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ABSTRACT Although tachinids are one of the most diverse families of Diptera and represent the largest group of nonhymenopteran parasitoids, their local diversity and distribution patterns of most species in the family are poorly known. In this study, 2 yr of samples from a Malaise trap were used to analyze the local richness and temporal distribution of a tachinid community in southwestern Ohio. In total, 883 tachinid specimens were collected, consisting of 117 species belonging to 69 genera. The majority of the specimens were collected in fall, followed by summer and spring, with 67, 22, and 11%, respectively. Estimated rarefaction curves indicate a predicted species richness of 217 species and suggest that we have sampled only a fraction of the diversity of Tachinidae occurring at this particular site. The species recorded in this study represent 16 and 19% of the species that are likely to occur in the northeastern United States and Ohio, respectively. In North America, there have been few, if any, previous attempts to quantify the diversity of tachinids on a local scale. Our results provide a baseline for understanding the temporal and spatial diversity of these ecologically and agronomically important parasitoids.

KEY WORDS Tachinidae, species richness, parasitoid diversity, temporal distribution, voltinism

Diptera or true flies are one of the most anatomically varied and ecologically diverse groups of insects. This group represents 10–15% of the world's biodiversity (Brown 2005, Yeates et al. 2007) and contains ≈157,000 described species (Thompson 2008). Estimates of the total diversity of Diptera suggest that this order contains a minimum of 1,000,000 (Brown 2001b) to 1,700,000 species (Stork 1997), suggesting that >90% of Diptera species remain undescribed. In the Nearctic region, which probably has the best known fauna after the Palearctic region, an estimated 65% of Diptera have been described, <25% have been revised taxonomically, and less than one percent have been studied in detail (Thompson 2009). Thus, documenting and describing the diversity of Diptera represents a special need to fill the large void in our knowledge of insect diversity.

The parasitic fly family Tachinidae includes ≈10,000 described species worldwide, classified into >1,500 genera (Brown 2001a,b; Irwin et al. 2003; O'Hara 2008). Although tachinids are one of the most species-rich families of Diptera (Irwin et al. 2003) and represent the largest group of nonhymenopteran parasitoids (Belshaw 1994), the ecology of most species in the family is poorly known. Currently, our knowledge is limited in terms of the diversity and distribution of populations across time and space, especially in the Nearctic and Neotropical regions (Stireman 2008).

There have been several recent studies focused on species diversity and temporal distributions of tachinids in the Palaearctic region, such as Belshaw (1992, 1993, 1994), Ford and Shaw (1991), Ford et al. (2000), Avci and Kara (2002), Cerretti et al. (2004), and Richter (2005), but there are few such studies for specific areas of the Nearctic region (O'Hara 2002, Strazanac et al. 2001, Strazanac and Butler 2005, Tooker et al. 2006, Stireman 2008).

In the Nearctic region, the family Tachinidae includes 1,345 described species, classified in 304 genera of which 20% are endemic to the region (O'Hara 2008). In this region, there have been several studies of the tachinid parasitoid communities associated with particular host groups. For example, tachinids attacking Lepidoptera in Canada (McGugan 1958), northern United States (Schaffner and Griswold 1934), eastern United States (Strazanac et al. 2001), and southeastern Arizona (Stireman and Singer 2003). Similarly, coarse information on the spatial distribution of tachinids can be gleaned from regional catalogs (e.g., O'Hara and Wood 2004), but these provide little indication of the richness of particular tachinid communities. To our knowledge, there is only a single published study (Stireman 2008) documenting in detail the richness and composition of a tachinid community at a particular geographic locale in North America (although see Strazanac and Butler (2005) for an multiyear analysis of the abundance of macrolepidoptera attacking Tachinidae). This is unfortunate given the diversity of

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this group and their importance as parasitoids of other insects (Stireman et al. 2006). Because tachinids belong to a higher trophic level, they may serve as sensitive indicators of the diversity and dynamics of populations of their host taxa. An understanding of how tachinid communities vary over space and time can be used as a proxy for understanding diversity patterns of other insects, particularly Lepidoptera (Stireman et al. 2006). Such information could provide an indication of the health of ecological communities and potentially inform local conservation efforts. Similarly, documenting occurrence/abundance patterns over time can provide insight into tachinid life history, voltinism and developmental time, and potential host associations, which could be used to assess their potential for biological control in forest and agricultural systems. Unfortunately, tachinids are a difficult group to identify, due in part to their great richness and diversity and the incomplete taxonomic literature available for the identification of species. This remains an impediment to their study and use as ecological indicators.

