn.) (Geo.)	1	0	2°	4 June
Eulophidae				
Eulophinae				
Elacherius cidariae Ashmead				
Heterocampa guttivitta (Wlk.) (Not.)	0	1	N	9 July
Hypagyrtis unipunctata (Haw.) (Geo.)	1	0	N	25 June
Eulophus anomocerus (Crawford)				
Amphipyra pyramidoides Gn. (Noc.)	1	0	N	30 May
Heterocampa guttivitta (Wlk.) (Not.)	0	1	R	11 July
Polia latex (Gn.) (Noc.)	0	1	N	5 Aug.
Eulophus sp.				

Table 2. Continued

Parasitoids sorted by family and subfamily along with associated hosts	Total no. parasitized larvae by forest		Parasitoid status[a]	First and last collection dates[b]
	GWNF	MNF		
Macrurocampa marthesia (Cram.) (Not.)	1	0	N	8 Aug.
Orthosia rubescens (Wlk.) (Noc.)	1	0	N	28 May
Cosmia calami (Harv.) (Noc.)	0	1	N	4 June
Euplectrus bicolor (Swederus)[f]				
Alsophila pometaria (Harr.) (Geo.)	0	3	N	28 May–4 June
Campaea perlala (Gn.) (Geo.)	1	0	N	2 July
Itame pustularia (Gn.) (Geo.)	0	1	N	2 July
Morrisonia confusa (Hbn.) (Noc.)	0	1	R	23 July
Polia latex (Gn.) (Noc.)	2	0	N	17 July–12 Aug.
Euplectrus maculiventris Westwood				
Alsophila pometaria (Harr.) (Geo.)	0	5	R	30 May–20 June
Itame pustularia (Gn.) (Geo.)	0	2	R	13 June
Melanolophia canadaria (Gn.) (Geo.)	1	0	N	30 May
Euplectrus sp.				
Polia latex (Gn.) (Noc.)	0	1	R	25 July
Perilampidae				
Perilampinae				
Perilampus hyalinus Say				
Baileya opthalmica (Gn.) (Noc.)	1	0	2°	8 Aug.
Trigonalidae				
Poecilogonalos costalis (Cresson)				
Acronicta ovata Grt. (Noc.)	1	1	2	16 July

First and last collection dates of parasitized larvae are given, with dates pooled from both sample years. Literature was reviewed to determine whether parasitoid–host associations were previously reported (see text).

[a] Parasitoid status: R, parasitoid–host relationship recorded in literature; N, parasitoid–host relationship not recorded in literature; 2°, secondary parasitoid (parasitoid host unknown).

[b] Collection dates of Lepidoptera were pooled from both sample years.

[c] Lepidopteran families: Arc., Arctiidae; Geo., Geometridae; Lyc., Lycaenidae; Las., Lasiocampidae; Lym., Lymantriidae; Noc., Noctuidae; Not., Notodontidae; Sat., Saturniidae.

[d] Species could be distinguished from others reared, but exact species determination could not be made.

[e] Species determination not certain.

[f] Non-native species.

[g] New species not yet described.

[h] Larvae may have ingested parasitoid eggs in laboratory from foliage pooled from both forests.

The number of hymenopteran parasitoid species parasitizing macrolepidopteran larvae fluctuated during the collecting seasons, with the largest number collected in late May to early June (Fig. 2). Seasonal fluctuations in parasitoid richness followed a similar trend as species richness of macrolepidopteran larvae during the same sampling periods, where there was an early and late season peak (Butler and Strazanac 2000). Most of the parasitoid species were collected during a narrow period of the sampling season (Table 2), possibly reflecting parasitoid voltinism patterns, host range, and host life history traits.

Meteorus hyphantriae Riley (Braconidae) was the primary parasitoid most frequently reared from native macrolepidoptera. This species was reared exclusively from *Acronicta ovata* Grote (Noctuidae) ($n = 14$ larvae; Table 2); a host reported by Butler (1993). We reared six additional host species that were reported by Krombein et al. (1979); however, no *M. hyphantriae* adults were reared. It is possible that some of these hosts we reared were parasitized by *M. hyphantriae* but died as immatures.

