







Annotated checklist of arthropod-pathogenic species in the Entomophthoromycotina (Fungi, Zoopagomycota) in North America

Ann E. Hajek¹, Kelsey L. Scott², Sergio R. Sanchez-Peña³, Cezary Tkaczuk⁴, Brian Lovett^{2*}, Kathryn E. Bushley^{2*}

¹ Department of Entomology, Cornell University, Ithaca, NY 14853-2601, USA

² Emerging Pests and Pathogens Research Unit, USDA-ARS, Ithaca, NY 14853, USA

³ Departamento de Parasitología, Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, 25315, Mexico

⁴ Department of Horticulture and Plant Protection, University of Siedlce, 08-110 Siedlce, Poland

Corresponding author: Ann E. Hajek (aeh4@cornell.edu)

Abstract

The subphylum Entomophthoromycotina (Phylum Zoopagomycota) includes many arthropod pathogens, some of which are renowned for their abilities to alter host behavior prior to death and cause epizootics that impact host populations. The last checklist of arthropod-pathogenic species in this group was published in 1963 and consisted of 39 species in a single genus. Since then, more species have been named, and their taxonomy has changed extensively. We have constructed an updated checklist for species of Entomophthoromycotina in North America; this checklist includes species in the continental United States, Canada, and Mexico. Data were compiled based on available published literature and metadata available from the ARSEF culture collection, adjusting names based on current taxonomy. In North America, the arthropod-pathogenic Entomophthoromycotina now include 80 species belonging to 14 genera, within two classes, plus one species in a form genus. This checklist provides a current framework for future studies of the biodiversity of this group of fungi.



Academic editor:

Christian Wurzbacher

Received: 14 October 2024

Accepted: 12 December 2024

Published: 5 March 2025

Citation: Hajek AE, Scott KL, Sanchez-Peña SR, Tkaczuk C, Lovett B, Bushley KE (2025) Annotated checklist of arthropod-pathogenic species in the Entomophthoromycotina (Fungi, Zoopagomycota) in North America. MycoKeys 114: 329–366. <https://doi.org/10.3897/mycokeys.114.139257>

Copyright: This is an open access article distributed under the terms of the CC0 Public Domain Dedication.

Key words: Biodiversity, entomopathogenic fungi, Entomophthorales, mycodiversity, pathogen species list

Introduction

Most species in the fungal subphylum Entomophthoromycotina (Phylum Zoopagomycota; Spatafora et al. 2016) are pathogens of arthropods. Many species in this group naturally cause epizootics (Pell et al. 2001), highlighting their potential use for biological control of arthropod pests. Species in this group are also renowned for altering the behavior of infected arthropod hosts in fixed, predictable patterns (de Bekker et al. 2021), including ‘summit behavior’ just prior to host death (e.g., Elya et al. 2018) or producing psychoactive metabolites to stimulate continued flight by spore-ejecting infected cicada hosts (Boyce et al. 2019).

* These authors contributed equally to this work.

Despite their promising roles in the control of insect pests and their fascinating biology, relatively few studies have documented the biodiversity, distribution, and ecology of entomophthoralean fungi in natural ecosystems. Most inventories of species of arthropod-pathogenic fungi in the Entomophthoromycotina originate from Europe. Twenty-six species have been listed for Spain (Niell and Santamaria 2001), 24 for Sweden (Gustafsson 1965), 12 for Norway (Klingen et al. 2002), 29 for Austria (Barta et al. 2005; Tkaczuk et al. 2011), and 35 for the United Kingdom (www.mapmate.co.uk/checklist). The much higher counts for Switzerland (95; Keller 2008; S. Keller pers. comm.) and Poland (94; Sosnowska et al. 2004; Mułenko et al. 2008; Dubiel 2016) are consistent with the suggestion that this group of fungi is most diverse in central Europe (Keller 2008). However, this statement might be biased by the prolific work of researchers specifically studying the subject in that geographical area. Outside of Europe, lists of species have also been reported for China (79; Zha et al. 2016), Israel (31; Ben-Ze'ev 1993), the Philippines (19; Villacarlos and Mejia 2004; Villacarlos 2008), Argentina (16; López Lastra et al. 2019), and Australia (10; Glare and Milner 1987), as well as in several different publications from Mexico (Remaudière and Latgé 1985; Sanchez-Peña 1990, 2000).

For North America, Roland Thaxter published a comprehensive monograph on the family Entomophthoraceae in the United States in 1888, in which he reported on 26 species (Thaxter 1888). Following this, Charles (1941) reported 36 species in this group for North America, and in 1963, Hutchison reported 39 species of entomophthoralean fungi that occurred in North, Central, and South America and provided information about hosts and geographic distributions of these species. In the 21st century, a protochecklist of all nonlichenized fungi in North America included 38 species of arthropod-pathogens in the Entomophthoromycotina (Bates and Miller 2018). The protochecklist entries were based on herbarium specimens from the US (plus its territories), Canada, and Mexico, and in many instances, the names of arthropod pathogens that were included are not the currently accepted names.

Although there has not been an up-to-date summary of arthropod pathogens in North American species after 1963, the discovery, taxonomic changes, and research since that time have been prolific. It is very clear that an updated checklist is sorely needed; for example, the most recent protochecklist for all North American fungi does not use current taxonomic genera and species designations for this group (Bates and Miller 2018), certainly because this information might not be easy to find. Therefore, our goal with this annotated checklist was to present arthropod hosts and distributions for arthropod-pathogenic species in the Entomophthoromycotina that occur in North America, using the currently accepted taxonomy. This will facilitate continued progress in this field and summarize disparate observations as a compendium.

Materials and methods

Study area

This checklist of arthropod-pathogenic North American species includes records from the continental United States, Canada, and Mexico.

The data

Published records that were used to begin generating this checklist were found in Thaxter (1888), Charles (1941), Hutchison (1963), and Bałazy (1993). The catalogue of the USDA Agricultural Research Service Collection of Entomopathogenic Fungi (ARSEF 2020) was also used to search for North American records falling within the arthropod-pathogenic Entomophthoromycotina. Subsequently, search engines were used to explore records for additional North American species, using a recent worldwide list of species within the arthropod pathogens of the Entomophthoromycotina (Sacco and Hajek 2023). Personal communication records for R.A. Humber are from his notes regarding specimens in the Thaxter collection at the Farlow Herbarium, Harvard University. Throughout the checklist, only naturally occurring fungi associated with field-collected arthropod hosts were included. Samples from laboratory manipulations, often from studies of host specificity, have not been included.

Within the Entomophthoromycotina, extensive taxonomic reorganization has occurred in relatively recent years, and many generic names have changed. For example, in 1963, *Entomophthora* is given as the generic name for all 39 species in the Western Hemisphere (Hutchison 1963). However, for all except 4 of these species, the generic names have since changed. We used Humber (1989), Index Fungorum (<http://www.indexfungorum.org>), and MycoBank (Robert et al. 2005) to assist with all taxonomic decisions about fungi. We only include information from records with fungal identifications to the species level. For all arthropod hosts, only the currently accepted genus and species names are used.

For all records, hosts and distributions are provided with associated citations. For distributional information for North America, we generally referred to states or provinces but also provided citations for references where more specific details about collection site locations were found. For some records, only the name of the country was available. In at least one publication, the locations of species by country were not provided, and this record therefore could not be included (e.g., Remaudière et al. 1978). Two-letter, capitalized abbreviations of US states and Canadian provinces were used. For records from Mexico, we used 'conventional' abbreviations that are 2–4 letters long for states (https://en.wikipedia.org/wiki/Template:Mexico_State-Abbreviation_Codes). In all cases, the country name occurs alongside states or provinces. GPS coordinates for sites are not included, as for most entries, references are older, and GPS information was not available. Alternatively, descriptions of sites were too vague or broad for us to infer a GPS location. GPS information provided in more recent reports is available via the citations provided.

For information about hosts, only pathogens in the Entomophthoromycotina infecting arthropods were included (Sacco and Hajek 2023). For example, reports of vertebrate infections by *Conidiobolus coronatus* and reports of species only isolated from soil (e.g., many *Conidiobolus* spp.) were not included.

Many arthropod-pathogenic species in the Entomophthoromycotina have not been isolated into pure culture. Among those that have, numerous have been frozen and deposited in culture collections. The USDA-ARS entomopathogenic fungi collection (ARSEF) is the world's largest repository of these isolates, and we have indicated for each species whether a culture is available

in ARSEF. We have not included GenBank accession numbers for numerous reasons, including that DNA data for most of these fungi are lacking or difficult to link to specimens, as many of these are older records prior to the DNA era. We can only confidently link accessions correctly to a few known specimens, and these are scarce. For those fungal species that have been sequenced, accession numbers can be found in the references cited or in GenBank.

References are always provided, but we did not exhaustively include references; if several references report a host/fungus association from the same state/province, we only included one of such references. Summaries were cited if these existed.

Results

Records for host species and distributions are reported below. For species with more extensive lists of hosts and distributions, detailed accounts are included in tabular form. For example, for some species reported from many states across much of North America, hosts and distribution are summarized below, but individual host species and specific collection locations are listed in tables. Species names below followed by an asterisk have arthropod pathogenic North American isolates in the ARSEF culture collection.

Class Neozygitomycetes

Order Neozygitales

Family Neozygitaceae

Neozygites

[1] *Neozygites floridanus* (J. Weiser & Muma) Remaud. & S. Keller, 1980

In the US, *N. floridanus* has been reported infecting six species of mites in the family Tetranychidae (Arachnida, Trombidiformes) in the southeastern US states, as well as IA, KS, PA, and TX (US) (Lopes Ribeiro et al. 2009) (Table 1). This species is frequently referred to as *N. floridana*, which is taxonomically incorrect.

Table 1. Recorded arthropod hosts of *Neozygites floridanus* in the US, all in the family Tetranychidae (Arachnida, Trombidiformes).

Host Species	Country	States	References
<i>Eotetranychus sexmaculatus</i>	US	FL	Lopes Ribeiro et al. 2009
<i>Eutetranychus banksi</i>	US	FL, TX	Pickett and Gilstrap 1986; Lopes Ribiero et al. 2009
<i>Oligonychus pratensis</i>	US	KS	Dick and Buschman 1995
<i>Panonychus citri</i>	US	FL	Lopes Ribiero et al. 2009
<i>Tetranychus urticae</i>	US	AL, GA, IA, KS, MS, NC, NY, SC	Lopes Ribiero et al. 2009; ARSEF 2020
<i>Bryobia</i> sp.	US	PA	C. Tkaczuk, unpubl. data
-	US	PA	C. Tkaczuk, unpubl. data

[2] *Neozygites fresenii* (Nowak.) Remaud. & S. Keller, 1980

On multiple aphid species (Hemiptera, Aphididae) from a broad distribution across the US, as well as ON (Canada) and Mexico (Fig. 1, Table 2).



Figure 1. Distribution of recorded occurrences of *Neozygites fresenii* in the US, Canada, and Mexico (see references in Table 2). Dark gray = locations by state in the US or province in Canada; light gray = a record from an unspecified area within Mexico.

Table 2. Recorded arthropod hosts of *Neozygites fresenii* in the US, Canada, and Mexico, all hosts Hemiptera.

Host Family	Host Species	Country	States/Provinces	References
Aphididae	<i>Aphis glycines</i>	US	AR, NY	Nielsen and Hajek 2005; Galligan 2007
	<i>Aphis gossypii</i>	US	AL, AR, GA, LA, MS, MO, NC, SC, TN, TX	Sanchez-Peña 1993; Steinkraus et al. 1996
	<i>Aphis gossypii</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis pomi</i>	US	MA, ME, NC	Thaxter 1888
	<i>Aphis solitaria</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis spiraecola</i>	US	FL	Charles 1941
	<i>Capitophorus elaeagni</i>	Mex	-	Remaudière and Latgé 1985
	<i>Myzus persicae</i>	US	FL	Charles 1941
	<i>Periphyllus lyropictus</i>	US	NH	Charles 1941
	<i>Schizaphis graminum</i>	US	ID	Feng et al. 1990
	<i>Schizolachnus piniradiatae</i>	Can	ON	Soper and MacLeod 1963
Pseudococcidae	-	US	PA	C. Tkaczuk, unpubl. data
	<i>Planococcus citri</i>	US	LA	Charles 1941

[3] *Neozygites fumosus* (Spear) Remaud. & S. Keller, 1980

On the mealybug *Planococcus citri* (Hemiptera, Pseudococcidae) in FL and LA (US) (Spear 1922). This species is frequently referred to as *N. fumosa*, which is taxonomically incorrect.

[4] *Neozygites lageniformis* (Thaxt.) Remaud. & S. Keller, 1980

Infecting 'Aphides on *Betula populifolia*' and '*Solidago*' in MA, ME, and NC (US) (Thaxter 1888), and infecting *Macrosiphum euphorbiae* and *Aphis nasturtii* (Hemiptera, Aphididae) in ME (US) (Shands et al. 1972).

[5] *Neozygites parvisporus* (D.M. MacLeod & K.P. Carl) Remaud. & S. Keller, 1980

On *Frankliniella* sp. (Thysanoptera, Thripidae) in BC (Mexico) (Remaudière and Latgé 1985). This species is frequently referred to as *N. parvispora*, which is taxonomically incorrect.

[6] *Neozygites turbinatus* (R.G. Kenneth) Remaud. & S. Keller, 1980

On *Cinara curvipes* (Hemiptera, Aphididae, Lachninae) in Jal (Mexico) (Remaudière and Latgé 1985). This species is frequently referred to as *N. turbinata*, which is taxonomically incorrect.

Class Entomophthoromycetes**Order Entomophthorales****Family Conidiobolaceae*****Conidiobolus*****[7] *Conidiobolus coronatus* (Constantin) A. Batko 1964***

On diverse insects, including termites (Isoptera, Kalotermitidae and Termitidae), aphids, and leafhoppers (Hemiptera), Diptera, Hymenoptera, and Thysanoptera. A truly polyphagous fungus, this species is also known to infect Collembola (Entognatha), Araneida, and Opiliones (Palpatores). It has been reported from across the US, Ver (Mexico), and AB (Canada) (Hutchison 1963; Matanmi et al. 1974; ARSEF 2020) (Table 3).

Table 3. Recorded arthropod hosts of *Conidiobolus coronatus* in the US, Canada, and Mexico.

Host Class	Host Order /Suborder	Host Family	Host Species	Country	States/ Provinces	References
Arachnida	Araneida	-	-	Can	AB	ARSEF 2020
	Opiliones/"Palpatores"	-	-	Can	AB	ARSEF 2020
Entognatha	Collembola	-	-	US	NC	ARSEF 2020
Insecta	Diptera	Anthomyiidae	<i>Delia platura</i>	US	WI	Matanmi et al. 1974
			<i>Delia radicum</i>	US	WI	Matanmi et al. 1974
		Bibionidae	<i>Plecia nearctica</i>	US	FL	Kish et al. 1974
		Sciaridae	<i>Lycoriella ingenua</i>	Mex	Ver	ARSEF 2020
	Hemiptera	Aphididae	<i>Aulacorthum solani</i>	US	ME	Harris 1948
			<i>Macrosiphum euphorbiae</i>	US	ME	Harris 1948
			<i>Metopolophium dirhodum</i>	US	ID	ARSEF 2020
			<i>Myzus persicae</i>	US	ME	Harris 1948
		Cercopidae	<i>Aeneolamia albofasciata</i>	Mex	Oax	Remaudière and Latgé 1985
			<i>Aeneolamia contigua</i>	Mex	Tamps	Guzmán and Alcocer-Gómez 1972
	Cicadellidae	<i>Empoasca fabae</i>	US	NY	ARSEF 2020	
	Hymenoptera	Formicidae	-	Can	AB	ARSEF 2020
	Isoptera	Kalotermitidae	-	US	CA, LA	Hutchison 1963
		Termitidae	-	US	CA, LA	Hutchison 1963
	Orthoptera	Acrididae	-	Mex	-	Remaudière and Latgé 1985
Thysanoptera	Thripidae	-	US	VT	ARSEF 2020	
		<i>Frankliniella occidentalis</i>	US	FL	ARSEF 2020	

Family Neoconidiobolaceae***Neoconidiobolus*****[8] *Neoconidiobolus thromboides* (Drechsler) B. Huang & Y. Nie, 2020***

Well known as an aphid (Hemiptera, Aphididae) pathogen: on numerous aphid hosts across the US and in AB, ON, and QC (Canada). It has also been reported from another hemipteran, the leafhopper *Empoasca fabae* in NY (US) (Hemiptera, Cicadellidae), a helemomyzid fly in ME (US) (Diptera, Heliomyzidae), and an acridid in MT (US) (Orthoptera, Acrididae) (ARSEF 2020; Castrillo and Harris-Shultz 2024). *Delia radicum* and *Delia platura* (Diptera, Anthomyiidae) were also reported infected in WI (US) (Matanmi et al. 1974) (Table 4).