Here, we document and analyze the tachinid species richness obtained from a single trap over two seasons and assess the temporal distribution of abundance and voltinism of the tachinid community. This information provides a point estimate for understanding the geographic distribution of tachinid diversity and potentially the diversity of their host taxa. We also examine how tachinid abundance and diversity varies seasonally and examine the phenological patterns of a broad array of tachinid species. Several new geographic records of Tachinidae also are documented.

Materials and Methods

Collection. Tachinid specimens were collected in a single 2.5- by 1.8-m white mesh Townes style Malaise trap located in Greene County, southwestern Ohio, in the Huffman Metropark (39°48′27.91″ N, 84°05′35.58″W, ≈250 m in elevation). This ≈114-ha largely undeveloped park is surrounded by suburban development, Wright-Patterson Air Force Base, and some intensive corn–soybean [*Zea mays* L.–*Gycine max* (L.) Merr.[rqb] agriculture. However, it is connected to other seminatural wooded and prairie areas through riparian forest along the Mad River, which flows through the park. The trap was placed adjacent and perpendicular to the forest edge on the northwest side of an ≈10-m-wide NW–SE-oriented narrow grass- and forb-dominated field in a powerline right-of-way. This field is periodically mowed every one to two years. Sampling this "edge" habitat is likely to maximize total richness and diversity because it draws tachinids from both open and forest-associated communities. The plant community in the immediate vicinity of the trap was dominated primarily by Asteraceae (e.g., *Solidago* spp., *Symphyotrichum* spp.) and Poaceae (e.g., *Sorghastrum nutans* Nash). The narrow field was bordered by second growth deciduous forest consisting largely of maples (*Acer* spp.), ashes (*Fraxinus* spp.), hickory (*Carya* spp.), and honeysuckle

[*Lonicera maackii* (Rupr.) Maxim.]. The trap was monitored from 25 June until 17 November in 2008 and on 4 March until 12 November in 2009. It was periodically checked, once or twice per week, for the 2008 and 2009 seasons. Potassium cyanide was used as the killing agent in a dry trap head. Material collected in the trap was taken to a laboratory at Wright State University, Dayton, OH, where specimens were sorted, pinned, and identified.

Identification. Tachinid specimens were initially sorted by morpho-species and then identified to genus using the key to Nearctic genera of Tachinidae by Wood (1987). Once the genus was identified, species identifications were attempted using keys and descriptions from primary literature. Species designations were further refined or confirmed by comparison with type or paratype specimens housed in the National Museum of Natural History (NMNH) in Washington, DC; the Canadian National Collection (CNC) in Ottawa, ON, Canada; or both. For some particularly difficult taxa (e.g., *Lixophaga* Townsend, *Myopharus* Brauer & Bergenstamm, and *Winthemia* Robineau-Desvoidy), final identifications were made with the aid of Dr. D. M. Wood (Agriculture and Agri-Food Canada).

Analysis. Estimated species accumulation curves (rarefaction curves) were calculated for sample and specimen accumulation. The 2008–2009 rarefaction curve of samples and its 95% CL was calculated and plotted using 1,000 permutations with the function "specaccum" from the *vegan* package (Oksanen et al. 2007). Rarefaction curves using samples for individual years were calculated using 1,000 randomizations with the function "spp.est" from the *fossil* package in R (Vavrek 2009). Similarly, rarefaction curves of specimens for 2008–2009, and individual years were calculated and plotted using 1,000 randomizations. Similarity indices between years were estimated with Sorensen binary coefficients, which compute the similarity of two samples based on present–absence of species (Southwood and Henderson 2000). Finally, we used *fossil* package to estimate ACE, ICE, Chao-1, Chao-2, and Jack-1 species richness estimators for sample-based and specimen-based species accumulation, and their 95% CL based on 1,000 randomizations (Vavrek 2009).

We used a multivariate analysis with nonmetric dimensional scaling (NMDS) of sampling dates and species to explore patterns in species composition over time. An advantage of NMDS is that the procedure is less dependent on data distribution than constrained methods, such as principal component analyses (Hochkirch and Adorf 2007). Increasing distance between sites in NMDS ordination space is indicative of greater compositional dissimilarity. We calculated the NMDS using the function "metaMDS" in the statistical package *vegan* in R (Oksanen et al. 2007). In *vegan*, metaMDS first transforms the data by Wisconsin double standardization, a method which first standardizes species and subsequently the samples by totals (Faith et al. 1987, Minchin 1987). We used Bray–Curtis dissimilarities as a measure of ecological

distance. Weekly or semiweekly samples were pooled into larger samples representing specimens collected the first and second half of each month. To evaluate variation in the community, we analyzed variation between years, seasons, and the interactions between seasons and years by using canonical correspondence analysis (CCA) in the R *vegan* package (Ter Braak 1986, Oksanen et al. 2007). To assess whether tachinid communities differed significantly between seasons and years, we performed a significance test of constraints on the CCA ordination (essentially a multivariate analysis of variance [ANOVA]) with 500 permutations using the function "anova.cca" (Oksanen et al. 2007).