Many reared hymenopteran parasitoid species were represented by a single adult ($n = 24$ parasitoid species). Because many hymenopteran parasitoids died before eclosion, however, it is difficult to accurately determine the relative abundance of individual parasitoid species. Their apparent scarcity may be an artifact of our inability to rear some individual species in an artificial environment. Also, some species may be poorly represented, or excluded entirely, due to sampling bias. For example, macrolepidopteran larvae were collected during the day, which biased our sampling toward diurnal feeding macrolepidopteran hosts; however, some nocturnal feeding macrolepidoptera were collected under canvas bands. Also, sampling focused mainly on oak feeding macrolepidoptera and to a lesser extent, those that feed on maple and hickory. Therefore, macrolepidoptera with host plants other than those included in our sampling were not targeted and were collected by coincidence. An example of this was *M. americanum*, which was collected frequently on a few of the study sites that had high densities of black cherry, *Prunus serotina* Ehrh. (Rosaceae), one of its preferred hosts.

***L. dispar* Hymenopteran Parasitoids.** Total parasitism of *L. dispar* was 17.1%, with 8.4% by hymenopterans, 6.0% by tachinids, and 2.7% unidentifiable (most likely Tachinidae or Hymenoptera) (Table 3). *Cotesia melanoscela* (Ratzeburg) (Braconidae) was responsible for almost all of the *L. dispar* parasitism (8.3%) by Hymenoptera and was the only primary hymenopteran parasitoid reared to adult from *L. dispar* in this study (Tables 2 and 3). This was consistent with par-

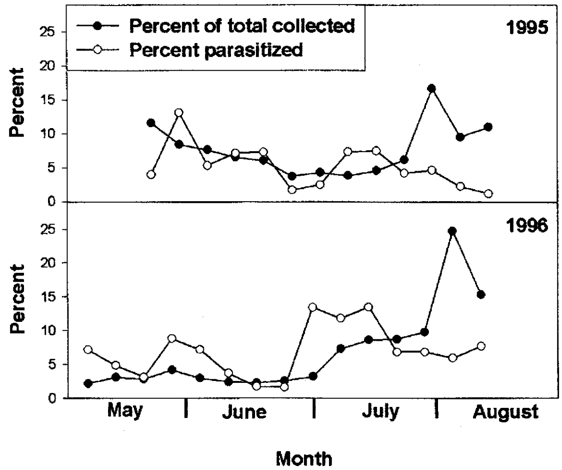

Fig. 1. Percentage of total macrolepidopteran larvae collected and percentage of reared macrolepidopteran larvae that were parasitized by hymenopteran parasitoids by sample date during the collection period May–August in 1995 and 1996 in the Monongahela National Forest and the George Washington National Forest. Data were pooled from both forests.

asitism rates previously reported for *L. dispar* by this species (Doane and McManus 1981, Ticehurst 1984, Kolodny-Hirsch et al. 1988).

C. melanoscela is a non-native species first introduced into North America in 1911 for biological control of *L. dispar,* from which it is commonly recovered (Burgess and Crossman 1929, Marsh 1979, Doane and McManus 1981). Whereas *C. melanoscela* has been occasionally reared from native macrolepidopteran species (Schaffner and Griswold 1934, Butler 1990), we did not recover it from any native hosts during our study.

Phobocampe unicincta (Viereck) (Ichneumonidae) was the only other identified primary hymenopteran parasitoid species reared from *L. dispar* during this study. Two individuals were reared from *L. dispar* larvae in the GWNF in 1996; however, they failed to eclose from their cocoons. The infrequency of *P. unicincta* was not unexpected, given that it often occurs only at low levels in most *L. dispar* populations in North America (Tigner 1974, Barbosa 1977). Moreover, the study areas were located on the leading edge of the *L. dispar* front; therefore, *P. unicincta* may have not yet become firmly established in those locations.

Hymenopteran Parasitoid Host Records. A total of 80 hymenopteran parasitoid–macrolepidopteran host associations were generated from this study, 53 of which were not found reported in the literature. Considering the 42 primary hymenopteran parasitoid species reared from native macrolepidoptera, 32 (76%) species produced host records that were not previously reported. Of the 27 records previously reported in the literature, 10 (37%) were originally reported by Krombein et al. (1979), and the remainder were reported by Allen (1972), Butler (1990, 1993), Marsh and Shaw (1998), and Whitfield et al. (1999).

Euplectrus bicolor (Swederus) (Eulophidae) generated four new host records from native species, the most new records for any single parasitoid in our study. This parasitoid is native to Europe and was first reported in North America in 1923 (Lacroix 1924, Thomsen 1927). Krombein et al. (1979) reported two hosts from *E. bicolor,* whereas Butler (1993) reported two additional hosts. As a result of our study, the number of currently known North American host records for this species has doubled, and a new host family, e.g., Geometridae, has been added.