Table 4. Recorded arthropod hosts of *Neoconidiobolus thromboides* in the US and Canada.

Host Order	Host Family	Host Species	Country	States/ Provinces	References
Diptera	Anthomyiidae	<i>Delia platura</i>	US	WI	Matanmi et al. 1974
		<i>Delia radicum</i>	US	WI	Matanmi et al. 1974
	Heliomyzidae	-	US	ME	ARSEF 2020
Hemiptera	Aphididae	<i>Aphis glycines</i>	US	MN, NY	Nielsen and Hajek 2005
		<i>Diuraphis tritici</i>	US	MT	Feng et al. 1991
		<i>Macrosiphum euphorbiae</i>	US	ME	ARSEF 2020
		<i>Melanaphis sacchari</i>	US	GA	Castrillo and Shultz 2024
		<i>Metopolophium dirhodum</i>	US	ID	ARSEF 2020
		<i>Myzus persicae</i>	US	FL, ME, WI	ARSEF 2020
		<i>Schizaphis graminum</i>	Can	AB	ARSEF 2020
		<i>Sitobion avenae</i>	US	ID	ARSEF 2020
		<i>Therioaphis maculata</i>	US	CA	ARSEF 2020
	<i>Uroleucon</i> sp.	Can	QC	ARSEF 2020	
	Cicadellidae	<i>Empoasca fabae</i>	US	NY	ARSEF 2020
Orthoptera	Acrididae	-	US	MT	ARSEF 2020

Family Batkoaceae***Batkoa*****[9] *Batkoa apiculata* (Thaxt.) Humber, 1989***

Broad host range including four families of Lepidoptera (Erebidae, Noctuidae, Tortricidae, Geometridae), numerous aphid species (Hemiptera, Aphididae), leafhoppers (Hemiptera, Cicadellidae), a spittlebug (Hemiptera, Cercopidae), Scirtidae and Helotidae (Coleoptera), and nematocerans (Diptera). Collected across the northern US, as far south in the US as TN and NC but also in SLP (Mexico) (Thaxter 1888; Hutchison 1963; ARSEF 2020) (Table 5).

[10] *Batkoa major* (Thaxt.) Humber, 1989*

Initially, described from Ptilodactylidae (Coleoptera) in NC (US) by Thaxter (1888). Epizootics occurred in *Lycorma delicatula*, an invasive species in the Fulgoridae (Hemiptera) in PA (US) in 2018 (Clifton et al. 2019). Following field surveys of host range in PA and NY (US), confirmed infections were observed in 3 families of Coleoptera, 8 families of Diptera, 5 families of Hemiptera, 6 families of Lepidoptera, and 1 family of Psocomorpha (Gryganskyi et al. 2022a) (Table 6).

Table 5. Recorded arthropod hosts of *Batkoa apiculata* in the US and Mexico.

Host Order	Host Family/Suborder	Host Species/Subfamily	Country	States	References
Coleoptera	Cantharidae	-	Mex	Oax	Remaudière and Latgé 1985
	Scirtidae	-	US	TN	Hutchison 1963
Diptera	Nematocera	-	US	ME, NC	Thaxter 1888
		-	Mex	Tamps	Remaudière and Latgé 1985
Hemiptera	Aphididae	<i>Acyrtosiphon pisum</i>	US	NY	ARSEF 2020
	Aphididae	<i>Macrosiphum euphorbiae</i>	US	ME	ARSEF 2020
	Aphididae	<i>Myzus persicae</i>	US	ME	ARSEF 2020
	Aphididae	<i>Rhopalosiphum maidis</i>	US	MT	ARSEF 2020
	Aphididae	<i>Rhopalosiphum padi</i>	US	CO	ARSEF 2020
	Cercopidae	<i>Prosapia simulans</i>	Mex	-	Remaudière and Latgé 1985
	Cicadellidae	-	US	NH, NY	ARSEF 2020
	Cicadellidae	<i>Typhlocyba</i> sp.	US	ME, NC	Thaxter 1888
Lepidoptera	Erebidae	<i>Hyphantria cunea</i>	US	ME, NC	Thaxter 1888
	Erebidae	listed as 'Deltoid sp.'	US	ME, NC	Thaxter 1888
	Geometridae	<i>Petrophora</i> sp.	US	ME, NC	Thaxter 1888
	Tortricidae	<i>Tortrix</i> sp.	US	ME, NC	Thaxter 1888

Table 6. Recorded arthropod hosts of *Batkoa major* in the US and Mexico.

Host Order	Host Family	Host Species	Country	States	References
Coleoptera	Cantharidae	<i>Rhagonycha fraxini</i>	US	NY	Gryganskyi et al. 2022a
		<i>Rhagonycha</i> sp.	US	NY	Gryganskyi et al. 2022a
	Elateridae	<i>Athous brightwelli</i>	US	NY	Gryganskyi et al. 2022a
	Ptilodactylidae	<i>Ptilodactyla serricollis</i>	US	NC	Thaxter 1888
	Tenebrionidae	<i>Isomira sericea</i>	US	NY	Gryganskyi et al. 2022a
Diptera	Anthomyiidae	-	US	NY	Gryganskyi et al. 2022a
	Dolichopodidae	<i>Gymnopterus</i> sp.	US	NY	Gryganskyi et al. 2022a
		<i>Medetera</i> sp.	US	PA	Gryganskyi et al. 2022a
		<i>Thrypticus</i> sp.	US	NY	Gryganskyi et al. 2022a
	Drosophilidae	<i>Drosophila suzukii</i>	US	TN	ARSEF 2020
	Heleomyzidae	<i>Tephrochlamys rufiventris</i>	US	NY	Gryganskyi et al. 2022a
	Lauxaniidae	<i>Homoneura inserta</i>	US	NY, PA	Gryganskyi et al. 2022a
	Milichiidae	<i>Madiza glabra</i>	US	PA	Gryganskyi et al. 2022a
	Psychodidae	-	US	NY	Gryganskyi et al. 2022a
	Rhagionidae	-	US	NY	Gryganskyi et al. 2022a
		<i>Symphoromyia</i> sp.	US	NY	Gryganskyi et al. 2022a
	Sciaridae	-	US	NY, PA	Gryganskyi et al. 2022a
Hemiptera	Achilidae	-	US	NY	Gryganskyi et al. 2022a
	Aphididae	<i>Macrosiphum euphorbiae</i>	US	ME	ARSEF 2020
	Cercopidae	<i>Prosapia simulans</i>	Mex	Chis, Tamps	Remaudière and Latgé 1985
	Cicadellidae	-	US	NY	Gryganskyi et al. 2022a
		<i>Empoasca fabae</i>	US	NY	ARSEF 2020
	Cixiidae	<i>Cixius</i> sp.	US	NY	Gryganskyi et al. 2022a
	Derbidae	<i>Apache degeeri</i>	US	NY	Gryganskyi et al. 2022a
	Fulgoridae	<i>Lycorma delicatula</i>	US	PA	Gryganskyi et al. 2022a
Lepidoptera	Blastobasidae	-	US	NY	Gryganskyi et al. 2022a
	Crambidae	<i>Eudonia</i> sp.	US	NY	Gryganskyi et al. 2022a
	Erebidae	<i>Lophocampa caryae</i>	US	NY	Gryganskyi et al. 2022a
		<i>Lymantria dispar</i>	US	NY	Gryganskyi et al. 2022a
	Geometridae	<i>Lambdina fiscellaria</i>	US	NY	Gryganskyi et al. 2022a
	Oecophoridae	<i>Fabiola edithella</i>	US	NY	Gryganskyi et al. 2022a
	Tineidae	<i>Dryadula</i> sp.	US	NY	Gryganskyi et al. 2022a
Psocoptera	Amphipsocidae	<i>Polypsocus corruptus</i>	US	NY	Gryganskyi et al. 2022a
	Psocomorpha	-	US	PA	Gryganskyi et al. 2022a

[11] *Batkoa obscura* (I.M. Hall & P.H. Dunn) Gryganskyi, 2022*

On numerous species of aphids in CA, NY, ID, MT, and ME (US) and QC (Canada) (Table 7).

Table 7. Recorded arthropod hosts of *Batkoa obscura* in the US, Canada, and Mexico, all in the family Aphididae (Hemiptera).

Host Species	Country	States/ Provinces	References
<i>Acyrtosiphon pisum</i>	US	NY	ARSEF 2020
<i>Aphis nasturtii</i>	US	ME	Shands et al. 1972
<i>Aphis</i> sp.	Can	QC	ARSEF 2020
<i>Aulacorthum solani</i>	US	ME	Shands et al. 1972
<i>Capitophorus elaeagni</i>	Mex	-	Remaudière and Latgé 1985
<i>Capitophorus shepherdiae</i>	Mex	-	Remaudière and Latgé 1985
<i>Capitophorus xanthii</i>	Mex	-	Remaudière and Latgé 1985
<i>Hyperomyzus lactucae</i>	Mex	-	Remaudière and Latgé 1985
<i>Macrosiphum euphorbiae</i>	US	ME	Shands et al. 1962
<i>Macrosiphum</i> spp.	Mex	-	Remaudière and Latgé 1985
<i>Metopolophium dirhodum</i>	US	MT	Feng et al. 1991
<i>Microparsus (Picturaphis)</i> sp.	Mex	-	Remaudière and Latgé 1985
<i>Myzus persicae</i>	US	ME	Shands et al. 1962
<i>Myzus persicae</i>	Mex	-	Remaudière and Latgé 1985
<i>Rhopalosiphum maidis</i>	US	MT	Feng et al. 1991
<i>Rhopalosiphum maidis</i>	Mex	-	Remaudière and Latgé 1985
<i>Rhopalosiphum padi</i>	Can	QC	ARSEF 2020
<i>Rhopalosiphum padi</i>	Mex	-	Remaudière and Latgé 1985
<i>Rhopalosiphum</i> sp.	Mex	-	Remaudière and Latgé 1985
<i>Therioaphis maculata</i>	US	CA	ARSEF 2020
<i>Uroleucon ambrosiae</i>	Mex	-	Remaudière and Latgé 1985
<i>Uroleucon sonchi</i>	Mex	-	Remaudière and Latgé 1985
<i>Uroleucon</i> sp.	Can	QC	ARSEF 2020
<i>Uroleucon</i> sp.	Mex	-	Remaudière and Latgé 1985

[12] *Batkoa papillata* (Thaxt.) Humber, 1989

On 'several minute gnats' (Diptera, Nematocera) from NH and NC (US). In North America, known only from these initial collections by Thaxter (1888).

Family Entomophthoraceae
Subfamily Entomophthoroideae
Arthropaga

[13] *Arthropaga myriapodina* K.T. Hodge & A.E. Hajek, 2017

Reported from three species of millipedes (Myriapodina, Polydesmidae): *Apheloria virginensis corrugata*, *Nannaria* sp., and *Boraria infesta* in MA, MD, NC, NY, PA, and VA, Washington DC (US), and southern ON (Canada) (Hodge et al. 2017).

Entomophaga**[14] *Entomophaga aulicae* (E. Reichardt) Humber, 1984 (*aulicae* species complex)***

Entomophaga aulicae is a complex of morphologically identical species infecting only Lepidoptera, within which only *E. maimaiga* has been named as a separate species (treated below). Aside from *E. maimaiga*, fungal populations belonging to the *E. aulicae* complex infect lepidopteran species in the Noctuidae, Erebidae, Geometridae, Tortricidae, Lasiocampidae, Notodontidae, Sphingidae, and Saturniidae families from around the US and Canada (FPMI 1990; Walsh 1996; Speare and Colley 1912; ARSEF 2020). An invasive species in the Hesperidae (Lepidoptera) in QC (Canada) was also infected (McNeil and MacLeod 1982). Within the complex, genetic diversity has been detected, with two groups occurring in North America. Pathotype I includes hosts in the Geometridae, Tortricidae, Notodontidae, and Saturniidae from BC, ON, and NF (Canada) and ME, NY, and VT (US). Pathotype II includes species in the Noctuidae and Erebidae in GA, CA (US), and ON (Canada) (Hajek et al. 1996b; Walsh et al. 1990; Walsh 1996) (Table 8).

Table 8. Recorded arthropod hosts of *Entomophaga aulicae* in the US, Canada, and Mexico, with all hosts in the order Lepidoptera.

Host Family	Host species	Country	States/ Provinces	References	Group
Erebidae	<i>Catocala</i> sp.	US	CT	Speare and Colley 1912	-
	<i>Estigmene acrea</i>	US	CT	Speare and Colley 1912	-
	<i>Estigmene acrea</i>	Mex	Son	Young and Sifuentes 1959	-
	<i>Euchaetes egle</i>	US	-	Speare and Colley 1912	-
	<i>Euproctis chrysorrhoea</i>	US	MA, ME	Kirkland 1906; Boyd et al. 2021	-
	<i>Hypena scabra</i>	US	SC	Kalkar and Carner 2005	-
	<i>Hyphantria cunea</i>	Can	ON	Walsh et al. 1990	II
	<i>Orgyia antiqua nova</i>	Can	NF	Thaxter 1888	-
	<i>Orgyia leucostigma</i>	Can	NS	van Frankenhuyzen et al. 2002	-
	<i>Orgyia vetusta</i>	US	CA	Hajek et al. 1996b	II
	<i>Pyrrharctia isabella</i>	US	ME	Hitchings 1908	-
	<i>Spilosoma virginica</i>	US	OH, TX	Webster 1894; Mitchell 1919	-
Geometridae	<i>Epirrita autumnata</i>	Can	BC	FPMI 1990	-
	<i>Lambdina fiscellaria</i>	Can	BC, NF	Walsh et al. 1990; Hajek et al. 1996b	I
	<i>Nepytia freemani</i>	Can	BC	FPMI 1990	-
	<i>Rheumaptera hastata</i>	Can	ON	Walsh et al. 1990	I
	<i>Sabulodes griseata</i>	Can	BC	ARSEF 2020	-
Lasiocampidae	<i>Malacosoma americanum</i>	US	CT	Speare and Colley 1912	-
	<i>Malacosoma disstria</i>	US	NY	ARSEF 2020	-
Noctuidae	<i>Agrotis</i> sp.	US	CT	Thaxter 1891	-
	<i>Amphipyra pyramidoides</i>	US	-	Speare and Colley 1912	-
	<i>Helicoverpa zea</i>	US	GA	Hamm 1980	-
	? <i>Heliothis</i> sp.	US	GA	Walsh et al. 1990	II
	<i>Heliothis virescens</i>	US	GA	Hamm 1980	-
	<i>Lithophane</i> sp.	US	CT	Thaxter 1891	-
	<i>Mamestra</i> sp.	US	CT	Thaxter 1891	-
	<i>Mythimna</i> sp.	Can	ON	ARSEF 2020	-
<i>Spodoptera frugiperda</i>	US	GA	Hamm 1980	-	
Nolidae	<i>Nola cereella</i>	US	GA	Hamm 1980	-

Host Family	Host species	Country	States/ Provinces	References	Group
Notodontidae	<i>Cecrita biundata</i>	Can	ON	ARSEF 2020	
	<i>Cecrita guttivitta</i>	US	NY, VT	Hajek et al. 1991; 1996b	I
	<i>Ellida caniplaga</i>	Can	ON	ARSEF 2020	-
Saturniidae	<i>Dryocampa rubicunda</i>	Can	ON	Walsh et al. 1990	I
Sphingidae	-	US	ME	FPMI 1990	-
	<i>Manduca quinquemaculata</i>	US	CT	Thaxter 1891	-
	<i>Manduca sexta</i>	US	CT	Thaxter 1891	-
	<i>Pachysphinx modesta</i>	US	ME	Farlow Herbarium unpubl. data	-
	<i>Eumorpha fasciata</i>	US	FL	ARSEF 2020	-
Tortricidae	<i>Choristoneura fumiferana</i>	US	ME	Walsh et al. 1990	
	<i>Choristoneura fumiferana</i>	Can	NF, ON	Walsh et al. 1990	I
	<i>Choristoneura occidentalis</i>	Can	BC	Hajek et al. 1996b	I

[15] *Entomophaga batkoi* (Balazy) S. Keller, 1888

On a species in the Phalangidae in ME (US) (R.A. Humber pers. comm.).