To evaluate the species observed in this study in a regional context, we used distributional information from the "Tachinidae of America north of Mexico" regional catalog (O'Hara and Wood 2004). We used this information to assess the proportion of species present in the entire Nearctic region and the northeastern United States that we sampled. In addition, we compared our observed species with the species that are likely to occur specifically in Ohio. To estimate the species that are likely to be present in Ohio, we estimated a rough distributional polygon from the locations reported for each species listed in O'Hara and Wood's (2004) tachinid regional catalog; if the polygon of the species included Ohio, we recorded that species as present in Ohio. Cases where species were found only in neighboring states or provinces were considered equivocal. This list of potential Ohio species is included as Supp Table S1 [online only].

Results and Discussion

Richness and Composition of Tachinid Taxa. From June 2008 to November 2009, in 399 d of sampling, 883 tachinid specimens in total were collected, consisting of 117 species belonging to 69 genera (see Table 1 for a complete list of species and genera). We collected 390 specimens classified into 79 species in 2008 and 493 specimens classified into 82 species in 2009. The subfamilies Exoristinae and Tachininae were the best represented in samples, comprising 54% (63 species, 34 genera, and six tribes) and 21% (25 species, 16 genera, and 10 tribes) of the total species, respectively. The subfamilies Phasiinae and Dexiinae comprised less than one third of the species with 13% (15 species, eight genera, and six tribes) and 12% (14 species, 11 genera, and five tribes) of the total species, respectively (Table 1). Fewer than 50% of the species were shared between years. Thirty-five species were only found in 2008, and 38 were only found in 2009. Of the 117 species identified, 36% were represented by only a single specimen, 20% were represented by two specimens, and only 20% were well represented by ≥ 10 specimens (Fig. 1). The species abundance distribution indicates that rare species represent approximately two thirds of the species recorded in this studied (Fig. 1). This large proportion of rare species may reflect transient tachinids that mostly use other habitats (e.g., forest), or they could represent truly rare,

perhaps more specialized, species. However, the high number of rare species is probably due in part to insufficient seasonal and spatial replication of sampling and that many tachinid species may not be efficiently sampled with the method used.

At least two species appear to be undescribed; one species of *Blepharipa* Rondani, which has been collected previously but never described, and a unique species of *Phytomyptera* Rondani, close to *P. aristalis.* In addition, definitive identifications of seven additional species could not be made despite external comparison to reliably identified museum specimens. These species include three *Carcelia* Riboneau-Desvoidy species, one close to *C. flavirostris*, one close to *C. falenaria*, and one close to *C. lagoae;* two *Eucelatoria* Townsend species; a *Lixophaga* Townsend species; and a species of *Myiopharus* Brauer & Bergenstamm. This reflects in part lack of suitable material and a need for revision of these groups, but some of these, particularly the latter four blondeliine taxa, may represent additional undescribed species. We found new locality records for five species (*Admontia badiceps, Billea trivittata, Catharosia minuta, Cylindromyia nana*, and *Exorista trudis;* see Table 1 for authority names), which have not previously been recorded from the northeastern region of America north of Mexico. In addition, we found new locality records for two species (*Chaetostigmoptera manca* and *Cylindromyia interrupta*) that have not been recorded from Ohio (O'Hara and Wood 2004).

The species recorded in this study represent 9 and 23% of all species and genera of Tachinidae described for the Nearctic region, respectively (O'Hara 2008). The Catalog of the Tachinidae (Diptera) of America North of Mexico by O'Hara and Wood (2004), reports 649 species in total occurring in the northeastern region, of which 16% were recorded in this study. Specifically for Ohio, the recorded species in this study represent 19% of the 547 species that are likely to occur in Ohio (Supp Table S1 [online only]).

Species Richness Analyses. Estimated rarefaction curves using both samples (Fig. 2) and specimens (Fig. 3) all end with a fairly steep slope, suggesting that we have sampled only a fraction of the species of Tachinidae occurring at this particular site. The specimen-based Chao-1 estimator of total species richness predicts that the community of Tachinidae in the sampled area consists of ≈ 205 species (95% CI, 192–217; Table 2). Similarly, the sample-based Chao-1 estimator predicts that the community of Tachinidae in the sampled area consists of ≈ 190 species, (95% CI, 179–201; Table 2). Jack-1 species richness estimator resulted in similar estimates (Table 1). These estimators indicate that with sufficient effort we could potentially sample over one third of tachinid species likely to occur in Ohio with this single trap.