In conclusion, many of the more commonly reared species were found in both forests, suggesting that the forests share similar hymenopteran parasitoid fauna. It

Table 3. Percentage parasitized by primary hymenopteran parasitoids and total number of macrolepidopteran larvae reared from collections made May through August in 1995 and 1996 in GWNF and MNF

Species	Family	% parasitized[a] (total larvae reared)		
		GWNF	MNF	Combined
Lymantria dispar (L.)[b]	Lymantriidae	5.8 (1,358)	11.6 (863)	8.4 (2,221)
Acronicta ovata Grt.	Noctuidae	7.4 (149)	1.4 (361)	3.1 (510)
Polia latex (Gn.)	Noctuidae	4.5 (224)	21.1 (133)	10.6 (357)
Hypoprepia fucosa Hbn.	Arctiidae	1.8 (110)	8.8 (113)	5.4 (223)
Phoberia atomaris Hbn.	Noctuidae	4.0 (75)	5.0 (20)	4.2 (95)
Nadata gibbosa (J.E. Smith)	Notodontidae	7.3 (55)	20.6 (34)	12.4 (89)
Melanolophia canadaria (Gn.)	Geometridae	4.0 (50)	9.7 (31)	6.2 (81)
Orthosia rubescens (Wlk.)	Noctuidae	5.1 (59)	5.9 (17)	5.3 (76)
Heterocampa guttivitta (Wlk.)	Notodontidae	0.0 (41)	8.8 (34)	4.0 (75)
Besma quercivoraria (Gn.)	Geometridae	10.3 (29)	2.4 (41)	5.7 (70)
Itame pustularia (Gn.)	Geometridae	15.6 (45)	15.8 (19)	15.6 (64)
Alsophila pometaria (Harr.)	Geometridae	3.4 (29)	24.2 (33)	14.5 (62)
Malacosoma americanum (F.)	Lasiocampidae	0.0 (22)	0.0 (37)	0.0 (59)
Catocala amica (Hbn.)	Noctuidae	3.6 (56)	0.0 (1)	3.5 (57)
Morrisonia confusa (Hbn.)	Noctuidae	8.3 (24)	3.2 (31)	5.5 (55)
Halysidota tessellaris (J.E. Smith)	Arctiidae	5.9 (34)	11.8 (17)	7.8 (51)

Larvae arranged in decreasing order beginning with the largest number reared.

[a] Calculated by dividing number of larvae reared by number of larvae from which primary hymenopteran parasitoid adults, and recognizable larvae and pupae emerged.

[b] Non-native species.

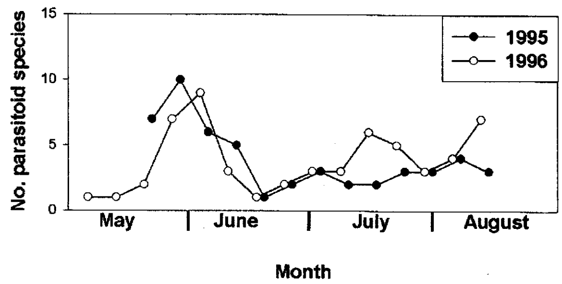

Fig. 2. Number of hymenopteran parasitoid species reared to adults from macrolepidopteran larvae by sample date during the collection period May-August in 1995 and 1996 in the Monongahela National Forest and the George Washington, National Forest. Data were pooled from both forests.

is unclear whether the infrequently reared hymenopteran parasitoid species represented on only one forest during this study are specific to that particular forest, or whether they exist in both localities but we failed to detect them due to low population levels or bias in our sampling methods. One of the more common parasitoids, *E. bicolor*, reared from native macrolepidoptera is a non-native species and apparently highly polyphagous given the number of host species reported in previous literature (Krombein et al. 1979, Butler 1993) and in our study. Impacts of this species on native hosts should be more fully examined.

New host records have been added for 32 of the hymenopteran parasitoid species reared in this study. The number of new records generated from this study and other recent studies, such as Butler (1990, 1993), Wood and Butler (1991), Whitfield et al. (1999), and Strazanac et al. (2001) emphasizes the lack of attention parasitoid–host associations of forest macrolepidoptera have been given. The data reported here will be valuable in evaluating nontarget impacts of gypsy moth suppression tactics to hymenopteran parasitoids in the George Washington and the Monongahela National Forests.

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