[16] *Entomophaga calopteni* (Bessey) Humber, 1989 (*E. grylli* species complex)*

A member of the *Entomophaga grylli* species complex, also known as Pathotype 2. Infects species in the Acrididae, with most infections in the subfamily Melanoplineae, although lower levels of infection have been found in the subfamilies Oedopodinae and Gomphocerinae. Reported from AZ, IA, KS, MT, ND, SD, and WY (US), AB and SK (Canada), and NL and Coah (Mexico) (Thaxter 1888; Soper et al. 1983; Erlandson et al. 1988; Bidochka et al. 1995, 1996; Casique-Valdes et al. 2012, 2022; ARSEF 2020).

[17] *Entomophaga grylli* Pathotype I (Fresen.) A. Batko, 1964 (*E. grylli* species complex)*

A member of the *Entomophaga grylli* species complex, also known as Pathotype 1 or *E. macleodii* (an unpublished name). Principally infects grasshopper species in the subfamily Oedopodinae (Acrididae), although also known to infect Gomphocerinae and occasionally Melanoplineae. Reported from AZ, ND, NY, MT, and OR (US), and AB, ON, and SK (Canada), and Coah (Mexico) (Bidochka et al. 1996; Casique-Valdes et al. 2012, 2022; Kistner and Belovsky 2013; ARSEF 2020).

[18] *Entomophaga kansana* (J.A. Hutchison) A. Batko, 1964

Reported from Calliphoridae, Sarcophagidae, Muscidae, and Tachinidae (Diptera) near Lawrence, KS (US) (Hutchison 1962).

[19] *Entomophaga maimaiga* Humber, Shimazu & R.S. Soper, 1988 (*aulicae* species complex)*

Entomophaga maimaiga is a North Asian species only infecting Lepidoptera, accidentally introduced to North America, probably from Japan, at some time after 1971, but before 1989 (Weseloh 1998; Nielsen et al. 2005). Principal hosts are larvae of *Lymantria dispar* (Lepidoptera, Erebidae). Surveys of naturally occurring host specificity documented low levels of infections in 3 of 7 lymantriines (Hajek

et al. 2004). Rare infections also occurred in *Catocala ilia* (Erebidae) and *Malacosoma disstria* (Lasiocampidae) (Hajek et al. 1996a), *Agrochola bicolorago* (Noctuidae); an unidentified gelechiid (Lepidoptera) was also infected (Hajek et al. 2000). *E. maimaiga* was discovered in 1989 in seven northeastern US states (Hajek et al. 1990) and has since spread (naturally and with human assistance)



Figure 2. Distribution of recorded occurrences of *Entomophaga maimaiga* in the US and Canada, by state and province (Hajek et al. 2021; S. Picq pers. comm.).

into a total of 19 US states (Hajek et al. 2021). *E. maimaiga* has also been reported from ON and QC (Canada) (Nealis et al. 1999, S. Picq pers. comm.) (Fig. 2).

[20] *Entomophaga tabanivora* (J.F. Anderson & Magnar.) Humber, 1989

On *Tabanus nigrovittatus* and *Atylotus thoracicus* (Diptera, Tabanidae) in MA and NY (US) (Anderson and Magnarelli 1979; Mullens et al. 1983).

[21] *Entomophaga tenthredinis* (Fresen.) A. Batko, 1964

On sawfly larvae (Hymenoptera, Tenthredinidae), including *Pristiphora erichsonii* in ON (Canada), larvae of an unidentified tenthredinid species in ME (US), and the introduced pine sawfly, *Diprion similis*, in WI (US) (Thaxter 1888; Klein and Coppel 1973; FPMI 1990).

Entomophthora

[22] *Entomophthora chromaphidis* O.F. Burger & Swain, 1918

An aphid pathogen (Hemiptera, Aphididae) on *Chromaphis juglandicola* in CA (Burger and Swain 1918), the cereal aphids *Metopolophium dirhodum* in ID, WA (US) and *Sitobion avenae* in ID (US) (Humber and Feng 1991), *Myzus per-*

sicae in ID (Kish et al. 1994), and *Aphis glycines* in NY (US) (Nielsen and Hajek 2005). Also reported on *Psocus* sp. (Psocodea, Psocidae) in CA (US) (Burger and Swain 1918). At least some of the entries under *E. planchoniana* (Table 9) could instead be *E. chromaphidis* (see Humber and Feng 1991; Barta and Cagáñ 2006); further study is necessary.

[23] *Entomophthora culicis* (A. Braun) Fresen., 1858

Reported by Thaxter (1888) on Diptera: “*Culex* [Culicidae], and numerous genera of minute flies or gnats” in MA, ME, and NH. On unidentified midges (Chironomidae) in NY (US) (Kramer 1981b) and unidentified black flies (Simuliidae) in AB (Canada) (Shemanchuk and Humber 1978).

[24] *Entomophthora erupta* (Dustan) I.M. Hall, 1959

On Miridae (Hemiptera): *Neolygus communis*, *Adelphocoris lineolatus*, *Irbisia solani*, *Lygocoris pabulinus*, and *Plagiognathus* sp. in NS (Canada) (Dustan 1924), and *I. solani* in CA (US) (Hall 1959). Also reported from *A. lineolatus* from NY (US) (Wheeler 1972).

[25] *Entomophthora muscae* (Cohn) Fresen., 1856*

Entomophthora muscae is a species complex of morphologically similar species infecting Diptera, including from 4 to 8 described species (Elya and De Fine Licht 2021). Three species within the complex occur in North America: *E. muscae sensu stricto* (s.s), *E. scatophagae* (treated separately), and *E. schizophorae* (treated separately). *Entomophthora muscae* s.s infects *Musca domestica* (Muscidae) in CA, NY, NC, and NE, and probably across most of the US and Canada, and in Coah (Mexico) (Sanchez-Peña unpubl. observations). Also on *Coenosia tigrina* (Muscidae) and *Delia radicum* (Anthomyiidae) in NC (US) (Gryganskyi et al. 2013), and six species of *Drosophila* (Drosophilidae) in CA (US): *Drosophila melanogaster*, *D. simulans*, *D. hydei*, *D. immigrans*, *D. pseudoobscura*, *D. repleta* (Elya et al. 2018). Further studies of hosts and distributions of the different members of this species complex in North America are necessary.

[26] *Entomophthora planchoniana* Cornu, 1873

On diverse species of aphids (Aphididae) across the US and Mexico (Table 9). However, at least some of the entries under *E. planchoniana* in Table 9 could instead be *E. chromaphidis* (see Humber and Feng 1991; Barta and Cagáñ 2006); further study is necessary.

Table 9. Recorded arthropod hosts of *Entomophthora planchoniana* in the US and Mexico, with all hosts in the family Aphididae (Hemiptera).

Host Species	Country	States	References
<i>Acyrtosiphon malvae</i>	Mex	-	Remaudière and Latgé 1985
<i>Acyrtosiphon pisum</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis asclepiadis</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis coreopsidis</i>	Mex	-	Remaudière and Latgé 1985

Host Species	Country	States	References
<i>Aphis fabae</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis gossypii</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis lugentis</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis nasturtii</i>	US	ME	Shands et al. 1972
<i>Aphis solitaria</i>	Mex	-	Remaudière and Latgé 1985
<i>Aphis spiraecola</i>	Mex	-	Remaudière and Latgé 1985
<i>Aulacorthum solani</i>	US	ME	Shands et al. 1972
<i>Brevicoryne brassicae</i>	Mex	-	Remaudière and Latgé 1985
<i>Capitophorus elaeagni</i>	Mex	-	Remaudière and Latgé 1985
<i>Capitophorus shepherdiae</i>	Mex	-	Remaudière and Latgé 1985
<i>Capitophorus xanthii</i>	Mex	-	Remaudière and Latgé 1985
<i>Chaetosiphon fragaefolii</i>	US	CA	Dara 2017
<i>Cryptomyzus galeopsidis</i>	US	ME	Shands et al. 1962
<i>Hayhurstia atriplicis</i>	Mex	-	Remaudière and Latgé 1985
<i>Hyperomyzus</i> sp.	Mex	-	Remaudière and Latgé 1985
<i>Latgerina orizabaensis</i>	Mex	-	Remaudière and Latgé 1985
<i>Macrosiphum euphorbiae</i>	US	ME	Shands et al. 1962
<i>Macrosiphum</i> spp.	Mex	-	Remaudière and Latgé 1985
<i>Melanocallis caryaefoliae</i>	US	GA	Ekbom and Pickering 1990
<i>Metopolophium dirhodium</i>	US	ID	Feng et al. 1991
<i>Metopolophium dirhodium</i>	Mex	BC	Remaudière and Latgé 1985
<i>Monellia caryella</i>	US	GA	Ekbom and Pickering 1990
<i>Monelliopsis pecanis</i>	US	GA	Ekbom and Pickering 1990
<i>Myzus ornatus</i>	Mex	-	Remaudière and Latgé 1985
<i>Myzus persicae</i>	US	ME	Shands et al. 1962
<i>Myzus persicae</i>	Mex	-	Remaudière and Latgé 1985
<i>Obtusicauda</i> sp.	Mex	BC	Remaudière and Latgé 1985
<i>Rhopalosiphum maidis</i>	US	ID	Feng et al. 1991
<i>Rhopalosiphum maidis</i>	Mex	Coah	Sanchez-Peña 2000
<i>Rhopalosiphum padi</i>	Mex	BC	Remaudière and Latgé 1985
<i>Rhopalosiphum padi</i>	Mex	-	Remaudière and Latgé 1985
<i>Rhopalosiphum</i> sp.	Mex	-	Remaudière and Latgé 1985
<i>Sitobion avenae</i>	US	ME	Shands et al. 1962
<i>Uroleucon ambrosiae</i>	Mex	-	Remaudière and Latgé 1985
<i>Uroleucon sonchi</i>	Mex	-	Remaudière and Latgé 1985
<i>Uroleucon</i> sp.	Mex	-	Remaudière and Latgé 1985
<i>Utamphorophora crataegi</i>	Mex	-	Remaudière and Latgé 1985

[27] *Entomophthora scatophagae* Giard, 1888

A member of the *E. muscae* species complex (Jensen et al. 2006). On *Scatophaga stercoraria* (Diptera, Anthomyiidae) in NY (Steinkraus and Kramer 1988).

[28] *Entomophthora schizophorae* S. Keller & Wilding, 1988

A member of the *E. muscae* species complex, infecting only Diptera (Elya and De Fine Licht 2021). Isolates from NE and NY (US) infect *Pollenia rudis* (Diptera, Polleniidae), and both also infect *Musca domestica*, although at lower prevalence (Steinkraus et al. 1993a; Watson et al. 1993; Six and Mullens 1996). Also, infects *Hylemya* sp. (Anthomyiidae) in PA (US) (C. Tkaczuk unpubl. data).

Eryniopsis

[29] *Eryniopsis caroliniana* (Thaxter) Humber, 1984

On *Tipula* sp. (Diptera, Tipulidae) in NC (US) (Thaxter 1888).

[30] *Eryniopsis lampyridarum* (Thaxter) Humber, 1984

On *Chauliognathus pensylvanicus* and *Chauliognathus marginatus* (Coleoptera, Cantharidae) in AR, MD, KS, NC, PA, SC, and VA (US) (Thaxter 1888; Carner 1980; Steinkraus et al. 2017) (Fig. 3). Also, on *Chauliognathus* sp. in Coah (Mexico) (RI Torres-Acosta & S. Sanchez-Peña, unpubl. observation: <https://www.youtube.com/watch?v=NRBO7zc1J-o>).

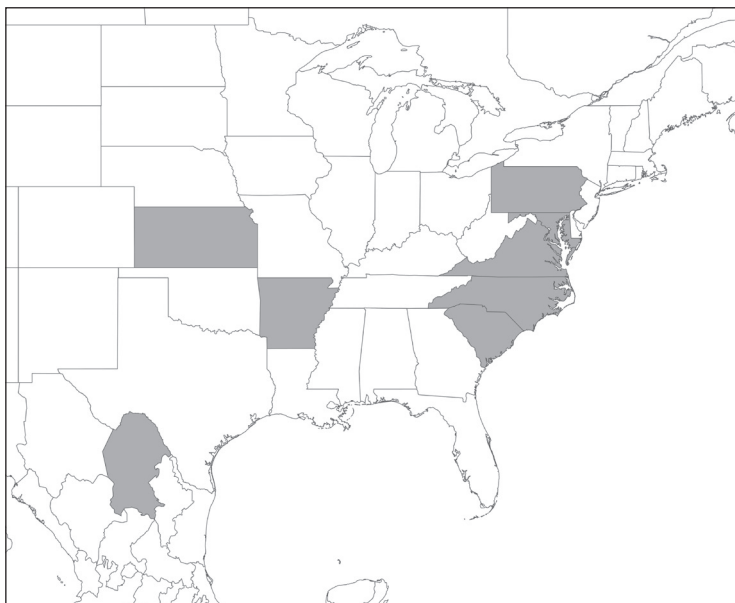


Figure 3. Distribution of recorded occurrences of *Eryniopsis lampyridarum* in the US and Mexico, by state (see references in the text).

Massospora

[31] *Massospora cicadina* Peck, 1878*

On species of the genus *Magisicada* (Hemiptera, Cicadidae) in the eastern US (Macias et al. 2020).

[32] *Massospora diceroproctae* R.S. Soper, 1974

On *Diceroprocta delicata*, *Diceroprocta cinctifera*, *Diceroprocta vitripennis*, and *Diceroprocta biconica* (Hemiptera, Cicadidae) in TX (and possibly LA, FL) (US) (Macias et al. 2020).

[33] *Massospora fidicinae* R.S. Soper, 1974

On *Fidicina* sp. (Hemiptera, Cicadidae) in Chis (Mexico) (Macias et al. 2020).

[34] *Massospora levispora* R.S. Soper, 1963

On *Okanagana rimosa* and *Okanagana sperata* (Hemiptera, Cicadidae) in CA (US) and ON (Canada) and *Platypedia putnami* (Hemiptera, Cicadidae) in CA, NM, and UT (US) (Macias et al. 2020).

[35] *Massospora spinosa* Cif., A.A. Machado & Vittal, 1956

On *Quesada gigas* (Hemiptera, Cicadidae) in NL (Mexico) (Macias et al. 2020).

Orthomyces

[36] *Orthomyces aleyrodis* Steinkr., Humber & Oliv., 1998

On *Trialeurodes abutiloneus* (Hemiptera, Aleyrodidae) in AL (US) (Steinkraus et al. 1998).

Subfamily Erynioideae

Erynia

[37] *Erynia aquatica* (J.F. Anderson & Ringo ex J.F. Anderson & Anagnost.) Humber, 1981*

On larvae and pupae of Culicidae (Diptera) in the US: *Aedes canadensis* (CT, RI), *Culiseta morsitans* (CT), *Aedes stimulans* (NY), *Aedes fitchii* (NY), *Aedes cantator* (CT), *Aedes* sp. (NY) (Anderson and Ringo 1969; Molloy and Wraight 1982; Andreadis and Magnarelli 1983; Steinkraus and Kramer 1989; Christie 1996; ARSEF 2020).