It is difficult to determine whether the community we have sampled is more or less diverse than other areas in North America, because there have been few if any previous attempts to quantify the local species richness of tachinids. The only published analysis of a community of tachinid flies in the Nearctic region that

Table 1. Tachinid species and their seasonality distribution over summer 2008 to fall 2009, Huffman Metropark, OH

Subfamily/tribe/genus	ESP Mar. 2	MSP April 1 2	LSP May 1 2	ES June 1 2	MS July 1 2	LS Aug. 1 2	EF Sept. 1 2	MF Oct. 1 2	LF Nov. 1	Total
Dexiinae										
Campylochetini										
Campylochaeta plathypenae (Sabrosky)										112
Dexiini										
Billea trivittata (Curran)										1
Zelia tricolor (Coquillet)										3
Epigrimyiini										
Epigrimyia polita Twn.*										5
Thelairini										
Spathidexia cerussata Reinhard										2
Spathidexia clemonsi Twn.*										1
Spathidexia dunningii (Coquillet)										11
Thelaira americana Brooks										5
Voriini										
Blepharomyia tibialis (Curran)										1
Eulasiona aperta (Reinhard)										21
Eulasiona cinerea (Curran)										6
Kirbya setosa (Twn.*)										7
Periscepsia laevigata (van der Wulp)										2
Voria aurifrons (Twn.*)										1
Exoristinae										
Blondeliini										
Admontia badiceps Reinhard										35
Admontia degeerioides (Coquillet)										2
Blondelia eufitchiae (Twn.*)										4
Blondelia hyphantriae (Tothill)										7
Celatoria diabroticae (Shimer)										12
Chaetostigmoptera manca (Greene)										10
Cryptomeigenia theutis (Walker)										3
Eucelatoria dimmocki (Aldrich)										8
Eucelatoria sp. 1										1
Eucelatoria sp. 2										1
Euhalidaya genalis (Coquillet)										1
Euthelyconychia xylota (Curran)										10
Lixophaga discalis (Coquillet)										23
Lixophaga fasciata Curran										12
Lixophaga plumbea Aldrich										3
Lixophaga sp. 1										1
Lixophaga variabilis (Coquillet)										7
Medina barbata (Coquillet)										22
Medina quinteri (Twn.*)										28
Myiopharus doryphorae (Riley)										2
Myiopharus infernalis (Twn.*)										1
Myiopharus macellus (Reinhard)										1
Myiopharus sp. nr. *ancilla* (Walker)										2
Opsomeigenia pusilla (Coquillet)										1
Oxynops anthracinus (Bigot)										19
Thelairodoria setinervis (Coquillet)										1
Vibrissina leibyi (Twn.*)										9

we know of analyzed the richness and seasonal diversity of tachinids in an upland savanna in southeastern Arizona (Stireman 2008). In this study, Stireman (2008) recorded a community of 79 species with an estimated total of 122 species from eight monthly pan trap samples. We recorded a community of 117 species with an estimated total of 179–217 species (Table 1),

suggesting a richer tachinid community at our site in Ohio. However, the number of species collected per year is quite similar across these studies (i.e., ≈80). The similarity of these two communities, as calculated with the Sorensen index, is 16%. This low similarity is not surprising given the vast distance between these two sampling points, the large difference in the veg-

