

# The arthropod-pathogenic Entomophthorales from Switzerland : is central Europe the centre of their global species-richness?

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## The arthropod-pathogenic Entomophthorales from Switzerland – is central Europe the centre of their global species-richness?

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A total of 236 species of arthropod-pathogenic Entomophthorales are described up to June 2007. Eighty-eight species are recorded from Switzerland corresponding to 38 % of the world-wide known species. They are listed together with their collection sites and their hosts. 65 % of the 54 species of the subfamily Entomophthoroideae, 42 % of the 103 species of the subfamily Erynioideae and 37 % of the 19 species of the family Neozygitaceae are recorded from Switzerland. No species of the subfamily Massosporoideae and of the family Meristacraceae were found so far in Switzerland.

Key words. Entomopathogenic fungi; mycodiversity; species list; catalogue; hosts; locations.

### INTRODUCTION

The fungus order Entomophthorales (Zygomycetes) currently consists of 236 arthropod-pathogenic species (Keller 2006, 2007a, 2007c; Keller & Petrini 2005). They are placed in the four families Ancylistaceae (genus *Conidiobolus* with 11 arthropod-pathogenic species), Entomophthoraceae (three subfamilies and 12 genera with 205 species), Neozygitaceae (two genera with 19 species) and Meristacraceae (genus *Meristacrum* with a single species). Thirty-seven species are not classified and known only in their resting spore stage; they lack the criteria to attribute them to a specific genus. Therefore, they are summarized in the form-genus *Tarichium* and considered to belong to the family Entomophthoraceae. The large majority of the classified species attack insects, only seven species are known from mites (Acari) and two from Phalangiidae (Arachnida).

Arthropod-pathogenic Entomophthorales exist world-wide but seem to have their highest species richness in temperate climates. They attack arthropods in all kinds of habitats, but they are rare on subterranean hosts. Insects infected with Entomophthorales usually die at exposed places, often at the top of plants, fixed to walls or plant parts; infected specimens of gregarious insects like aphids normally remain in the colonies. It may be difficult to recognize whether a dead insect was killed by an entomophthoralean fungus as the infection is hardly discernable if the fungus is not sporulating. At high humidities, the fungus starts to sporulate predominantly on the soft body parts which may result in a white halo of discharged spores around the cadaver. Species of Entomophthoraceae that sporulate on living insects can only be detected through the examination of hosts caught alive.

Most species of the arthropod-pathogenic Entomophthorales have a narrow host range, some are known only from a single host species. Their importance lies in the ability to cause epizootics and to reduce host populations dramatically within a short time. Therefore, they are very important natural enemies and efficient regulators of host populations (Bałazy 1993; Keller 2007b). Considering the fact that

nearly 70 species are recorded from pest insects and mites and seven species from vectors of human and animal diseases one can estimate the potential of these fungi for pest and vector control. This is one of the reasons why these fungi gain increasing interest.

The aim of this paper is to attract the attention of mycologists and other naturalists to this interesting group of fungi in order to inspire them to contribute to the improvement of our knowledge in ecology, physiology, host-pathogen interactions and other aspects. Many more faunistic studies in Europe and in other parts of the world are necessary to prove or to deny the hypothesis that central Europe is really the centre of the global species-richness.

#### MATERIAL AND METHOD

Dead insects with and without external signs of fungus diseases were collected. A small part of the collection was immediately placed in 70 % ethanol in order to get the earliest development stages under the given conditions and thus to facilitate identification. Most of the collection was transported to the laboratory and placed in small Petri dishes on wet filter paper or on the surface of water to induce sporulation. Actively projected conidia were collected with a slide or picked up from the water surface. Details on preparation, staining and mounting techniques are given elsewhere (Keller 1987, 1991; Papierok 2007; Papierok and Hajek 1997).

The record list is arranged in alphabetical order. Each species is listed together with its authority. If the authorities are not followed by the publication year, the complete references of such species are given by Bałazy (1993) for the genera *Conidiobolus* and *Meristacrum* and for the form-genus *Tarichium* and for the remaining species by Keller and Petrini (2005). The distribution of the species is indicated by the communities where the fungi were collected followed by the abbreviations for the respective Swiss canton in brackets. Collections from narrowly limited geographical locations are defined by geographical coordinates originating from 'Swisstopo' geodata (Anonymus).