[38] *Erynia conica* (Nowak.) Remaud. & Hennebert, 1980*

On Chironomidae, Chaoboridae, Simuliidae, and Tipulidae (Diptera) in NC, NH, and NY (US) (Thaxter 1888; Cuebas-Incle 1992; ARSEF 2020). On Simuliidae (Diptera) in QC (Canada): *Simulium venustum* complex, *Simulium verecundum/rostratum*, *Simulium vittatum* complex (Nadeau et al. 1994).

[39] *Erynia curvispora* (Nowak.) Remaud. & Hennebert, 1980*

Reported from adult *Simulium decorum* (Diptera, Simuliidae) in NY (US) and QC (Canada) (Kramer 1983; Nadeau et al. 1994), *Aedes triseriatus* (Diptera, Culicidae) in ME (US), and unidentified *Simulium* in NY (US) and QC (Canada) and Trichoptera in QC (Canada) (ARSEF 2020).

[40] *Erynia gracilis* (Thaxter) Remaud. & Hennebert, 1980

On “very minute gnats” (Diptera) in NC (US) (Thaxter 1888).

[41] *Erynia ovispora* (Nowak.) Remaud. & Hennebert, 1980

On a ‘small gnat attached to bark’ in TN (Diptera) (US) (R.A. Humber pers. comm.).

[42] *Erynia rhizospora* (Thaxter) Remaud. & Hennebert, 1980*

On Neuroptera and “several genera” of adult Phryganeidae (Trichoptera) in ME and NC (US) (Thaxter 1888). Also reported on Trichoptera in NY (US) (ARSEF 2020).

[43] *Erynia sepulchralis* (Thaxter) Remaud. & Hennebert, 1980*

On unidentified adult crane flies (Diptera, Tipulidae) in western NC and eastern TN (US) (Thaxter 1888), and on *Tipula caloptera* in NY (US) (Kramer 1980).

[44] *Erynia variabilis* (Thaxter) Remaud. & Hennebert, 1980

On 'minute gnats of various genera' in NC (Diptera) (US) (Thaxter 1888).

Pandora

[45] *Pandora americana* (Thaxter) S. Keller, 2007

On Diptera: *Musca domestica* (Muscidae), *Calliphora vomitoria*, and *Lucilia caesar* (Calliphoridae) and 'numerous other large flies.' Common in New England and less common in NC (US) (Thaxter 1888). Also reported in the US from *Calliphora* sp. (WI), *C. vomitoria* (AL), *Phormia regina* (TX) (Calliphoridae), and *Muscina stabulans* (TN) (Muscidae) (Charles 1941).

[46] *Pandora blissi* (G. Lakon) D.M. MacLeod & Müller-Kögler, 1973; *nomen dubium*

On the chinch bug, *Blissus leucopterus* (Hemiptera, Blissidae) in IA, IL, KS, MN, and OH (Billings and Glenn 1911). This species was initially placed in the genus *Empusa* by Thaxter (Gillette 1888). The 1888 species description was minimal (Gillette 1888), and no types were designated (but 'co-types' are present at Harvard). The provisional genus *Pandora* is based on ongoing evaluation of museum specimens.

[47] *Pandora blunckii* (G. Lakon ex G. Zimm.) Humber, 1989*

On *Plutella xylostella* (Lepidoptera, Plutellidae) in Gto. (Mexico) (ARSEF 2020) and on Diptera (possibly Sciaridae) in NY (US) (ARSEF 2020).

[48] *Pandora bullata* (Thaxt. & D.M. MacLeod ex Humber) Humber, 1989

On Calliphoridae (Diptera): including *Phormia regina*, *Lucilia sericata*, *Protophormia terraenovae*, *Calliphora vomitoria*, and perhaps other *Calliphora* spp. and Sarcophagidae (Diptera): *Sarcophaga aldrichi* in ON (Canada) and NY, MI, and MA (US) (MacLeod et al. 1973; Kramer 1979; Nielsen et al. 2001).

[49] *Pandora delphacis* (Hori) Humber, 1989*

On Hemiptera: *Spissistilus festinus* (Hemiptera, Membracidae) in AL, AR (US) (Miller and Harper 1987; ARSEF 2020), and *Empoasca fabae* (Hemiptera, Cicadellidae) and Miridae in NY (ARSEF 2020).

[50] *Pandora dipterigena* (Thaxter) Humber, 1989*

On Diptera: "small Tipulidae; other small flies or gnats belonging especially to the Mycetophilidae" in MA, ME, NC, and NH (US) (Thaxter 1888), unknown

dipterans in ME and NY (US) (ARSEF 2020), and nematocerans in Mich. (Mexico) (Remaudière and Latgé 1985).

[51] *Pandora echinospora* (Thaxter) Humber, 1989

On *Minettia duplicata* (Diptera, Lauxaniidae) and 'rarely other smaller Diptera' in ME, NH, and NC (US) (Thaxter 1888).

[52] *Pandora formicae* (Humber & Balazy) Humber, 1989

On Formicinae (Hymenoptera, Formicidae) in ME (US) (R.A. Humber pers. comm.).

[53] *Pandora gammae* J. Weiser ex. Humber, 1989

On noctuid larvae (Lepidoptera): *Chrysodeixis includens* in AL and GA (US) in GA (US) and Tamps (Mexico) and *Trichoplusia ni* in AL (US) and Coah (Mexico) (Harper and Carner 1973; Newman and Carner 1975; Gilreath et al. 1986; Sanchez-Peña 1990, 2000). Also on *Mocis* sp. in NL and Coah (Mexico) (S.R. Sanchez-Peña unpubl. data).

[54] *Pandora gastropachae* (Racib.) Hajek & Gryganskyi, 2024*

In hardwood forests on *Malacosoma disstria* (Lepidoptera, Lasiocampidae), ranging from BC to QC (Canada) and ME to FL and AL (US) (Filotas et al. 2003).

[55] *Pandora gloeospora* (Vuillemin) Humber, 1989*

On *Lycoriella mali* (Diptera, Sciaridae) in mushroom production facilities in MD, DE, and southeastern PA (US) (Miller and Keil 1990, AP Gryganskyi pers. comm.) and cadavers producing conidia found on oyster mushrooms (*Pleurotus* sp.) in FL (US) (MW Miller pers. comm.).

[56] *Pandora heteropterae* (Balazy) S. Keller, 2005*

On *Lygus lineolaris* (Hemiptera, Miridae) in AR (US) (Hannam and Steinkraus 2010).

[57] *Pandora ithacensis* (Kramer) Hajek & Gryganskyi, 2024*

On Diptera: *Symphoromyia hirta* and *Rhagio mystaceus* (Rhagionidae) and *Empis obesa* (Empididae) in NY (US) (Kramer 1981a) and an unidentified rhagionid in PA (US) (C. Tkaczuk unpubl. data).

[58] *Pandora montana* (Thaxter) Hajek & Gryganskyi, 2024

On Diptera on the alpine summit of Mt. Washington, NH (US), infecting "minute gnats, apparently *Chironomus* sp." (Thaxter 1888).

[59] *Pandora muscivora* (J. Schröt.) S. Keller, 2005

On *Syrphus* sp. (Diptera, Syrphidae) in ME (US) (MyCoPortal 2024).

[60] *Pandora neoaphidis* (Remaud. & Hennebert) Humber, 1989*

On diverse aphids (Hemiptera, Aphididae) across the US, Mexico, and QC (Canada). In addition, single records of *Lygus* sp. (Hemiptera, Miridae) in NY (US) (ARSEF 2020) and *Aeneolamia albofasciata* (Hemiptera, Cercopidae) in Mexico (Remaudière and Latgé 1985) (Table 10). These last records of this fungus on spittlebugs and mirids should be reconsidered due to the unambiguous nature of this fungus as a specialized aphid pathogen, and the brief and rather incomplete description in these records.

Table 10. Recorded arthropod hosts of *Pandora neoaphidis* in the US, Canada, and Mexico, all hosts in the order Hemiptera.

Host Family	Host Species	Country	States/ Provinces	References
Aphididae	<i>Acyrtosiphon kondoi</i>	US	CA	Pickering and Gutierrez 1991
	<i>Acyrtosiphon pisum</i>	US	CA, GA, ID, IL, MN, NY, PA, WA	Folsom 1909; Pickering et al. 1989; Pickering and Gutierrez 1991; ARSEF 2020; C. Tkaczuk unpubl. data
	<i>Acyrtosiphon pisum</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis asclepiadis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis coreopsidis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis fabae</i>	US	WA	ARSEF 2020
	<i>Aphis fabae</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis glycines</i>	US	NY	ARSEF 2020; Nielsen and Hajek 2005
	<i>Aphis gossypii</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis lugentis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis solitaria</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aphis</i> sp.	Can	QC	ARSEF 2020
	<i>Aphis</i> sp.	US	WA	ARSEF 2020
	<i>Aphis spiraeicola</i>	Mex	-	Remaudière and Latgé 1985
	<i>Aulacorthum solani</i>	US	ME	Shands et al. 1972
	<i>Brachycaudus helichrysi</i>	Mex	-	Remaudière and Latgé 1985
	<i>Brachyunguis tetrapteralis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Brevicoryne brassicae</i>	Mex	-	Remaudière and Latgé 1985
	<i>Capitophorus elaeagni</i>	Mex	-	Remaudière and Latgé 1985
	<i>Capitophorus shepherdiae</i>	Mex	-	Remaudière and Latgé 1985
	<i>Capitophorus xanthii</i>	Mex	-	Remaudière and Latgé 1985
	<i>Cavariella hendersoni</i>	Mex	-	Remaudière and Latgé 1985
	<i>Diuraphis noxia</i>	US	CO, ID	ARSEF 2020; Feng et al. 1990
	<i>Hayhurstia atriplicis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Hyperomyzus lactucae</i>	Mex	-	Remaudière and Latgé 1985
	<i>Hyperomyzus</i> sp.	Mex	-	Remaudière and Latgé 1985
	<i>Illinoia</i> sp.	Mex	-	Remaudière and Latgé 1985
	<i>Impatiens americanum</i>	Mex	-	Remaudière and Latgé 1985
	<i>Macrosiphum euphorbiae</i>	US	FL, ID, ME	ARSEF 2020; Feng et al. 1990
	<i>Macrosiphum</i> spp.	Mex	-	Remaudière and Latgé 1985
<i>Melanaphis sacchari</i>	Mex	Coah	ARSEF 2020	
<i>Metopolophium dirhodum</i>	US	ID, MT	ARSEF 2020; Feng et al. 1990, 1991	
<i>Myzus ornatus</i>	Mex	-	Remaudière and Latgé 1985	
<i>Myzus persicae</i>	US	AR, ID, ME, VA, WA	Harris 1948; Elkassabany et al. 1992; Kish et al. 1994; Dara and Semtner 2001	
<i>Myzus persicae</i>	Mex	-	Remaudière and Latgé 1985	

Host Family	Host Species	Country	States/ Provinces	References
Aphididae	<i>Myzus persicae nicotianae</i>	US	KY, VA	ARSEF 2020; Dara and Semtner 2001
	<i>Rhopalosiphum padi</i>	US	ID	Feng et al. 1990
	<i>Rhodobium porosum</i>	Mex	-	Remaudière and Latgé 1985
	<i>Rhopalosiphum maidis</i>	US	ID, MT	Feng et al. 1990, 1991
	<i>Rhopalosiphum maidis</i>	Mex	-	Remaudière and Latgé 1985
	<i>Rhopalosiphum padi</i>	Mex	-	Remaudière and Latgé 1985
	<i>Rhopalosiphum</i> sp.	Mex	-	Remaudière and Latgé 1985
	<i>Schizaphis graminum</i>	US	ID	ARSEF 2020; Feng et al. 1990
	<i>Schizaphis graminum</i>	Mex	-	Remaudière and Latgé 1985
	<i>Sibobion avenae</i>	US	ID	Feng et al. 1990
	<i>Sitobion</i> sp.	Mex	-	Remaudière and Latgé 1985
	<i>Uroleucon ambrosiae</i>	Mex	-	Remaudière and Latgé 1985
	<i>Uroleucon sonchi</i>	Mex	-	Remaudière and Latgé 1985
	<i>Uroleucon</i> sp.	Can	QC	FPMI 1990
	<i>Uroleucon</i> sp.	Mex	-	Remaudière and Latgé 1985
	<i>Utamphorophora crataegi</i>	Mex	-	Remaudière and Latgé 1985
<i>Wahlgreniella arbuti</i>	Mex	-	Remaudière and Latgé 1985	
Cercopidae	<i>Aenolamia albofasciata</i>	Mex	-	Remaudière and Latgé 1985
Miridae	<i>Lygus</i> sp.	US	NY	ARSEF 2020

[61] *Pandora nouryi* (Remaud. & Hennebert) Humber, 1989*

On aphids (Hemiptera: Aphididae) on potato in ME (US) (ARSEF 2020).

[62] *Pandora pieris* (Z.Z. Li & Humber) Hajek & Gryganskyi, 2024*

On larvae of *Pieris rapae* (Lepidoptera, Pieridae) in NY (US) (Li and Humber 1984).

[63] *Pandora sylvestris* Hajek & Gryganskyi, 2024

On larvae of *Lophocampa caryae* (Lepidoptera, Erebididae) from MI and VT (US) (Hajek et al. 2024a).

[64] *Pandora virescens* (Thaxter) Hajek & Gryganskyi, 2024

On Noctuidae (Lepidoptera): *Mythimna unipuncta* in AR (US), *Dargida procinctus* in OR (US), and *Ochropleura fennica* in ON (Canada) (Steinkraus et al. 1993b).

[65] *Pandora vomitoriae* (Rozsypal) Hajek & Gryganskyi, 2024

On adult Calliphoridae (Diptera): 'blue bottle flies' in Coah. (Mexico) (Sanchez-Peña 2000) and *Lucilia sericata* in NY (US) (B. Lovett unpubl. data).

Zoophthora

[66] *Zoophthora aphrophorae* (Rostr.) S. Keller, 2007

On the pine spittlebug, *Aphrophora parallela* (Hemiptera, Aphrophoridae), in PA (US) (Knull 1932).

[67] *Zoophthora canadensis* (MacLeod, Tyrrell & Soper) Remaud. & Hennebert, 1980

On *Schizolachnus piniradiatae* (Hemiptera, Aphididae) in red pine plantations in ON (Canada) (MacLeod et al. 1979).

[68] *Zoophthora forficulae* (Giard) A. Batko, 1964

On *Forficula auricularia* (Dermaptera, Forficulidae) in OR and WA (US) (Rockwood 1950; Hutchison 1963).

[69] *Zoophthora geometralis* (Thaxt.) A. Batko, 1964

On adults of *Eupithecia* sp., *Petrophora* sp., and *Thera* sp. (Lepidoptera, Geometridae) in ME (US) (Thaxter 1888).

[70] *Zoophthora ichneumonis* Bałazy, 1993

On an adult ichneumonid (Hymenoptera) in PA (US) (C. Tkaczuk, unpubl. data).

[71] *Zoophthora independentia* A.E. Hajek, Humber & Gryganskyi, 2016

Resting spore stages occurred within adult *Tipula submaculata* (Diptera, Tipulidae) in NY (US) (Hajek et al. 2016).

[72] *Zoophthora occidentalis* (Thaxter) A. Batko, 1964*

First reported on 'aphides on *Betula populifera*' in MA and ME (US) (Thaxter 1888). On aphids (Hemiptera, Aphididae), *Myzus persicae*, *Macrosiphum euphorbiae*, and *Aphis fabae* in ME (US); *Acyrtosiphon pisum* and *Aphis glycines* in NY (US); and *Sitobion avenae* in ID (US) (Feng et al. 1990; Nielsen and Hajek 2005; Barta and Cagáñ 2006; ARSEF 2020).