Table 1. Continued

Subfamily/tribe/genus	Season																Total
	ESP Mar.	MSP April		LSP May		ES June		MS July		LS Aug.		EF Sept.		MF Oct.		LF Nov.	
	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	
Eryciini																	
Aplomya theclarum (Scudder)																	30
Carcelia reclinata (A. & W.**)																	1
Carcelia laxifrons Villenueve																	1
Carcelia sp. nr. *flavirostris* (Wulp)																	1
Carcelia sp. nr. *falenaria* (Rondani)																	4
Carcelia sp. nr. *lagoae* (Twn.*)																	1
Drino rhoeo (Walker)																	1
Lespesia aletiae (Riley)																	6
Lespesia cuculliae (Webber)																	1
Lespesia flavifrons Beneway																	3
Lespesia schizurae (Twn.*)																	1
Lespesia stonei Sabrosky																	1
Lydella radicis (Twn.*)																	1
Nilea erecta (Coquillet)																	2
Nilea valens (A. & W.**)																	2
Phebellia curriei (Coquillet)																	1
Prooppia crassiseta (A. & W.**)																	1
Siphosturmia phyciodis (Coquillet)																	12
Exoristini																	
Chetogena claripennis (Macquart)																	1
Exorista dydas (Walker)																	2
Exorista trudis (Reinhard)																	2
Goniini																	
Belvosia unifasciata (R.-D.***)																	28
Blepharipa n. sp.																	1
Chaetogaedia analis (van der Wulp)																	1
Gonia aldrichi Tothill																	23
Houghia sternalis (Coquillet)																	1
Hyphantrophaga virilis (A. & W.**)																	1
Leschenaultia bicolor (Macquart)																	2
Leschenaultia reinhardi T. & G.****																	1
Masiphyini																	
Masiphya confusa Aldrich																	23
Winthemiini																	
Nemorilla pyste (Walker)																	1
Winthemia quadripustulata (F.)																	5
Winthemia manducae S. & DeL.*****																	3
Winthemia occidentis Reinhard																	1
Winthemia rufopicta (Bigot)																	5
Winthemia sinuata Reinhard																	10
Phasiinae																	
Catharosiini																	
Catharosia minuta (Twn.*)																	21
Catharosia nebulosa (Coquillet)																	5
Cylindromyiini																	
Cylindromyia binotata (Bigot)																	5
Cylindromyia euchenor (Walker)																	14
Cylindromyia fumipennis (Bigot)																	4
Cylindromyia interrupta (Meigen)																	2
Cylindromyia nana (Twn.*)																	2
Hemyda aurata R.-D.***																	1
Gymnosomatini																	
Gymnoclytia immaculata (Macquart)																	4
Gymnoclytia occiuda (Walker)																	1
Gymnosoma par Walker																	8

Table 1. Continued

Subfamily/tribe/genus	Season									Total
	ESP Mar.	MSP April	LSP May	ES June	MS July	LS Aug.	EF Sept.	MF Oct.	LF Nov.	
	2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1	
Leucostonatini										
Leucostoma gravipes van der Wulp										2
Phasiini										
Phasia punctigera (Twn.*)										1
Phasia purpurascens (Twn.*)										1
Trichopodini										
Xanthomelanodes arcuatus (Say)										13
Tachininae										
Acemyini										
Ceracia dentata (Coquillet)										29
Ernestiini										
Linnaemya comta (Fallen)										2
Graphogastrini										
Phytomyptera longicornis (Coquillet)										1
Phytomyptera sp. nr. *aristalis* (Twn.*)										1
Phytomyptera palpigera (Coquillet)										2
Leskiini										
Clausicella turmalis (Reinhard)										2
Genea pavonacea (Reinhard)										122
Minthoini										
Paradidyma affinis Reinhard										1
Paradidyma conica (Twn.*)										1
Paradidyma petiolata Reinhard										4
Paradidyma singularis (Twn.*)										9
Myiophasiini										
Cholomyia inaequipes Bigot										1
Gnadochaeta metallica (Twn.*)										1
Gnadochaeta nigrifrons (Twn.*)										2
Polideini										
Exoristoides johnsoni Coquillet										2
Lydina americana (Twn.*)										2
Siphonini										
Actia autumnalis (Twn.*)										3
Actia interrupta Curran										6
Actia rufescens (Greene)										2
Siphona illinoensis Twn.* or *cristata* (Fabricius)										2
Strongygastrini										
Strongygaster triangulifera (Loew)										8
Tachinini										
Archytas apicifer (Walker)										2
Archytas nivalis Curran										1
Copecrypta ruficauda (van der Wulp)										2
Deopalpus hirsutus Twn.*										6
Total	3	8 1	4 3	2 2	4 3	1 4	9 2	1 7	24	883

Shown are the bars from the log base 2 of the total individuals plus 1; thus 1, 2, 3, 4, 5, and 6 bars represent 1, 2, 5, 11, 22, and 45 specimens, respectively. Seasonality is indicated by ESP, early spring (Mar.); MSP, middle spring (April); LSP, late spring (May); ES, early summer (Jun); MS, middle summer (Jul); LS, late summer (Aug); EF, fall (Sept.); MF, middle fall (Oct.); and LF, late fall (Nov). The number 1 represents the first fortnight and number 2 the second fortnight of each month. *Twn., Townsend; **A. & W., Aldrich & Webber; ***R.-D., Robineau-Desvoidy; ****T. & G., Toma & Guimares; and *****S. & DeL., Sabrosky & DeLoach.

etative community, and the different methods of sampling (pan versus Malaise trap).