#### RESULTS

##### List of arthropod-pathogenic Entomophthorales of Switzerland

#### **Family Ancylistaceae**

##### Genus *Conidiobolus*

1. *C. caecilius* Keller (2007c).

On *Caecilius flavidus* and *Caecilius* sp. (Psocoptera, Caeciliidae) at Zürich-Reckenholz (ZH) and Widen/Neunkirch (SH).

2. *C. coronatus* (Cost.) Batko.

On larval *Ceutorhynchus napi* (Coleoptera, Curculionidae) from soil at Zürich-Reckenholz (ZH), collected many times from soil with the *Galleria* bait method (Zimmermann 1986) throughout Switzerland.

3. *C. obscurus* (Hall & Dunn) Remaudière & Keller.

On many species of aphids (Homoptera, Aphidinae, Callaphidinae) throughout Switzerland.

### Family Entomophthoraceae, subfamily Entomophthoroideae

#### Genus *Batkoa*

1. *B. apiculata* (Thaxter) Humber.

On several species of flies of the families Empididae (*Hilara* spp.), Psilidae, Rhagionidae and from Nematocera, mainly Sciaridae. Widely distributed in north and east Switzerland. A specimen on *Rosalia alpina* (Coleoptera, Cerambycidae) collected near Schiers (GR) is attributed to this species.

2. *B. cercopidis* (Keller) Huang, Humber & Hodge (2007).

On several cercopid species (Homoptera, Cercopidae) from many localities in north-eastern Switzerland.

3. *B. gigantea* (Keller) Humber.

On *Tipula paludosa* (Diptera, Tipulidae) from Zürich-Reckenholz (ZH), Alterswilen (TG), Nussbaumen (TG).

4. *B. hydrophila* Keller (2007c).

On unidentified adult Plecoptera from Fischingen (TG), coordinates 715960/251130, and Steg/Fischenthal (ZH), coordinates 714960/245850.

5. *B. limoniae* (Keller) Niell & Santamaria (2001).

On *Limonia tripunctata* (Diptera, Limoniidae) and related species from Tägerwilen (TG), Felben (TG), Hausener Seen (ZH) and Etzelkofen (BE).

6. *B. major* (Thaxter) Humber.

On *Tipula vernalis* (Diptera, Tipulidae) from Zürich-Reckenholz (ZH).

7. *B. papillata* (Thaxter) Humber.

On adult Chironomidae and Simuliidae (Diptera, Nematocera) from Hallau (SH), Trasadingen (SH), Frauenfeld (TG), Stammheim (ZH), Hausener Seen (ZH) and Pramagnon/Pouta Fontana (VS).

8. *B. pseudapiculata* (Keller) Huang, Humber & Hodge (2007).

On several species of flies from several localities in Klettgau SH.

#### Genus *Entomophaga*

1. *E. antochae* Keller (2007c).

On *Antocha vitripennis* (Diptera, Limoniidae) from Rüdlingen (ZH), coordinates 685800/270200.

2. *E. aulicae* (Reichardt in Bail) Humber.

On unidentified larvae of Lepidoptera in grass from Oberhallau (SH) and Watt (ZH).

3. *E. batkoi* (Bałazy) Keller.

On *Oligolophus tridens* (Arachnida, Phalangiidae) from Siblingen (SH), Neunkirch (SH), Bommen/Alterswilen (TG), Boppelsen (ZH) and Watt (ZH).

4. *E. conglomerata* (Sorokin) Keller.

On adult Chironomidae (Diptera, Nematocera) from Stammheim (ZH).

5. *E. grylli* (Fres.) Batko.

On different species of Acrididae (Saltatoria, Caelifera) from Siblingen (SH), Oberhallau (SH), Watt (ZH), Schönenberg/Kradolf (TG), Sonogno (TI) and Alpe Piora (TI).

6. *E. lagriae* Bałazy.