[73] *Zoophthora phalloides* A. Batko, 1966

Aphid pathogens (Hemiptera, Aphididae) on *Macrosiphum euphorbiae*, *Neartaphis bakeri*, *Uroleucon* sp., and *Acyrtosiphon pisum* in QC (Canada), ME and NH (US) (Remaudière et al. 1978). On *A. pisum* in Oax. (Mexico) and *Therioaphis maculata* in Mexico (ARSEF 2020) and NY (US) (Milner and Soper 1981).

[74] *Zoophthora phytonomi* (Arthur) A. Batko, 1964*

Two genotypes infecting weevils in the genus *Hypera* (Coleoptera, Curculionidae) occur in North America (Hajek et al. 1995). The genotype principally infecting *Hypera postica* was first found in 1973 in ON (Canada) and subsequently in 21 eastern US states (Fig. 4). This genotype was also reported in *H. punctata* from NY (US). The second genotype infected *Hypera punctata* in ON (Canada) and NY and DE (US) (Hajek et al. 1995).



Figure 4. Distribution of recorded occurrences of *Zoophthora phytonomi* in the US and Canada (Hajek et al. 1995). Dark gray = states and provinces where this pathogen was reported from both *Hypera postica* and *Hypera phytonomi*; light gray = US states where this pathogen was only reported from *H. postica* (Hajek et al. 1995).

[75] *Zoophthora porteri* (R.S. Soper) A.E. Hajek, Humber & Gryganskyi, 2016

Resting spore stages occurred within adult *Tipula colei* (Diptera, Tipulidae) in TN (US) (Hajek et al. 2016).

[76] *Zoophthora radicans* (Bref.) A. Batko, 1964*

On hosts in diverse families across Hemiptera, Lepidoptera, Hymenoptera, and Diptera. Widespread distribution across the US, Canada, and Mexico (Table 11).

Table 11. Recorded arthropod hosts of *Zoophthora radicans* in the US, Canada, and Mexico.

Host Order	Host Family	Host Species	Country	States/ Provinces	References
Diptera	Drosophilidae	-	US	FL	ARSEF 2020
	Nematocera	-	Mex	Dgo	Remaudière and Latgé 1985
	Tipulidae	-	US	ME	FPMI 1990
Hemiptera	Aphididae	<i>Acyrtosiphon pisum</i>	US	GA	Pickering et al. 1989
		<i>Aphis nasturtii</i>	US	ME	Shands et al. 1972
		<i>Macrosiphum euphorbiae</i>	US	ME	Shands et al. 1962
		<i>Metopolophium dirhodum</i>	US	ID, MT	Feng et al. 1990
		<i>Myzus ornatus</i>	Mex	-	Remaudière and Latgé 1985
		<i>Sitobion avenae</i>	US	ID	Feng et al. 1990
		<i>Therioaphis maculata</i>	US	NY	ARSEF 2020
		<i>Therioaphis maculata</i>	Mex	CDMX	FPMI 1990
		<i>Therioaphis trifolii</i>	Mex	CDMX	Remaudière and Latgé 1985
	Cicadellidae	<i>Empoasca fabae</i>	US	IL, MI, NY, WI	ARSEF 2020; McGuire et al. 1987
	Pentatomidae	<i>Bagrada hilaris</i>	Mex	Coah	Torres-Acosta et al. 2016
	Psyllidae	<i>Trioza</i> sp.	Can	QC	ARSEF 2020
		<i>Psylla trimaculata</i>	Can	QC	FPMI 1990
<i>Cacopsylla mali</i>		Can	NS	Gilliatt 1925	
Triozidae	<i>Bactericera cockerelli</i>	Mex	Coah	Torres-Acosta et al. 2016	

Host Order	Host Family	Host Species	Country	States/ Provinces	References
Hymenoptera	-	-	US	ME	ARSEF 2020
	Diprionidae	<i>Neodiprion tsugae</i>	US	AK	ARSEF 2020
Lepidoptera	Geometridae	<i>Lambdina fiscellaria</i>	Can	NF	Otvos et al. 1973
	Hesperiidae	<i>Thymelicus lineola</i>	Can	QC	FPMI 1990
	Noctuidae	<i>Autographa precationis</i>	US	IN	Yendol and Paschke 1987
		<i>Rachiplusia ou</i>	US	IN	Yendol and Paschke 1987
		<i>Trichoplusia ni</i>	US	IN	Yendol and Paschke 1987
		<i>Trichoplusia ni</i>	Mex	Coah	Sanchez-Peña 2000
	Plutellidae	<i>Plutella xylostella</i>	Mex	Gto	ARSEF 2020
	Tortricidae	<i>Acleris variana</i>	US	ME	ARSEF 2020
		<i>Acleris variana</i>	Can	NF	FPMI 1990
		<i>Archips argyrospila</i>	US	PA	Knoll 1932
		<i>Choristoneura biennis</i>	Can	BC	FPMI 1990
<i>Choristoneura fumiferana</i>		US	ME	Vandenbergh and Soper 1975	
<i>Choristoneura fumiferana</i>		Can	BC, NS, ON	FPMI 1990	
<i>Rhopobota naevana</i>		US	MA	Sawyer 1933	

[77] *Zoophthora rhagonycharum* (Balazy) S. Keller, 2007

Resting spore stages in adult *Rhagonycha vilis* and *Rhagonycha fraxini* (Coleoptera, Cantharidae) in NY (US) (Hajek et al. 2024b).

Strongwellsea

[78] *Strongwellsea castrans* A. Batko & Weiser, 1965

On *Delia platura* (Diptera, Anthomyiidae) in WI (US) (Strong et al. 1960) and *Delia radicum* in ON (Canada) (Nair and McEwen 1973).

[79] *Strongwellsea magna* Humber, 1976

On *Fannia canicularis* (Diptera, Fanniidae) in CA (US) (Humber 1976).

FORM GENUS

Tarichium

[80] *Tarichium megaspermum* Cohn, 1875

On two species of Noctuidae (Lepidoptera): *Euxoa messoria* and *Euxoa ochrogaster* in BC and ON (Canada) (Bucher and MacLeod 1974; Steinkraus et al. 1993b).

Incomplete and questionable records

For some species we could not resolve the identification of the fungal species, especially older identifications based only on morphology or species for which confusion exists regarding the correct fungal species name to use. For example, the species *Entomophthora carpentieri*, named by Giard in 1888 from only resting spores collected in Europe, was identified by V.K. Charles from *Horistonius uhleri* (Coleoptera, Elateridae) collected in 1934 by J.N. Tenhet in SC (My-

CoPortal 2024). However, this fungal species is considered questionable by Keller (1991) and Bałazy (1993), and any potential synonymous species are not known in North America, and so it has not been included in this checklist.

One isolate of *Entomophaga conglomerata* is listed in the ARSEF culture collection (ARSEF 2020), but a recent publication demonstrated that this isolate instead belongs in the genus *Batkoa* (Gryganskyi et al. 2022b), and therefore this example was not included. Tipulids in NHand NC (US), collected by Thaxter, harbored a fungus named *Entomophthora thaxteri* (MacLeod and Müller-Kögler 1973), but this species was not adequately described. However, trying to find the correct genus and species for this species has been difficult. Over time, it has been suggested that this species could be *E. conglomerata*, *Entomophaga tipulae*, or *Entomophthora tipulae* (MacLeod and Müller-Kögler 1973; Bałazy 1993). In addition, because Thaxter found only resting spores in adults, perhaps this is *Zoophthora independentia* or *Z. porteri*. Therefore, this species (whatever it is) is not included in the checklist. In the case of *Pandora blissi*, this genus name is provided as *nomen dubium*; the native host of this species is no longer as abundant as in the past (Waldbauer 2005), and studies are currently underway to obtain specimens so the correct genus can be determined.

Sometimes, pathogen/host associations seem incorrect in initial reports. For example, in 1909, *Zoophthora radicans* was reported infecting the weevil *Hypera punctata* in IL (US) (Folsom 1909). However, now we know that *Zoophthora phytonomi* (not described until 1964) infects this weevil species in other regions (Fig. 4), and we have no examples of *Z. radicans* infecting Coleoptera (see Table 11). In this case, we have not included this location information under *Z. phytonomi* (Fig. 4) or under *Z. radicans* (Table 11).

Finally, as we do not include entries for which a species name has not been provided. Thus, we could not include an unidentified species infecting the economically important northern corn rootworm, *Diabrotica barberi* (Naranjo and Steinkraus 1988); in this case beetle cadavers only contained resting spores. We also could not include the only example from the Arctic. *Zoophthora* sp. was reported causing epizootics in outbreak populations of the noctuid *Eurois occulta* in West Greenland (Avery and Post 2013). The larval cadavers that had summited on the vegetation only contained resting spores, and the species could not be identified or described at that time.

Discussion

In 1963, a checklist of entomophthoralean fungi from the Western Hemisphere listed 39 species, all ascribed to the same genus: *Entomophthora* (Hutchison 1963). Today, with increased collection data and the incorporation of taxonomic changes within this group, our survey of arthropod pathogens in the Entomophthoromycotina found in North America includes 80 species in 14 genera, within 2 classes, plus one species in a form genus. A recent checklist of all fungi in North America (Bates and Miller 2018) lists only 38 arthropod-pathogenic species belonging to the Entomophthoromycotina. This checklist most likely relied on the Hutchison (1963) checklist, as it was the most recent available checklist for this group (Hutchison, 1963), underscoring the necessity for an updated checklist of Entomophthoromycotina in North America.

In their checklist for all North American fungi, Bates and Miller (2018) discuss the issue that there are many instances where European names were initially assigned to North American taxa based on morphological similarities. However, North American strains could represent cryptic taxa native to this continent that should be described as separate species, particularly if supported by molecular findings. We assume that this type of work will be undertaken in the future. However, at present many species in this group have not been isolated *in vitro* and/or there are no herbarium samples that can be used for DNA extraction. Therefore, to move forward along these molecular lines, in many cases, new specimens must be collected for analyses.

In fact, many species of arthropod pathogenic Entomophthoromycotina found worldwide have not been isolated in culture, and sequences are not available for molecular identification. In nature, viable cells of these fungi are quite ephemeral, and it is therefore difficult to collect them for isolation. The exception to this would be cadavers bearing resting spores (azygospores or zygosporangia). However, resting spores are often not found or, if found, are dormant and difficult to either germinate or use for DNA extraction (but see Bidochka et al. 1995; Eilenberg and Jensen 2018; Hajek et al. 2018). The ARSEF collection has North American cultures or samples from 29 of the species included in this checklist (approximately 36%). We hope that this annotated checklist will make it more possible in the future for the culture and sequencing of additional species in North America.

Taxonomic changes in this group have been relatively frequent since the first publication on species of Entomophthoromycotina in the United States by Thaxter in 1888, referring to this group as the Entomophthoraeae. These taxonomic changes pose challenges for understanding whether names for host/fungus associations in the older literature are accurate today. For example, *E. muscae* is now known to be a species complex (Elya and De Fine Licht 2021), with one species named *E. muscae* s.s delimited within the complex. Therefore, for older records when *E. muscae* is mentioned, it is unclear which of the species in the complex is being discussed and how to apply historical findings to the modern circumscription of the species *E. muscae* itself. Therefore, since this checklist treats the three species of this species complex known from North America separately, the older reports of *E. muscae* have usually not been included in order not to introduce errors. The *Entomophaga grylli* species complex raised similar problems. Today, two members of this complex occur in North America, and older literature did not differentiate between them, with the result that older reports for collection locations could not be included.

Likewise, confusion has occurred with *Pandora neoaphidis*, for which the correct nomenclature was only resolved in 1980 (Barta and Cagáñ 2006). From 1888 (Thaxter) until 1980, in North America, *P. neoaphidis* was incorrectly known as *Empusa aphidis* and later *Entomophthora aphidis*. However, in 1980 *Entomophthora aphidis* was synonymized with *Zoophthora aphidis*, a species known only from relatively few host aphids in western and central Europe. We assume that records of *Empusa* or *Entomophthora aphidis* in North America before 1980 probably refer to *P. neoaphidis*, especially for collections from Maine, due to the common occurrence of *E. aphidis* and the presence of cultures of *P. neoaphidis* from Maine collected in 1972 and 1977 in the ARSEF collection (ARSEF 2020).

Our records of the distribution of fungal species are predominantly based on reports in the literature. The time of year, or even year of collection, is not always reported. Additionally, entomophthoralean fungi have been collected by only a handful of experts and remain vastly understudied across many locations in North America. Therefore, if a state or province is not listed, this is not definitive proof that a species is not present there, but rather this suggests that further surveys are necessary.

This annotated checklist provides data on these arthropod pathogens by connecting arthropod host species and fungal species at different locations within North America. Therefore, for each record, three specific pieces of information were needed: 1) host species, 2) fungal species, and 3) collection location. Unfortunately, some publications (although relatively few) did not provide separate data for these three metadata types and thus could not be included. Such problems arose with Remaudière et al. (1978), where all fungal pathogens and their aphid hosts were merged for one trip covering NH (US), and ON and QC (Canada). Similarly, we could not include data from Feng et al. (1990), in which data from collections of three species of aphid-pathogenic *Conidiobolus* species were merged so that locations and hosts of individual species were not listed (one of these species is now a *Batkoa*), or from Wraight et al. (1993), in which data for fungal infections of several cereal aphid species were merged.

Conclusion

In conclusion, we provide an updated checklist of arthropod pathogenic fungi in the Entomophthoromycotina detected in North America, using the latest taxonomy and largely based on published literature. While this checklist includes many more species than the last checklist (Hutchison 1963), there are still many arthropod-pathogenic species known from this subphylum (see Sacco and Hajek 2023) that have not been found in North America. Additional sampling is needed to determine if these are truly absent from the continent or await discovery as well as whether new discoveries await. Additionally, given the paucity of molecular data (De Fine Licht et al. 2016), sequencing of additional species from verified specimens, together with improved taxonomies, is an area of future research that will enhance DNA-based identification of these fungi. This updated checklist provides a framework for future efforts sampling and documenting the biodiversity of this important, yet understudied, group of fungi.

Acknowledgments

We thank Don Steinkraus, Jørgen Eilenberg, Bo Huang, Andrew Miller, Ibtissem Ben Fekih, Romina Manfrino, Kathie Hodge, and Jim Liebherr for assistance with entries in the checklist. We thank Siegfried Keller, Yong Nie, and an anonymous reviewer for their editorial assistance. We thank Konstanze Bensch and Paul Kirk for help with mycological nomenclatural rules. We also thank Allen Milby and Genevieve Tocci of the Farlow Herbarium at Harvard for help with a few specimens from Thaxter. Lovett and Bushley gratefully acknowledge USDA-ARS funding (Project Number: 8062-22410-007-000D), and Scott is supported under a 2024 USDA-ARS SCINet AI COE Postdoctoral Fellowship.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

This work was supported in part by Cornell University and by the U.S. Department of Agriculture, Agricultural Research Service.

Author contributions

Conceptualization: AEH. Data curation: AEH, KLS, CT, SSP. Formal analysis: AEH. Funding acquisition: KEB. Investigation: AEH, SSP, CT. Methodology: AEH. Project administration: AEH. Software: BL, KLS. Supervision: KEB, AEH. Validation: AEH. Visualization: KLS, BL. Writing - original draft: AEH. Writing - review and editing: CT, SSP, KLS, AEH, BL, KEB.

Author ORCIDs

Ann E. Hajek  <https://orcid.org/0000-0001-5740-4717>

Kelsey L. Scott  <https://orcid.org/0000-0003-1378-5348>

Sergio R. Sanchez-Peña  <https://orcid.org/0000-0002-1505-8657>

Cezary Tkaczuk  <https://orcid.org/0000-0002-4096-2154>

Brian Lovett  <https://orcid.org/0000-0002-5721-7695>

Kathryn E. Bushley  <https://orcid.org/0000-0002-9083-8602>

Data availability

All of the data that support the findings of this study are available in the main text.