There have been a few studies of tachinid communities conducted in the Palearctic region, and despite the region and methodological differences, some comparisons can be made with these studies. Belshaw (1992) sampled four different habitats in England with eight malaise traps over 6 mo and found that grass and shrub habitats exhibit the richest communities, with >50 species (over two traps). This is less than half of the total species that we recovered with comparable sampling effort in terms of trap-days. However, the expected difference in species richness of these samples when rarefied to 51 specimens is much smaller (23
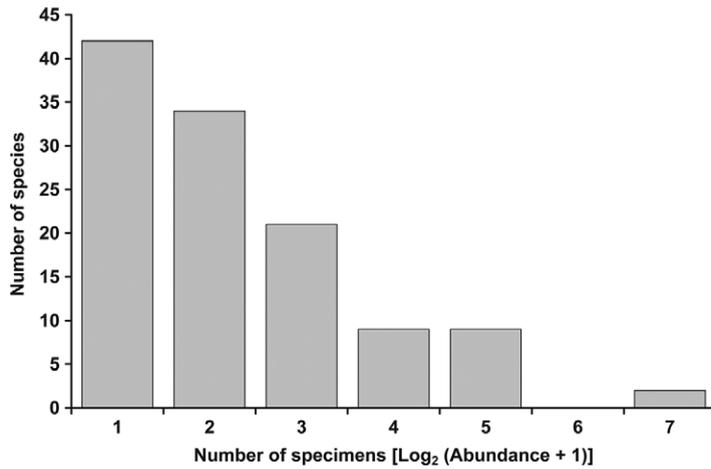
Fig. 1. Rank-abundance of tachinid species sampled in this study. The x-axis is the log base two of the specimens abundance plus 1.

Belshaw versus 29 current expected species). In Italy, Cerretti et al. (2004) sampled two different habitats, ground versus canopy forest, with four malaise traps for a period of 7 mo and found a total of 41 species (30 species only in ground traps, five exclusively in the canopy, and seven in both habitats). Here, we found approximately double this number of species, in each year, with only one trap. These comparisons suggest a significantly richer fauna at our forest edge site in Ohio than in these Palearctic sites; however, such comparisons must be treated with caution due to differences in habitat and sampling procedures.

Temporal Distribution. A two-dimensional final solution was selected for the NMDS. The best species

ordination plot was selected after seven tries (Fig. 4). The stress obtained for this dimensionality was 20, suggesting that not too much confidence should be placed on the details of the plot (McCune and Grace 2002). However, clear separation of dates in the NMDS plot (Fig. 4) suggests that the sampled tachinid fauna consists of relatively distinct seasonal communities as has been found in many other insect groups, including potential tachinid hosts (e.g., Summerville and Crist 2003). Spring dates are located at the bottom left corner, summer dates are at the center top, and fall dates are clustered at the right corner of the plot. The CCA of the seasonal patterns observed in the NMDS plot was statistically significant ($P = 0.01$; Table 3), indicating that the composition of the tachinid community clearly varies over the season. Similarly, year and its interaction with season were statistically significant ($P = 0.03$; Table 3), indicating substantial
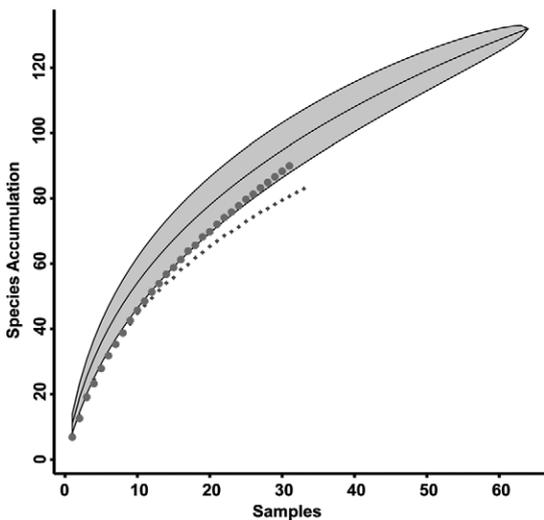

Fig. 2. Accumulation curves of tachinid species against the number of samples. The gray polygon is the species richness for 2008 + 2009 with the species richness accumulation in the center ± 95% CI. Circles and diamonds are the species richness accumulation curves for 2008 and 2009, respectively. Curves are based on 1,000 randomizations.
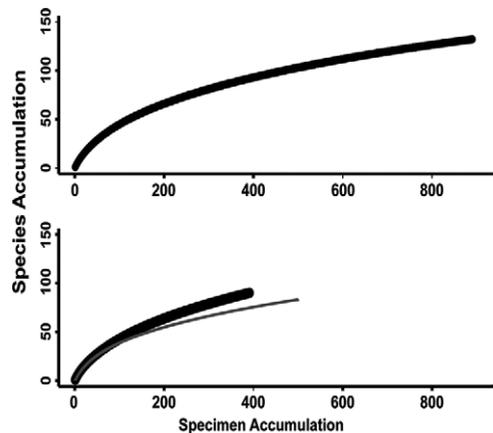