On *Lagria hirta* (Coleoptera, Lagriidae) from the Poschiavo valley (Bałazy, 1993).

7. *E. tenthredinis* (Fres.) Batko.

On sawfly larvae (Hymenoptera, Tenthredinidae) from Zürich-Reckenholz (ZH), Zürich-Waid (ZH), Watt (ZH), Frauenfeld (TG), Iselisberg (TG), Alterswilen (TG) and Randen (SH).

8. *E. thuricensis* Keller (2007c).

On *Cicadella viridis* (Homoptera, Cicadellidae) from the east side of the Katzensee and Allmend Katzensee (ZH).

9. *E. tipulae* (Fres.) Humber.

On *Tipula (Acutipula) luna* and unidentified tipulids (Diptera, Tipulidae) from Burgrain/Willisau (LU), Dörflingen (SH) and Rickenbach (ZH).

10. *E. transitans* (Keller) Hajek *et al.*

On *Limonia tripunctata* (Diptera, Limoniidae) from the Katzensee (ZH), coordinates 679370/254380.

### Genus *Entomophthora*

1. *E. brevinucleata* Keller & Wilding.

On different species of Cecidomyiidae (Diptera) fixed to the underside of leaves of grasses, herbs, bushes and trees. Widely distributed in north and east Switzerland.

2. *E. byfordii* Keller.

On *Bradysia* sp. (Diptera, Sciaridae) from Conthey (VS), Jenaz (GR) and Gächlingen (SH).

3. *E. culicis* (Braun) Fresenius.

On adults of different species of Culicidae and Chironomidae (Diptera, Nematocera). Widely distributed in aquatic and other wet environments throughout Switzerland.

4. *E. ferdinandii* Keller.

On *Delia kullensis* (Diptera, Anthomyiidae) from Widen/Neunkirch (SH), coordinates 681050/283270.

5. *E. grandis* Keller.

On *Episyrphus balteatus*, *Eupeodes corollae* and *Scaeva pyrastris* (Diptera, Syrphidae) from Hallau (SH), Solothurn (SO), Stammheim and Rafz (ZH).

6. *E. helvetica* Keller & Ben-Ze'ev in Ben-Ze'ev, Keller & Ewen.

On larval *Notostira elongata* (Heteroptera, Miridae) from Zürich-Reckenholz (ZH), Widen/Neunkirch and Siblingen (SH).

7. *E. muscae* (Cohn) Fresenius.

On *Musca domestica* (Diptera, Muscidae). Widely distributed in houses and stables throughout Switzerland, often causing epizootics.

8. *E. planchoniana* Cornu.

On many aphid species (Homoptera: Aphidinae, Callaphidinae, Chaitophorinae, Lachninae, Myzocallidinae and Pemphiginae). Widely distributed throughout Switzerland.

9. *E. rivularis* Keller, Niell & Santamaria.

On *Siphonoperla* sp., probably *S. torrentium* (Plecoptera, Chloroperlidae) from Fischingen (TG), coordinates 715960/251130.

10. *E. scatophagae* Giard.

On *Scatophaga stercoraria* (Diptera, Scatophagidae). Widely distributed on pastures in north, east and central Switzerland, often causing epizootics.

11. *E. schizophorae* Keller & Wilding.

On *Delia platura*, *Chamaepsila rosae*, *Pollenia rudis*, *Musca domestica* and *Platypalpus* sp. (Diptera). Widely distributed throughout Switzerland.

12. *E. simulii* Keller.

On adults of *Simulium* (*Wilhelmia*) *lineatum* (Diptera, Simuliidae) from Rüdlingen (SH), coordinates 685800/270200, and unidentified simuliids from Eschenz/Nili (TG).

13. *E. syrphi* Giard.

On *Melanostoma mellinum*, *M. scalare* and *Platycheirus clypeatus* (Diptera, Syrphidae) from different localities in Klettgau (SH), Stammheim (ZH), Hausener Seen (ZH), Frauenfeld (TG) and Jenaz (GR).

14. *E. trinucleata* Keller.

On unidentified species of Sciaridae (Diptera) from Zürich-Reckenholz (ZH), Siblingen and Schleithem (SH).