References

- Anderson JF, Magnarelli LA (1979) *Entomophthora tabanivora*, a new pathogen in horseflies (Diptera, Tabanidae). *Journal of Invertebrate Pathology* 34(3): 263–266. [https://doi.org/10.1016/0022-2011\(79\)90072-7](https://doi.org/10.1016/0022-2011(79)90072-7)
- Anderson JF, Ringo SL (1969) *Entomophthora aquatica* sp. n. infecting larvae and pupae of floodwater mosquitoes. *Journal of Invertebrate Pathology* 13(3): 386–393. [https://doi.org/10.1016/0022-2011\(69\)90191-8](https://doi.org/10.1016/0022-2011(69)90191-8)
- Andreadis TG, Magnarelli LA (1983) *Erynia aquatica* in a salt-marsh mosquito, *Aedes cantator*. *Journal of Invertebrate Pathology* 42(2): 277–279. [https://doi.org/10.1016/0022-2011\(83\)90073-3](https://doi.org/10.1016/0022-2011(83)90073-3)
- ARSEF [USDA, Agricultural Research Service, Collection of Entomopathogenic Fungal Cultures] (2020) Entomophthorales. https://www.ars.usda.gov/ARSUserFiles/80620520/Entomophthorales_June2020.pdf [accessed 10 August 2023]
- Avery M, Post E (2013) Record of a *Zoopthora* sp. (Entomophthoromycota, Entomophthorales) pathogen of the irruptive noctuid moth *Eurois occulta* (Lepidoptera) in West Greenland. *Journal of Invertebrate Pathology* 114(3): 292–294. <https://doi.org/10.1016/j.jip.2013.09.005>
- Bałaży S (1993) Entomophthorales. *Flora of Poland. Fungi (Mycota)*, Vol. 24. Polish Academy of Sciences, Kraków, 356 pp.

- Barta M, Cagán L (2006) Aphid-pathogenic Entomophthorales (their taxonomy, biology and ecology). *Biologia* 61(Suppl 21): S543–S616. <https://doi.org/10.2478/s11756-007-0100-x>
- Barta M, Keller S, Cate P, Wegensteiner R (2005) Observations on the occurrence of Entomophthorales in Austria. *IOBC/WPRS Bulletin* 28(3): 49–52.
- Bates ST, Miller AN (2018) The protochecklist of North American nonlichenized Fungi. *Mycologia* 110(6): 1222–1348. <https://doi.org/10.1080/00275514.2018.1515410>
- Ben-Ze'ev IS (1993) Check-list of fungi pathogenic to insects and mites in Israel, updated through 1992. *Phytoparasitica* 21(3): 213–237. <https://doi.org/10.1007/BF02980944>
- Bidochka MJ, Walsh SRA, Ramos ME, St. Leger RJ, Silver JC, Roberts DW (1995) Pathotypes of the *Entomophaga grylli* species complex of grasshopper pathogens differentiated with random amplification of polymorphic DNA and cloned-DNA probes. *Applied and Environmental Microbiology* 61(2): 556–560. <https://doi.org/10.1128/aem.61.2.556-560.1995>
- Bidochka MJ, Walsh SRA, Ramos ME, St. Leger RJ, Silver JC, Roberts DW (1996) Fate of biological control introductions: Monitoring an Australian fungal pathogen of grasshoppers in North America. *Proceedings of the National Academy of Sciences of the United States of America* 93(2): 918–921. <https://doi.org/10.1073/pnas.93.2.918>
- Billings FH, Glenn PA (1911) Results of the artificial use of the white-fungus disease in Kansas: With notes on approved methods of fighting chinch bugs. US Department of Agriculture, Bureau of Entomology, Bulletin 107: 1–15 pp. <https://doi.org/10.5962/bhl.title.37201>
- Boyce GR, Gluck-Thaler E, Slot JC, Stajich JE, Davis WJ, James TY, Cooley JR, Panaccione DG, Eilenberg J, De Fine Licht H, Macias AM, Berger MC, Wickert KL, Stauder CM, Spahr EJ, Maust MD, Metheny AM, Simon C, Kritsky G, Hodge KT, Humber RA, Gullion T, Short DPG, Kijimoto T, Mozgai D, Arguedas N, Kasson MT (2019) Psychoactive plant- and mushroom-associated alkaloids from two behavior modifying cicada pathogens. *Fungal Ecology* 41: 147–164. <https://doi.org/10.1016/j.funeco.2019.06.002>
- Boyd KS, Drummond F, Donahue C, Groden E (2021) Factors influencing the population fluctuations of *Euproctis chrysorrhoea* (Lepidoptera, Erebidae) in Maine. *Environmental Entomology* 50(5): 1203–1206. <https://doi.org/10.1093/ee/nvab060>
- Bucher GE, MacLeod DM (1974) Rediscovery of *Tarichium megaspermum* (Entomophthoraceae) in Canadian cutworms (Noctuidae). *Journal of Invertebrate Pathology* 23(2): 157–163. [https://doi.org/10.1016/0022-2011\(74\)90179-7](https://doi.org/10.1016/0022-2011(74)90179-7)
- Burger GF, Swain AF (1918) Observations on a fungus enemy of the walnut aphid in southern California. *Journal of Economic Entomology* 11(3): 278–288. <https://doi.org/10.1093/jee/11.3.278>
- Carner GR (1980) *Eryniopsis lampyridarum*, a fungal pathogen of the soldier beetle, *Chauliognathus pennsylvanicus*. *Journal of Invertebrate Pathology* 36(3): 394–398. [https://doi.org/10.1016/0022-2011\(80\)90044-0](https://doi.org/10.1016/0022-2011(80)90044-0)
- Casique-Valdes R, Sanchez-Peña S, Torres-Acosta RI, Bidochka MJ (2012) A PCR-based method to identify *Entomophaga* spp. infections in North American grasshoppers. *Journal of Invertebrate Pathology* 109(1): 169–171. <https://doi.org/10.1016/j.jip.2011.11.009>
- Casique-Valdés R, Torres-Acosta RI, Sánchez-Peña SR (2022) *Metarhizium acridum* and other entomopathogenic fungi from grasshoppers at arid sites in north-eastern Mexico. *The Southwestern Entomologist* 47(3): 547–448. <https://doi.org/10.3958/059.047.0302>
- Castrillo LA, Harris-Shultz K (2024) Entomophthoralean and hypocrealean fungal pathogens of the sugarcane aphid, *Melanaphis sacchari* (Hemiptera, Aphididae),

- on sorghum in Georgia. *Journal of Invertebrate Pathology* 204: 108157. <https://doi.org/10.1016/j.jip.2024.108107>
- Charles V (1941) A preliminary check list of entomogenous fungi of North America. USDA Bureau of Entomology and Plant Quarantine, *Insect Pest Survey Bulletin* 21(Supplement 9): 707–785.
- Christie GD (1996) *Erynia aquatica*, a fungal disease of immature mosquitoes identified from a woodland pool in Bristol, Rhode Island. In: Proceedings of the Northeastern Mosquito Control Association, 42nd Annual Meeting, Mystic, Connecticut, USA, December 1996. <http://www.nmca.org/paper20a.htm>
- Clifton EH, Castrillo LA, Gryganskyi A, Hajek AE (2019) A pair of native fungal pathogens drives decline of a new invasive herbivore. *Proceedings of the National Academy of Sciences of the United States of America* 116(19): 9178–9180. <https://doi.org/10.1073/pnas.1903579116>
- Cuebas-Incle EL (1992) Infection of adult mosquitoes by the entomopathogenic fungus *Erynia conica* (Entomophthorales, Entomophthoraceae). *Journal of the American Mosquito Control Association* 8: 367–371.
- Dara SK (2017) *Entomophthora planchoniana* infecting the strawberry aphid, *Chaetosiphon fragaefolii* in California. *E-journal of Entomology and Biologicals*. <https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=25256>
- Dara SK, Semtner PJ (2001) Incidence of *Pandora neoaphidis* (Rem. et Henn.) Humber (Zygomycetes, Entomophthorales) in the *Myzus persicae* Sulzer complex (Homoptera, Aphididae) on three species of *Brassica* in the fall and winter. *Journal of Entomological Science* 36(2): 152–161. <https://doi.org/10.18474/0749-8004-36.2.152>
- de Bekker C, Beckerson WC, Elya C (2021) Mechanisms behind the madness: How do zombie-making fungal entomopathogens affect host behavior to increase transmission? *mBio* 12(5): e01872-21. <https://doi.org/10.1128/mBio.01872-21>
- De Fine Licht HH, Hajek AE, Jensen AB, Eilenberg J (2016) Utilizing genomics to study entomopathogenicity in the fungal phylum *Entomophthoromycota*: A review of current genetic resources. *Advances in Genetics* 94: 41–65. <https://doi.org/10.1016/bs.adgen.2016.01.003>
- Dick GL, Buschman LL (1995) Seasonal occurrence of a fungal pathogen, *Neozygites adjarica* (Entomophthorales, Neozygitaceae), infecting Banks grass mites, *Oligonychus pratensis*, and two-spotted spider mites, *Tetranychus urticae* (Acari, Tetranychidae), in field corn. *Journal of the Kansas Entomological Society* 68: 425–436.
- Dubiel G (2016) Preliminary data on the occurrence of *Entomophthorales* in Beskid Śląski Mts. *Nature Review* 27(3): 56–69. [Przegląd Przyrodniczy]
- Dustan AG (1924) Studies on a new species of *Empusa* parasitic on the green apple bug (*Lygus communis* var. *novascotiensis* Knight) in the Annapolis Valley. *Proceedings of the Acadian Entomological Society for 1923*(9): 14–36.
- Eilenberg J, Jensen AB (2018) Strong host specialization in fungus genus *Strongwellsea* (Entomophthorales). *Journal of Invertebrate Pathology* 157: 112–116. <https://doi.org/10.1016/j.jip.2018.08.007>
- Ekbom BS, Pickering J (1990) Pathogenic fungal dynamics in a fall population of the blackmargined aphid (*Monellia caryella*). *Entomologia Experimentalis et Applicata* 57(1): 29–37. <https://doi.org/10.1111/j.1570-7458.1990.tb01413.x>
- Elkassabany NM, Steinkraus DC, McLeod PJ, Correll JC, Morelock TE (1992) *Pandora neoaphidis* (Entomophthorales, Entomophthoraceae): A potential biological control agent against *Myzus persicae* (Homoptera, Aphididae) on spinach. *Journal of the Kansas Entomological Society* 65(2): 196–199.

- Elya C, De Fine Licht HH (2021) The genus *Entomophthora*: Bringing the insect destroyers into the twenty-first century. *IMA Fungus* 12(1): 34. <https://doi.org/10.1186/s43008-021-00084-w>
- Elya C, Lok TC, Spencer QE, McCausland H, Martinez CC, Eisen M (2018) Robust manipulation of the behavior of *Drosophila melanogaster* by a fungal pathogen in the laboratory. *eLife* 7: e34414. <https://doi.org/10.7554/eLife.34414>
- Erlandson MA, Johnson DL, Olfert OO (1988) *Entomophaga grylli* (Fresenius) infections in grasshopper (Orthoptera, Acrididae) populations in Saskatchewan and Alberta, 1985–1986. *Canadian Entomologist* 120(3): 205–209. <https://doi.org/10.4039/Ent120205-3>
- Feng M-G, Johnson JB, Kish LP (1990) Survey of entomopathogenic fungi naturally infecting cereal aphids (Homoptera, Aphididae) of irrigated grain crops in southwestern Idaho. *Environmental Entomology* 19(5): 1534–1542. <https://doi.org/10.1093/ee/19.5.1534>
- Feng M-G, Nowierski RM, Scharen AL, Sands DC (1991) Entomopathogenic fungi (Zygomycotina, Entomophthorales) infecting cereal aphids (Homoptera, Aphididae) in Montana. *The Pan-Pacific Entomologist* 7: 55–64.
- Filotas MJ, Hajek AE, Humber RA (2003) Prevalence and biology of *Furia gastropachae* (Zygomycetes, Entomophthorales) in populations of the forest tent caterpillar (Lepidoptera, Lasiocampidae). *Canadian Entomologist* 135(3): 359–378. <https://doi.org/10.4039/n02-004>
- Folsom JW (1909) The insect pests of clover and alfalfa. University of Illinois Agricultural Experiment Station Bulletin 134: 113–197.
- FPMI (Forestry Canada, Forest Pest Management Institute) (1990). Culture catalogue: entomopathogenic fungi. Forest Pest Management Institute, Sault Ste. Marie, Ontario, Canada.
- Galligan LD (2007) Interactions of the soybean aphid, cotton aphid, and tulip tree aphid with entomophthoralean fungi in the genus *Neozygites*. MS thesis, University Arkansas, Fayetteville, Arkansas, USA.
- Gillette CP (1888) Chinch bug diseases. Bulletin of the Experiment Station of Iowa at the State Agricultural College, Ames, Iowa 3: 57–62.
- Gilliatt FC (1925) Some new and unrecorded notes on the life history of *Entomophthora sphaerosperma*. *Proceedings of the Acadian Entomological Society for 1924*(10): 14–36.
- Gilreath ME, McCutcheon GS, Carner GR, Turnipseed SG (1986) Pathogen incidence in noctuid larvae from selected soybean genotypes. *Journal of Agricultural Entomology* 3: 213–226.
- Glare TR, Milner RJ (1987) New records of entomophthoran fungi from insects in Australia. *Australian Journal of Botany* 35(1): 69–77. <https://doi.org/10.1071/BT9870069>
- Gryganskyi AP, Humber RA, Stajich JE, Mullens B, Anishchenko IM, Vilgalys R (2013) Sequential utilization of hosts from different fly families by genetically distinct, sympatric populations within the *Entomophthora muscae* species complex. *PLoS ONE* 8(8): e71168. <https://doi.org/10.1371/journal.pone.0071168>
- Gryganskyi AP, Golan J, Hajek AE (2022a) Season-long infection of diverse hosts by the entomopathogenic fungus *Batkoa major*. *PLoS ONE* 17(5): e0261912. <https://doi.org/10.1371/journal.pone.0261912>
- Gryganskyi AP, Nie Y, Hajek AE, Hodge KT, Liu XY, Aadland K, Voigt K, Anishchenko IM, Kutovenko VB, Kava L, Vuck A, Vilgalys R, Huang B, Stajich JE (2022b) Early terrestrial fungal lineage of *Conidiobolus* – transition from saprotroph to parasitic lifestyle. *Journal of Fungi* 8(8): 789. <https://doi.org/10.3390/jof8080789>