Fig. 3. Accumulation curves of tachinids species against specimen number. (Top) Species richness accumulation for 2008 + 2009. (Bottom) Thick and thin curves are the species richness accumulation for 2008 and 2009, respectively. Curves are based on 1,000 randomizations.

Table 2. Estimates of total species richness of the tachinid community by specimens and samples for 2008–2009, 2008, and 2009, based on 1,000 randomizations

Estimator	2008/2009		2008		2009	
	by specimens	by samples	by specimens	by samples	by specimens	by samples
No. of observations	883	64	390	31	493	33
Species observed	117	117	80	80	82	82
Chao1	190	205	152	190	126	129
Chao1 (lower–upper)	179–201	192–217	139–165	172–209	115–139	117–141
Jack1	185	191	134	141	118	121
Jack1 (lower–upper)	185–189	191–195	134–137	141–144	118–122	121–126

differences in the species composition among years. The majority of the specimens were collected in fall, followed by summer and spring, with 67, 22, and 11%, respectively. The relatively low coefficient of similarity between 2008 and 2009 (Sorensen index, 55%), confirms the large differences in communities between years.

Variation in temporal abundance and seasonality may be explained by ecological characteristics such as species life cycle, voltinism, and seasonal fluctuations of available hosts. For example, species that were found in multiple, disparate seasons are likely to complete several generations per year. Specifically, *Aplomya theclarum, Belvosia unifasciata, Blondelia eufitchiae, Campylochaeta plathypenae, Celatoria diabroticae, Chaetostigmoptera manca, Cylindromyia binotata, Medina barbata, Medina quinteri, Oxynops anthracinus, Siphosturmia phyciodis, Spathidexia dunningii,* and *Thelaira americana* are likely to be multivoltine (Table 1, authority names given only in table). Similarly, the species *Blondelia hyphantriae, Catharosia nebulosa, Ceracia dentata, Cylindromyia euchenor,* *Cylindromyia fumipennis, Gymnoclytia immaculata, Lespesia flavifrons, Lixophaga discalis, Lixophaga plumbea, Lixophaga variabilis, Periscepsia laevigata, Phytomyptera palpigera, Vibrissina leibyi, Winthemia sinuata,* and *Zelia tricolor* exhibit a bivoltine distribution (Table 1, authority names given only in table). Conversely, many species were recovered in only a single sampling period or across two neighboring sampling periods. Many of these have low sample size, making it difficult to assess true voltinism. But univoltine life cycles are strongly suggested for those species for which appreciable numbers of individuals were obtained (e.g., five or more) only over a narrow sampling period. Such taxa include *Actia interrupta, Admontia badiceps, Catharosia minuta, Epigrimyia polita, Eulasiona aperta, Eulasiona cinerea, Euthelyconychia xylota, Genea pavonacea, Gonia aldrichi, Gymnosoma par, Kirbya setosa, Lespesia aletiae, Lixophaga fasciata, Masiphya confusa, Paradidyma singularis, Strongygaster triangulifera, Winthemia quadripustulata,* and *Xanthomelanodes arcuatus* (Table 1, authority names given only in table).
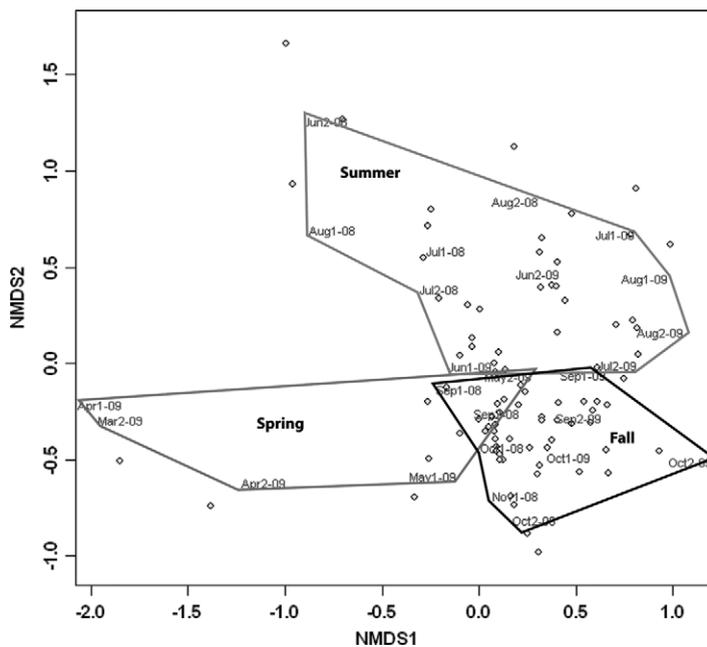