15. *E. weberi* (Lakon) Batko.

On larval *Raphidia ophiopsis* (Neuropteroidea, Raphidiidae) from St. Leonhard (VS).

Genus *Eryniopsis*

1. *E. caroliniana* (Thaxter) Humber.

On *Tipula paludosa* and *T. vernalis* (Diptera, Tipulidae). Widely distributed in north and east Switzerland, often causing epizootics in autumn.

2. *E. rhagionidis* Keller (2007c).

On unidentified species of Rhagionidae (Diptera) from Fischingen (TG), coordinates 715960/251130.

**Subfamily Erynoideae**

Genus *Erynia*

1. *E. aquatica* (Anderson & Anagnostakis) Humber.

On unidentified adult midges (Diptera, Nematocera) from Pouta Fontana (VS), Stammheim and Hausener Seen (ZH).

2. *E. conica* (Nowakowski) Remaudière & Hennebert.

On unidentified adult species of Chironomidae and Simuliidae (Diptera, Nematocera). Widely distributed in aquatic environments throughout Switzerland.

3. *E. curvispora* (Nowakowski) Remaudière & Hennebert.

On unidentified adult species of Chironomidae (Diptera, Nematocera) from Hausener Seen (ZH) and Trasadingen (SH).

4. *E. fluvialis* Keller (2007c).

On unidentified adult species of small midges (Diptera, Nematocera) from Fischingen (TG), coordinates 715960/251130, and Steg/Fiscenthal (ZH), coordinates 714960/245850.

5. *E. gracilis* (Thaxter) Remaudière & Hennebert.

On unidentified adult species of small midges (Diptera, Nematocera) from Fischingen (TG), coordinates 715960/251130, and Steg/Fiscenthal (ZH), coordinates 714960/245850.

6. *E. ovispora* (Nowakowski) Remaudière & Hennebert.

On Psychodidae and unidentified midges (Diptera, Nematocera). Widely distributed in aquatic environments in north and east Switzerland.

7. *E. plecopteri* Descals & Webster.

On unidentified adult species of Plecoptera from Fischingen (TG), coordinates 715960/251130.

8. *E. rhizospora* (Thaxter) Remaudière & Hennebert.

On several unidentified species of Trichoptera. Widely distributed in aquatic environments in north and east Switzerland.

9. *E. tumefacta* Keller (2007c).

On adult *Polietes lardarius* (Diptera, Muscidae) from Wattwil, coordinates 723210/239640 and Fischingen (TG), coordinates 715960/251130.

10. *E. variabilis* (Thaxter) Remaudière & Hennebert.

On adult unidentified small midges (Diptera, Nematocera) from Trasadingen (SH) and Katzenssee/Furtbach (ZH).

Genus *Furia*

1. *F. ellisiana* (Ben-Ze'ev) Humber.

On *Forficula auricularia* (Dermaptera, Forficulidae) at Zürich-Reckenholz (ZH) and Wädenswil (ZH).

2. *F. virescens* (Thaxter) Humber.

On unidentified species of noctuid larvae (Lepidoptera, Noctuidae) from different localities in the Klettgau (SH), Stammheim and Zürich-Reckenholz (ZH).

Genus *Pandora*

1. *P. americana* (Thaxter) Keller (2007c).

On *Pollenia cf. vespillo* and unidentified flies (Diptera, Calliphoridae) from Stammheim (ZH), Jenaz (GR) and Cazis (GR).

2. *P. athaliae* (Li & Fan) Li, Fan & Huang.

On larvae of *Athalia rosae* (Hymenoptera, Tenthredinidae) from Zürich-Affoltern (ZH) causing epizootics.

3. *P. blunckii* (Lakon ex Zimmermann) Humber.

On larvae of *Plutella maculipennis* (Lepidoptera, Plutellidae) from Zürich-Reckenholz (ZH).

4. *P. cicadellis* (Li & Fan) Li, Fan & Huang.

On unidentified cicadellids (Homoptera, Cicadina) from Widen/Neunkirch (SH) and Watt (ZH).