- Gustafsson M (1965) On species of the genus *Entomophthora* Fres. in Sweden. I. Classification and distribution. *Lantbrukshogskolans Annaler* 31: 103–212.
- Guzmán G, Alcocer-Gómez L (1972) Un hongo de importancia biológica en México, *Entomophthora coronata*. *Boletín de la Sociedad Mexicana de Micología* 6: 5–7. <https://doi.org/10.33885/sf.1972.2.406>
- Hajek AE, Humber RA, Elkinton JS, May B, Walsh SRA, Silver JC (1990) Allozyme and RFLP analyses confirm *Entomophaga maimaiga* responsible for 1989 epizootics in North American gypsy moth populations. *Proceedings of the National Academy of Sciences of the United States of America* 87: 6979–6982. <https://doi.org/10.1073/pnas.87.18.6979>
- Hajek AE, Humber RA, Walsh SRA, Silver JC (1991) Sympatric occurrence of two *Entomophaga aulicae* (Zygomycetes, Entomophthorales) complex species attacking forest Lepidoptera. *Journal of Invertebrate Pathology* 58(3): 373–380. [https://doi.org/10.1016/0022-2011\(91\)90183-Q](https://doi.org/10.1016/0022-2011(91)90183-Q)
- Hajek AE, Hodge KT, Lieberr JK, Day WH, Vandenberg JD (1995) Use of RAPD analysis to trace the origin of the weevil pathogen *Zoophthora phytonomi* in North America. *Mycological Research* 100(3): 349–355. [https://doi.org/10.1016/S0953-7562\(96\)80168-7](https://doi.org/10.1016/S0953-7562(96)80168-7)
- Hajek AE, Butler L, Walsh SRA, Silver JC, Hain FP, Hastings FL, O'Dell TM, Smitley DR (1996a) Host range of the gypsy moth (Lepidoptera, Lymantriidae) pathogen *Entomophaga maimaiga* (Zygomycetes, Entomophthorales) in the field versus laboratory. *Environmental Entomology* 25(4): 709–721. <https://doi.org/10.1093/ee/25.4.709>
- Hajek AE, Walsh SRA, Silver JC, Strong DR (1996b) A disjunct Californian strain of *Entomophaga aulicae* infecting *Orygia vetusta*. *Journal of Invertebrate Pathology* 68(3): 260–268. <https://doi.org/10.1006/jipa.1996.0094>
- Hajek AE, Butler L, Lieberr JK, Wheeler MM (2000) Risk of infection by the fungal pathogen *Entomophaga maimaiga* among Lepidoptera on the forest floor. *Environmental Entomology* 29(3): 645–650. <https://doi.org/10.1603/0046-225X-29.3.645>
- Hajek AE, Strazanac JS, Wheeler MM, Vermeylen F, Butler L (2004) Persistence of the fungal pathogen *Entomophaga maimaiga* and its impact on native Lymantriidae. *Biological Control* 30(2): 466–471. <https://doi.org/10.1016/j.biocontrol.2004.02.005>
- Hajek AE, Gryganskyi A, Bittner T, Lieberr JK, Lieberr JH, Moulton JK, Jensen AB, Humber RA (2016) Phylogenetic placement of two species known only from resting spores: *Zoophthora independentia* sp. nov. and *Z. porteri* comb nov. (Entomophthorales, Entomophthoraceae). *Journal of Invertebrate Pathology* 140: 68–74. <https://doi.org/10.1016/j.jip.2016.09.002>
- Hajek AE, Steinkraus DC, Castrillo LA (2018) Sleeping beauties: Horizontal transmission by entomophthoralean fungi via resting spores. *Insects* 9(3): 102. <https://doi.org/10.3390/insects9030102>
- Hajek AE, Diss-Torrance AL, Siegert NW, Liebhold AM (2021) Inoculative releases and natural spread of the fungal pathogen, *Entomophaga maimaiga* (Entomophthorales, Entomophthoraceae), into U.S. gypsy moth (Lepidoptera, Erebidiae) populations. *Environmental Entomology* 50: 1007–1015. <https://doi.org/10.1093/ee/nvab068>
- Hajek AE, Gryganskyi AP, Gouli SY, Bittner TD, Sullivan CF, Parker BL (2024a) Reassessing the diversity of the arthropod-pathogenic genus *Pandora* Batko (Entomophthoromycotina, Erynioideae). *Diversity* 16(10): 603. <https://doi.org/10.3390/d16100603>
- Hajek AE, Lieberr JK, Keller S (2024b) The first New World records of *Zoophthora rhagonycharum* (Zoopagomycota, Entomophthorales) infecting *Rhagonycha* spp. (Coleoptera, Cantharidae). *Check List* 20(1): 144–151. <https://doi.org/10.15560/20.1.144>

- Hall IM (1959) The fungus *Entomophthora erupta* (Dustan) attacking the black grass bug, *Irbisia solani* (Heidemann) (Hemiptera, Miridae), in California. *Journal of Insect Pathology* 1: 48–51.
- Hamm JJ (1980) Epizootics of *Entomophaga aulicae* in lepidopterous pests of sorghum. *Journal of Invertebrate Pathology* 36(1): 60–63. [https://doi.org/10.1016/0022-2011\(80\)90136-6](https://doi.org/10.1016/0022-2011(80)90136-6)
- Hannam JJ, Steinkraus DC (2010) The natural occurrence of *Pandora heteropterae* (Zygomycetes, Entomophthorales) infecting *Lygus lineolaris* (Hemiptera, Miridae). *Journal of Invertebrate Pathology* 103(2): 96–102. <https://doi.org/10.1016/j.jip.2009.11.002>
- Harper JD, Carner GR (1973) Incidence of *Entomophthora* sp. and other natural control agents in populations of *Pseudoplusia includens* and *Trichoplusia ni*. *Journal of Invertebrate Pathology* 22(1): 80–85. [https://doi.org/10.1016/0022-2011\(73\)90014-1](https://doi.org/10.1016/0022-2011(73)90014-1)
- Harris MR (1948) A phycomycete parasitic on aphids. *Phytopathology* 38: 118–122.
- Hitchings EF (1908) Brown-tail fungous work. 3rd Annual Report of the State Entomologist on the gipsy and brown-tail moths and other insect pests of the State of Maine, 20.
- Hodge KT, Hajek AE, Gryganskyi A (2017) The first entomophthoralean killing millipedes, *Arthropaga myriapodina* n. gen. n. sp., causes climbing before host death. *Journal of Invertebrate Pathology* 149: 135–140. <https://doi.org/10.1016/j.jip.2017.08.011>
- Humber RA (1976) The systematics of the genus *Strongwellsea* (Zygomycetes, Entomophthorales). *Mycologia* 68(5): 1042–1060. <https://doi.org/10.1080/00275514.1976.12019987>
- Humber RA (1989) Synopsis of a revised classification for the Entomophthorales (Zygomycotina). *Mycotaxon* 34: 441–460.
- Humber RA, Feng MG (1991) *Entomophthora chromaphidis* (Entomophthorales): The correct identification of an aphid pathogen in the Pacific northwest and elsewhere. *Mycotaxon* 41: 497–504.
- Hutchison JA (1962) Studies of a new *Entomophthora* attacking calyprate flies. *Mycologia* 54(3): 258–271. <https://doi.org/10.1080/00275514.1962.12024999>
- Hutchison JA (1963) The genus *Entomophthora* in the Western Hemisphere. *Transactions of the Kansas Academy of Science* 66(2): 237–254. <https://doi.org/10.2307/3626563>
- Jensen AB, Eilenberg J, Thomsen L (2006) Value of host range, morphological, and genetic characteristics within the *Entomophthora muscae* species complex. *Mycological Research* 110(8): 941–950. <https://doi.org/10.1016/j.mycres.2006.06.003>
- Kalkar O, Carner GR (2005) Characterization of the fungal pathogen, *Entomophaga aulicae* (Zygomycetes, Entomophthorales) in larval populations of the green cloverworm, *Plathypena scabra* (Lepidoptera, Noctuidae). *Turkish Journal of Biology* 29: 243–248.
- Keller S (1991) Arthropod-pathogenic Entomophthorales of Switzerland. II. *Erynia*, *Eryniopsis*, *Neozygites*, *Zoophthora* and *Tarichium*. *Sydowia* 43: 39–122.
- Keller S (2008) The arthropod-pathogenic Entomophthorales from Switzerland – Is central Europe the centre of their global species-richness? *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 81: 39–51. <https://doi.org/10.5169/seals-402957>
- Kirkland AH (1906) Report on some fungous parasites of the brown-tail moth. *First Annual Report of the Superintendent for Suppressing the Gypsy and Brown-tail Moths*, Wright & Potter, Boston, MA, 128–133.
- Kish LP, Allen GE, Kimbrough JW, Kuitert LC (1974) A survey of fungi associated with the lovebug, *Plecia nearctica*, in Florida. *The Florida Entomologist* 57(3): 281–284. <https://doi.org/10.2307/3493260>

- Kish LP, Majchrowicz I, Biever KD (1994) Prevalence of natural fungal mortality of green peach aphid (Homoptera, Aphididae) on potatoes and nonsolanaceous hosts in Washington and Idaho. *Environmental Entomology* 23(5): 1326–1330. <https://doi.org/10.1093/ee/23.5.1326>
- Kistner EJ, Belovsky GE (2013) Susceptibility to disease across developmental stages: Examining the effects of an entomopathogen on a grasshopper (Orthoptera, Acrididae) pest. *Journal of Orthoptera Research* 22(2): 73–77. <https://doi.org/10.1665/034.022.0206>
- Klein MG, Coppel HC (1973) *Entomophthora tenthredinis*, a fungal pathogen of the introduced pine sawfly in northwestern Wisconsin. *Annals of the Entomological Society of America* 66(5): 1178–1180. <https://doi.org/10.1093/aesa/66.5.1178>
- Klingen I, Haukeland S, Meadow R (2002) Checklist of naturally occurring pathogens of insects and mites in Norway. *Norwegian Journal of Entomology* 49: 23–28.
- Knoll JN (1932) Observations on three important forest insects. *Journal of Economic Entomology* 25(6): 1106–1203. <https://doi.org/10.1093/jee/25.6.1196>
- Kramer JP (1979) Interactions between blow flies (Calliphoridae) and *Entomophthora bullata* (Phycomycetes, Entomophthorales). *Journal of the New York Entomological Society* 87: 135–140.
- Kramer JP (1980) *Entomophthora sepulchralis* Thaxter (Entomophthoraceae): Its rediscovery and experimentally induced infections in muscoid flies. *Mycopathologia* 70(3): 163–167. <https://doi.org/10.1007/BF00443027>
- Kramer JP (1981a) A mycosis of the blood-sucking snipe fly *Symphoromyia hirta* caused by *Erynia ithacensis* sp.n. (Entomophthoraceae). *Mycopathologia* 75(3): 159–164. <https://doi.org/10.1007/BF00482810>
- Kramer JP (1981b) On adult midges (Chironomidae) as victims of the fungal pathogen *Entomophthora culicis* (Entomophthoraceae). *Aquatic Insects* 3(2): 99–102. <https://doi.org/10.1080/01650428109361053>
- Kramer JP (1983) A mycosis of the black fly *Simulium decorum* (Simuliidae) caused by *Erynia curvispora* (Entomophthoraceae). *Mycopathologia* 82(1): 39–43. <https://doi.org/10.1007/BF00436944>
- Li Z, Humber RA (1984) *Erynia pieris* (Zygomycetes, Entomophthoraceae), a new pathogen of *Pieris rapae* (Lepidoptera, Pieridae): Description, host range, and notes on *Erynia virescens*. *Canadian Journal of Botany* 62(4): 653–663. <https://doi.org/10.1139/b84-098>
- Lopes Ribeiro AE, Corrêa Gondim Jr MG, Calderan E, Delalibera Jr I (2009) Host range of *Neozygites floridana* isolates (Zygomycetes, Entomophthorales) to spider mites. *Journal of Invertebrate Pathology* 102(3): 196–202. <https://doi.org/10.1016/j.jip.2009.08.012>
- López Lastra CC, Manfrino RG, Toledo AV, Gutierrez AC, Mendiburo M (2019) Updated checklist of Entomophthoralean fungi from Argentina. Society for Invertebrate Pathology/International Organization for Biological Control Meeting, Valencia, Spain. Programme and Abstracts, 43.
- Macias AM, Geiser DM, Stajich JE, Łukasik P, Veloso C, Bublitz DC, Berger MC, Boyce GR, Hodge K, Kasson MT (2020) Evolutionary relationships among *Massospora* spp. (Entomophthorales), obligate pathogens of cicadas. *Mycologia* 112(6): 1060–1074. <https://doi.org/10.1080/00275514.2020.1742033>
- MacLeod DM, Müller-Kögler E (1973) Entomogenous fungi: *Entomophthora* species with pear-shaped to almost spherical conidia (Entomophthorales, Entomophthoraceae). *Mycologia* 64(4): 823–893. <https://doi.org/10.1080/00275514.1973.12019497>

- MacLeod DM, Tyrrell D, Soper RS, De Lyzer AJ (1973) *Entomophthora bullata* as a pathogen of *Sarcophaga aldrichi*. *Journal of Invertebrate Pathology* 22(1): 75–79. [https://doi.org/10.1016/0022-2011\(73\)90013-X](https://doi.org/10.1016/0022-2011(73)90013-X)
- MacLeod DM, Tyrrell D, Soper RS (1979) *Entomophthora canadensis* n.sp., a fungus pathogenic on the woolly pine needle aphid, *Schizolachnus piniradiatae*. *Canadian Journal of Botany* 57(23): 2663–2672. <https://doi.org/10.1139/b79-316>
- Matanmi BA, Libby JL, Maxwell DP (1974) Two Phycomycetes infecting root maggot adults in Wisconsin. *Environmental Entomology* 3(6): 1030–1031. <https://doi.org/10.1093/ee/3.6.1030>
- McGuire MR, Morris MJ, Armbrust EJ, Maddox JV (1987) An epizootic caused by *Erynia radicans* (Zygomycetes, Entomophthoraceae) in an Illinois *Empoasca fabae* (Homoptera, Cicadellidae) population. *Journal of Invertebrate Pathology* 50(1): 78–80. [https://doi.org/10.1016/0022-2011\(87\)90151-0](https://doi.org/10.1016/0022-2011(87)90151-0)
- McNeil JN, MacLeod DM (1982) Two species of fungus infecting the European skipper *Thymelicus lineola* (Lepidoptera, Hesperidae) in Quebec. *Canadian Entomologist* 114(1): 87–88. <https://doi.org/10.4039/Ent11487-1>
- Miller MK, Harper JD (1987) Occurrence of *Erynia delphacis* in the threecornered alfalfa hopper, *Spissistilus festinus* (Homoptera, Membracidae). *Journal of Invertebrate Pathology* 50(1): 81–83. [https://doi.org/10.1016/0022-2011\(87\)90152-2](https://doi.org/10.1016/0022-2011(87)90152-2)
- Miller MW, Keil CB (1990) Redescription of *Pandora gloeospora* (Zygomycetes, Entomophthorales) from *Lycoriella mali* (Diptera, Sciaridae). *Mycotaxon* 38: 227–231.
- Milner RJ, Soper RS (1981) Bioassay of *Entomophthora* against the spotted alfalfa aphid *Therioaphis trifolii* f. *maculata*. *Journal of Invertebrate Pathology* 37(2): 168–173. [https://doi.org/10.1016/0022-2011\(81\)90071-9](https://doi.org/10.1016/0022-2011(81)90071-9)
- Mitchell JD (1919) Notes on *Diacrisia virginica* (Lep.). *Entomological News* 30(7): 191–194.
- Molloy D, Wraight SP (1982) Rediscovery of *Erynia aquatica* (Entomophthoraceae) in snowpool mosquitoes. *Journal of Invertebrate Pathology* 40(1): 142–145. [https://doi.org/10.1016/0022-2011\(82\)90044-1](https://doi.org/10.1016/0022-2011(82)90044-1)
- Mużenko W, Majewski T, Ruskiewicz-Michalska M [Eds] (2008) A preliminary checklist of micromycetes in Poland. In: Mirek Z (Ed.) *Biodiversity of Poland*, Vol.9. W Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
- Mullens BA, Pechuman LL, Rutz DA (1983) A second finding of *Entomophthora tabanivora* and observations of *Atylotus thoracicus* (Diptera, Tabanidae). *Journal of Invertebrate Pathology* 42(2): 270–272. [https://doi.org/10.1016/0022-2011\(83\)90071-X](https://doi.org/10.1016/0022-2011(83)90071-X)
- MyCoPortal (2024) MyCoPortal. <http://www.mycportal.org/portal/index.php> [Accessed April 13, 2024]
- Nadeau MP, Dunphy GB, Boisvert JL (1994) Entomopathogenic fungi of the order Entomophthorales (Zygomycotina) in black fly populations (Diptera, Simuliidae) in Quebec. *Canadian Journal of Microbiology* 40(8): 682–686. <https://doi.org/10.1139/m94-108>
- Nair KSS, McEwen FL (1973) *Strongwellsea castrans* (Phycomycetes, Entomophthoraceae), a fungal parasite of the adult cabbage maggot, *Hylemya brassicae* (Diptera, Anthomyiidae). *Journal of Invertebrate Pathology* 22(3): 442–449. [https://doi.org/10.1016/0022-2011\(73\)90175-4](https://doi.org/10.1016/0022-2011(73)90175-4)
- Naranjo SE, Steinkraus DC (1988) Discovery of an entomophthoralean fungus (Zygomycetes, Entomophthorales) infecting adult northern corn rootworm, *Diabrotica barberi* (Coleoptera, Chrysomelidae). *Journal of Invertebrate Pathology* 51(3): 298–300. [https://doi.org/10.1016/0022-2011\(88\)90042-0](https://doi.org/10.1016/0022-2011(88)90042-0)