Fig. 4.   NMDS ordination plot showing samples dates and points (yellow) for species. The number after month summarizes the collection dates on the (1) first half or the (2) second half of the month. Polygons group spring, summer, and fall seasons.

Table 3. Permutation test for canonical correspondence analysis

Response	df	F	P
Season	2	1.8836	0.01**
Yr	1	1.2693	0.03**
Season × yr	1	1.3526	0.03**
Residuals	20		

For each response, 100 permutations were calculated.
** Groups are statistically different.

The significant effect of season in analyses of the community composition of tachinids in our samples can be easily understood by noting that many species were restricted to specific seasons. For example, *Cryptomeigenia theutis* and *Gonia aldrichi* were found only in spring; *Actia interrupta, Eucelatoria dimmocki, Kirbya setosa,* and *Masiphya confusa* were found only in summer; and *Actia autumnalis, Admontia badiceps, Epigrimyia polita, Eulasiona cincera, Lixophaga fasciata, Paradidyma singularis, Strongygaster triangulifera, Winthemia quadripustulata,* and *Xanthomelanodes arcuatus* were found only in fall (Table 1, authority names given only in table). Several of the presumed bivoltine species were also seasonally restricted: *Ceracia dentata* and *Cylindromyia euchenor* exhibited split distributions over spring and fall, and *Blondelia hyphantriae, Catharosia nebulosa, Lixophaga discalis, Winthemia sinuata,* and *Vibrissina leibyi* were absent from the spring samples (Table 1, authority names given only in table). Our inferences concerning voltinism and seasonality are preliminary as some of these patterns also could reflect changes in host seasonality and in habitat use (e.g., attraction to floral resources), and must be interpreted with caution.

The significant difference in community composition among years is probably due to three primary factors. First, there is probably a great deal of sampling error given that we sampled with a single Malaise trap. Many taxa were represented by just one or a few individuals as is typical for sampling studies of insects (Coddington et al. 2009), so we would expect differences among years solely due to chance. Second, the weather conditions differed between years. In general, the average temperature in spring was higher 2009 than 2008 (11.8 and 9.6°C, respectively), whereas the average temperature for summer was higher in 2008 than 2009 (22.3 and 21.4°C, respectively) (NCDC 2010). These changes in temperature might have an effect on temporal distribution of tachinids and their host. Third, each of the species that we collected probably undergoes natural year-to-year population fluctuations that are dependent on population dynamics of their hosts, their enemies, and weather events, leading to a high degree of variation in relative abundances from year to year.

In conclusion, the current study documents the richness and seasonal abundance of a community of tachinids in the southwestern Ohio. Both the observed and predicted species richness indicates the presence of a highly diverse tachinid fauna at this site, despite the "island-like" nature of the park it was located in, which is largely surrounded by development and/or intensive agriculture. The species recorded in this study represent 16 and 19% of the species that are likely to occur in the northeastern United States and Ohio, respectively. The sampled species likely represent only a fraction of the total tachinid community in the park and surrounding area.

Our primary goal in initiating this study was to provide a point estimate of tachinid species richness in eastern North America that can provide some comparative context for future studies of Tachinidae. To our knowledge, this study represents the first documented attempt to quantify the richness of a tachinid community in the northeastern United States. Despite our limited sampling, these results can be used as a baseline for understanding the temporal and spatial patterns of diversity of tachinid communities. We do not know, for example, how rapidly tachinid communities turn over with distance, or how they change with increasing habitat fragmentation. Additional data of the sort we have gathered here from other habitats and regions can be used to address these and other questions. However, to have a more complete picture of particular tachinid communities and understand patterns of spatial–temporal distribution and their relationship to voltinism, seasonal fluctuations of available hosts, and weather conditions, a broader sampling period and additional replicate traps will be needed. Trapping in other nearby habitats (e.g., forest interior and canopy, see Cerretti et al. 2004; Stireman 2008), may provide valuable information on the habitat specificity of the tachinid community and the effect of habitat structure on their seasonal patterns of abundance and diversity.

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