5. *P. dipterigena* (Thaxter) Humber.

On unidentified Sciaridae and other midges (Diptera, Nematocera). Widely distributed in north and east Switzerland.

6. *P. echinospora* (Thaxter) Humber.

On adult *Lyciella cf. pallidiventris* and unidentified species (Diptera, Lauxaniidae) from Osterfingen (SH) and Sonogno (TI).

7. *P. gammae* (Weiser) Humber.

On larval *Autographa gamma* and related species (Lepidoptera, Noctuidae) from Zürich-Reckenholz (ZH), Rafz (ZH), Stammheim (ZH) and Oberhallau (SH).



8. *P. lipai* (Bałazy, Eilenberg & Papierok) Keller.

On adult *Cantharis* (*Ancistronycha*) *abdominalis* and *C. (A.) erichsonii* (Coleoptera, Cantharidae) from Fischingen (TG), Steg/Fischenthal (ZH) and Wyler/Innertkirchen (BE).

9. *P. longissima* Keller (2007c).

On adult *Antocha vitripennis* (Diptera, Limoniidae) from Eendingen (AG), coordinates 665700/264740.

10. *P. minutospora* (Keller) Keller.

On adult *Trigonotylus ruficornis* (Heteroptera, Miridae) from Losone (TI)

11. *P. myrmecophaga* (Turian & Wuest in Humber) Keller.

From adult *Formica* (*Coptoformica*) *bruni* and an unidentified species (Hymenoptera, Formicidae) from Genolier (VD) and Widen/Neunkirch (SH).

12. *P. neophidis* (Remaudière & Hennebert) Humber.

On several species of aphids (Homoptera, Aphidinae and Callaphidinae). Widely distributed throughout Switzerland.

13. *P. philonthi* (Bałazy) Keller.

On adult unidentified staphylinid species (Coleoptera, Staphylinidae) from the Klettgau (SH).

14. *P. sciarae* (Olive) Keller (2007c).

On adults of *Bradysia* sp. (Diptera, Sciaridae) from Conthey (VS) and Burgrain/Willisau (LU).

#### Genus *Strongwellsea*

1. *S. castrans* Batko & Weiser.

On unidentified Anthomyiidae (Diptera) from Stammheim ZH, Katzenrüti/Rümlang (ZH) and Zürich-Reckenholz (ZH).

2. *S. pratense* Keller (2007c).

On *Coenosia albicornis* (Diptera, Muscidae) from Berg/Irchel (ZH).

#### Genus *Zoophthora*

1. *Z. aphidis* (Hoffmann in Fresenius) Remaudière & Hennebert.

On larvae and sexualis of *Anoecia corni* (Homoptera, Thelaxinae) and *Rhopalosiphum padi* (Homoptera, Aphidinae) from Oberhallau (SH), Nussbaumen (TG), Watt (ZH) and Zürich-Reckenholz (ZH).

2. *Z. aphrophorae* (Rostrup) Keller (2007c).

Unidentified species of cicadellids (Homoptera, Cicadina) from Zürich-Reckenholz (ZH).

3. *Z. crassitunicata* Keller.

On adult unidentified species of cantharid beetle, probably *Malthinus* sp. (Coleoptera, Cantharidae) from Rickenbach (ZH), coordinates 703450/268260.

4. *Z. elateridiphaga* (Turian) Ben-Ze'ev & Kenneth.

On adults of *Agriotes sputator* and *A. lineatus* (Coleoptera, Elateridae) from different localities in the Klettgau (SH), Uesslingen (TG), Andwil (ZG), Oensingen (SO) and Romanel/Lausanne (VD).

5. *Z. ichneumonis* Bałazy.

On adult unidentified species of Ichneumonidae and Torymidae (Hymenoptera) from Zürich-Reckenholz (ZH), Watt (ZH) and Fischingen (TG).

6. *Z. lanceolata* Keller.

Adult unidentified midges (Diptera, Nematocera) from Rickenbach (ZH), Eschenz (TG) and Felben (TG).

7. *Z. miridis* Bałazy & Mietkiewski.