- Nealis VG, Roden PM, Ortiz DA (1999) Natural mortality of the gypsy moth along a gradient of infestation. *Canadian Entomologist* 131(4): 507–519. <https://doi.org/10.4039/Ent131507-4>
- Newman GG, Carner GR (1975) Factors affecting the spore form of *Entomophthora gammae*. *Journal of Invertebrate Pathology* 26(1): 29–34. [https://doi.org/10.1016/0022-2011\(75\)90165-2](https://doi.org/10.1016/0022-2011(75)90165-2)
- Niell M, Santamaria S (2001) Additions to the knowledge of entomopathogenic Entomophthorales (Fungi, Zygomycota) from Spain. *Nova Hedwigia* 73(1–2): 167–197. <https://doi.org/10.1127/nova.hedwigia/73/2001/167>
- Nielsen C, Hajek AE (2005) Control of invasive soybean aphid, *Aphis glycines* (Hemiptera, Aphididae) populations by existing natural enemies in New York State. *Environmental Entomology* 34: 1036–1047. <https://doi.org/10.1093/ee/34.5.1036>
- Nielsen C, Sommer C, Eilenberg J, Hansen KS, Humber RA (2001) Characterization of aphid pathogenic species in the genus *Pandora* by PCR techniques and digital image analysis. *Mycologia* 93(5): 864–874. <https://doi.org/10.1080/00275514.2001.12063221>
- Nielsen C, Milgroom MG, Hajek AE (2005) Genetic diversity in the gypsy moth fungal pathogen *Entomophaga maimaiga* from founder populations in North America and source populations in Asia. *Mycological Research* 109(8): 941–950. <https://doi.org/10.1017/S0953756205003278>
- Otvos IS, MacLeod DM, Tyrrell C (1973) Two species of *Entomophthora* pathogenic to the eastern hemlock looper (Lepidoptera, Geometridae) in Newfoundland. *Canadian Entomologist* 105(11): 1435–1441. <https://doi.org/10.4039/Ent1051435-11>
- Pell J, Eilenberg J, Hajek AE, Steinkraus DC (2001) Biology, ecology and pest management potential of Entomophthorales. In: Butt TM, Jackson CW, Magan N (Eds) *Fungi as biocontrol agents: progress, problems and potential*. CABI Publishing, Wallingford, UK, 71-153. <https://doi.org/10.1079/9780851993560.0071>
- Pickering J, Gutierrez AP (1991) Differential impact of the pathogen *Pandora neoaphidis* (R. & H.) Humber (Zygomycetes, Entomophthorales) on the species composition of *Acyrtosiphon* aphids in alfalfa. *Canadian Entomologist* 123(2): 315–320. <https://doi.org/10.4039/Ent123315-2>
- Pickering J, Dutcher JD, Ekbohm BS (1989) An epizootic by *Erynia neoaphidis* and *E. radicans* (Zygomycetes, Entomophthoraceae) on *Acyrtosiphon pisum* (Hom., Aphididae) on legumes under overhead irrigation. *Journal of Applied Entomology* 107(1–5): 331–333. <https://doi.org/10.1111/j.1439-0418.1989.tb00265.x>
- Pickett CH, Gilstrap FE (1986) Natural enemies associated with spider mites (Acari: Tetranychidae) infecting corn in the High Plains region of Texas. *Journal of the Kansas Entomological Society* 59: 524–536.
- Remaudière G, Latgé J-P (1985) Importancia de los hongos patógenos de insectos (especialmente Aphididae y Cercopidae) en México y perspectivas de uso. *Boletín del Servicio del Defensa contra Plagas e Inspección Fitopatológica* 11: 217-225. [In Spanish]
- Remaudière G, Latgé J-P, Smirnoff WA (1978) Considérations écologiques sur quelques Entomophthorales pathogènes d'aphides communes dans l'est des U.S.A. et du Canada. *Phytoprotection* 59: 150–156.
- Robert V, Stegehuis G, Stalpers J (2005) The MycoBank engine and related databases. www.mycobank.org
- Rockwood LP (1950) Entomogenous fungi of the family Entomophthoraceae in the Pacific Northwest. *Journal of Economic Entomology* 43(5): 704–707. <https://doi.org/10.1093/jee/43.5.704>

- Sacco NE, Hajek AE (2023) Diversity and breadth of host specificity among arthropod pathogens in the Entomophthoromycotina. *Microorganisms* 11(7): 1658. <https://doi.org/10.3390/microorganisms11071658>
- Sanchez-Peña SR (1990) Some insect and spider pathogenic fungi from Mexico with data on their host ranges. *The Florida Entomologist* 73(3): 517–522. <https://doi.org/10.2307/3495473>
- Sanchez-Peña SR (1993) Entomogenous fungi associated with the cotton aphid in the Texas High Plains. *Southwestern Entomologist* 18: 69–71.
- Sanchez-Peña SR (2000) Entomopathogens from two Chihuahuan desert localities in Mexico. *BioControl* 45(1): 63–78. <https://doi.org/10.1023/A:1009915308907>
- Sawyer WH (1933) The development of *Entomophthora sphaerosperma* upon *Rhopobota vacciniana*. *Annals of Botany* 47(188): 799–809. <https://doi.org/10.1093/oxford-journals.aob.a090416>
- Shands WA, Hall IM, Simpson GW (1962) Entomophthoraceous fungi attacking the potato aphid in northeastern Maine in 1960. *Journal of Economic Entomology* 55(2): 174–179. <https://doi.org/10.1093/jee/55.2.174>
- Shands W, Simpson GW, Hall IM, Gordon CC (1972) Further evaluation of entomogenous fungi as a biological agent of aphid control in northeastern Maine. *Maine Life Science and Agriculture Experiment Station Technical Bulletin* 58, 33 pp.
- Shemanchuk JA, Humber RA (1978) *Entomophthora culicis* (Phycomycetes, Entomophthorales) parasitizing black fly adults (Diptera, Simuliidae) in Alberta. *Canadian Entomologist* 110(3): 253–256. <https://doi.org/10.4039/Ent110253-3>
- Six DL, Mullens BA (1996) Seasonal prevalence of *Entomophthora muscae* and introduction of *Entomophthora schizophorae* (Zygomycotina, Entomophthorales) in *Musca domestica* (Diptera, Muscidae) populations on California dairies. *Biological Control* 6(3): 315–323. <https://doi.org/10.1006/bcon.1996.0040>
- Soper RS, MacLeod DM (1963) Spore morphology of *Entomophthora fresenii* Nowakowski. *Journal of Insect Pathology* 5: 478–482.
- Soper RS, May B, Martinell B (1983) *Entomophaga grylli* enzyme polymorphisms as a technique for pathotype identification. *Environmental Entomology* 12(3): 720–723. <https://doi.org/10.1093/ee/12.3.720>
- Sosnowska D, Bałazy S, Prishchepa L, Mikulska N (2004) Biodiversity of arthropod pathogens in the Białowieża forest. *Journal of Plant Protection Research* 44(4): 313–321.
- Spatafora JW, Chang Y, Benny GL, Lazarus K, Smith ME, Berbee ML, Bonito G, Corradi N, Grigoriev I, Gryganskyi A, James TY, O'Donnell K, Roberson RW, Taylor TN, Uehling J, Vilgalys R, White MM, Stajich JE (2016) A phylum-level phylogenetic classification of zygomycete fungi based on genome-scale data. *Mycologia* 108(5): 1028–1046. <https://doi.org/10.3852/16-042>
- Speare AT (1922) Natural control of the citrus mealybug in Florida. *USDA Bulletin* 1117: 1–19. <https://doi.org/10.5962/bhl.title.108302>
- Speare AT, Colley RH (1912) The artificial use of the brown-tail fungus in Massachusetts with practical suggestions for private experiment, and a brief note on a fungous disease of the gypsy caterpillar. *Wright and Potter Printing Co., Boston, Mass.*
- Steinkraus DC, Kramer JP (1988) *Entomophthora scatophagae* desc. ampl. (Zygomycetes, Entomophthorales), a fungal pathogen of the yellow dung fly, *Scatophaga stercoraria* (Diptera: Anthomyiidae). *Mycotaxon* 32: 105–133.
- Steinkraus DC, Kramer JP (1989) Development of resting spores of *Erynia aquatica* (Zygomycetes: Entomophthoraceae) in *Aedes aegypti* (Diptera, Culicidae). *Environmental Entomology* 18(6): 1147–1152. <https://doi.org/10.1093/ee/18.6.1147>

- Steinkraus DC, Geden CJ, Rutz DA (1993a) Prevalence of *Entomophthora muscae* (Cohn) Fresenius (Zygomycetes, Entomophthoraceae) in house flies (Diptera, Muscidae) on dairy farms in New York and induction of epizootics. *Biological Control* 3(2): 93–100. <https://doi.org/10.1006/bcon.1993.1015>
- Steinkraus DC, Mueller AJ, Humber RA (1993b) *Furia virescens* (Thaxter) Humber (Zygomycetes, Entomophthoraceae) infections in the armyworm, *Pseudaletia unipunctata* (Haworth) (Lepidoptera, Noctuidae) in Arkansas with notes on other natural enemies. *Journal of Entomological Science* 28(4): 376–386. <https://doi.org/10.18474/0749-8004-28.4.376>
- Steinkraus DC, Boys GO, Hollingsworth RG, Bacheler JS, Durant, Freeman BL, Gaylor MJ, Harris FA, Knutson A, Lentz GL, Leonard BR, Luttrell R, Parker D, Powell JD, Ruberson JR, Sorenson C (1996) Multi-state sampling for *Neozygites fresenii* in cotton. *Proceedings of the Beltwide Cotton Conference* 2: 735–738.
- Steinkraus DC, Oliver JB, Humber RA, Gaylor MJ (1998) Mycosis of the bandedwinged whitefly (*Trialeurodes abutilonea*) (Homoptera, Aleyrodidae) caused by *Orthomyces aleyrodis* gen. & sp. nov. (Entomophthorales, Entomophthoraceae). *Journal of Invertebrate Pathology* 72(1): 1–8. <https://doi.org/10.1006/jipa.1997.4743>
- Steinkraus D, Hajek AE, Liebherr JK (2017) Zombie soldier beetles: Epizootics in the goldenrod soldier beetle, *Chauliognathus pennsylvanicus* (Coleoptera, Cantharidae) caused by *Eryniopsis lampyridarum* (Entomophthoromycotina, Entomophthoraceae). *Journal of Invertebrate Pathology* 148: 51–59. <https://doi.org/10.1016/j.jip.2017.05.002>
- Strong FE, Wells K, Apple JW (1960) An unidentified fungus parasitic on the seed-corn maggot. *Journal of Economic Entomology* 53(3): 478–479. <https://doi.org/10.1093/jee/53.3.478>
- Thaxter R (1888) The Entomophthoraeae of the United States. *Memoirs of the Boston Society of Natural History* 4: 133–201. <https://doi.org/10.5962/bhl.title.57312>
- Thaxter R (1891) Fungus disease of tomato worms. *Annual Report of the Connecticut Agricultural Experiment Station for 1890*, Tuttle, Morehouse and Taylor, New Haven, CT, 96 pp.
- Tkaczuk C, Bałazy S, Krzyczkowski T, Wegensteiner R (2011) Extended studies on the diversity of arthropod-pathogenic fungi in Austria and Poland. *Acta Mycologica* 46(2): 211–222. <https://doi.org/10.5586/am.2011.014>
- Torres Acosta RI, Humber RA, Sánchez Peña SR (2016) *Zoophthora radicans* (Entomophthorales), a fungal pathogen of *Bagrada hilaris* and *Bactericera cockerelli* (Hemiptera: Pentatomidae and Triozidae): Prevalence, pathogenicity, and interplay of environmental influence, morphology, and sequence data on fungal identification. *Journal of Invertebrate Pathology* 139: 82–91. <https://doi.org/10.1016/j.jip.2016.07.017>
- van Frankenhuyzen K, Ebling P, Thurston G, Lucarotti C, Royama T, Guscott R, Georgeson E, Silver J (2002) Incidence and impact of *Entomophaga aulicae* (Zygomycetes, Entomophthorales) and a nucleopolyhedrovirus in an outbreak of the whitemarked tussock moth (Lepidoptera, Lymantriidae). *Canadian Entomologist* 134(6): 825–845. <https://doi.org/10.4039/Ent134825-6>
- Vandenberg JD, Soper RS (1975) Isolation and identification of *Entomophthora* spp. Fres. (Phycomycetes, Entomophthorales) from the spruce budworm *Choristoneura fumiferana* Clem. (Lepidoptera, Tortricidae). *Journal of the New York Entomological Society* 88: 254–255.
- Villacarlos LT (2008) Updated records of Philippine Entomophthorales. *Philippine Entomologist* 22(1): 22–52. <https://www.ukdr.uplb.edu.ph/journal-articles/5449>
- Villacarlos LT, Mejia BS (2004) Philippine entomopathogenic fungi. I. Occurrence and diversity. *Philippine Agricultural Scientist* 87(3): 249–265.

- Waldbauer G (2005) Insights from Insects: What Bad Bugs Can Teach Us. Prometheus Books, Amherst, New York.
- Walsh SRA, Tyrrell D, Humber RA, Silver JC (1990) DNA restriction fragment length polymorphisms in the rDNA repeat unit of *Entomophaga*. *Experimental Mycology* 14(4): 381–392. [https://doi.org/10.1016/0147-5975\(90\)90061-W](https://doi.org/10.1016/0147-5975(90)90061-W)
- Walsh SRA (1996) Development of molecular markers for the detection and differentiation of *Entomophaga* strains pathogenic for insects. PhD thesis, University of Toronto, Toronto, Ontario, Canada.
- Watson DW, Mullens BA, Petersen JJ (1993) Behavioral fever response of *Musca domestica* (Diptera, Muscidae) to infection by *Entomophthora muscae* (Zygomycetes, Entomophthorales). *Journal of Invertebrate Pathology* 61(1): 10–16. <https://doi.org/10.1006/jipa.1993.1003>
- Webster FM (1894) Observations on some Entomophthorae. *The Journal of the Cincinnati Society of Natural History* 14: 173–177.
- Weseloh RM (1998) Possibility for recent origin of the gypsy moth (Lepidoptera, Lymantriidae) fungal pathogen *Entomophaga maimaiga* (Zygomycetes, Entomophthorales) in North America. *Environmental Entomology* 27(2): 171–177. <https://doi.org/10.1093/ee/27.2.171>
- Wheeler Jr AG (1972) Studies on the arthropod fauna of alfalfa: III. Infection of the alfalfa plant bug, *Adelphocoris lineolatus* (Hemiptera, Miridae) by the fungus *Entomophthora erupta*. *Canadian Entomologist* 104(11): 1763–1766. <https://doi.org/10.4039/Ent1041763-11>
- Wraight SP, Poprawski TJ, Meyer WL, Peairs FB (1993) Natural enemies of Russian wheat aphid (Homoptera, Aphididae) and associated cereal aphid species in spring-planted wheat and barley in Colorado. *Environmental Entomology* 22(6): 1383–1391. <https://doi.org/10.1093/ee/22.6.1383>
- Yendol WG, Paschke JD (1987) Infection of a looper complex by *Entomophthora sphaerosperma*. *Journal of Invertebrate Pathology* 9(2): 274–276. [https://doi.org/10.1016/0022-2011\(67\)90023-7](https://doi.org/10.1016/0022-2011(67)90023-7)
- Young WR, Sifuentes JA (1959) Biological and control studies on *Estigmene acrea*, a pest of corn in the Yaqui Valley, Sonora, Mexico. *Journal of Economic Entomology* 52(6): 1109–1111. <https://doi.org/10.1093/jee/52.6.1109>
- Zha LS, Wen TC, Kevin DH, Kang JC (2016) An updated checklist of fungal species in Entomophthorales and their host insects in China. *Junwu Xuebao* 35: 666–683. <https://doi.org/10.13346/j.mycosystema.150010>