On adult *Dicyphus pallidus* (Heteroptera, Miridae) from Hausener Seen (ZH).

8. *Z. nematocerus* Bałazy.

Adult unidentified species of Sciaridae (Diptera) from Burgrain/Willisau (LU) and Rüdlingen (SH).

9. *Z. occidentalis* (Thaxter) Batko.

On *Acyrtosiphon pisum* and *Rhopalosiphum padi* (Homoptera, Aphidinae) from different localities from the Klettgau (SH).

10. *Z. petchii* Ben-Ze'ev & Kenneth.

On adult cicadellids (Homoptera, Cicadina) from Fischingen (TG), coordinates 715960/251130.

11. *Z. phalloides* Batko.

On *Macrosiphum rosae*, *Metopolophium festucae* and *Rhopalosiphum padi* (Homoptera, Aphidinae) from Zürich-Reckenholz (ZH), Regensdorf (ZH), Siblingen (SH), Hüttwilen (TG) and Entlebuch (LU).

12. *Z. psyllae* Bałazy.

On larvae and adults of *Trioza urticae* (Homoptera, Psyllidae) from Widen/Neunkirch (SH), Watt (ZH) and Zürich-Reckenholz (ZH).

13. *Z. radicans* (Brefeld) Bakto.

From several species of aphids (Homoptera: Aphidinae, Callaphidinae, Chaitophorinae and Myzocallidinae), on adult unidentified Lepidoptera, on several species of Diptera, on adult *Amphinemoura sulcicollis* and other stoneflies (Plecoptera), on several species of Trichoptera (Keller, 2005). Widely distributed throughout Switzerland. *Zoophthora radicans* may be a complex of several species.

14. *Z. rhagonycharum* (Balazy) Keller (2007c)

On adult *Rhagonycha fulva* (Coleoptera, Cantharidae) from Boppelsen (ZH) and Klotener Ried (ZH).

15. *Z. viridis* Keller.

On adult *Notostira elongata* (Heteroptera, Miridae) from Zürich-Reckenholz (ZH), Watt (ZH) and Siblingen (SH).

**Family Neozygitaceae**Genus *Neozygites*1. *N. cinarae* Keller.

On *Cinara pilicornis* (Homoptera, Lachninae) from Watt (ZH).

2. *N. floridana* (Weiser & Muma) Remaudière & Keller.

On adult and larval *Tetranychus uricae* (Acari, Tetranychidae) from Watt (ZH), Zürich-Reckenholz (ZH), Stammheim (ZH), Alterswilen (TG).

3. *N. fresenii* (Nowakowski) Remaudière & Keller.

On many species of aphids (Homoptera, Aphidinae and Chaitophorinae). Widely distributed throughout Switzerland.

4. *N. microlophii* Keller.

On *Microlophium carnosum* (Homoptera, Aphidinae) from several localities in north and east Switzerland.

5. *N. parvispora* (MacLeod & Carl) Remaudière & Keller.

On *Thrips tabaci* and unidentified thrips (Thysanoptera, Thripidae) from different localities in the cantons BE, TG and ZH.

6. *N. remaudierei* Keller (2006).

On *Myzocallis coryli* (Homoptera, Myzocallidinae) from Belp (BE) and Fischingen (TG).

7. *N. turbinata* (Kenneth) Remaudière & Keller.

On *Tuberolachnus salignus* (Homoptera, Lachninae) from Zürich-Affoltern (ZH), Watt (ZH) and Stammheim (ZH).

## DISCUSSION

Eighty-eight species of arthropod-pathogenic Entomophthorales from Switzerland are listed. They belong to 12 genera of three families of the order Entomophthorales. Seventy-eight species belong to the family Entomophthoraceae which represents 38 % of the described species in the corresponding genera (Tab. 1). Seven species belong to the Family Neozygitaceae. They represent 41 % of all described species (Tab. 1). Thirty-two species were originally described from Swiss material. At least ten further entomophthoralean fungi were collected which could not be attributed unequivocally to a known species (Keller, unpubl.).

Tab. 1. The number of world-wide known species of arthropod-pathogenic Entomophthorales (APE) compared with the records from Switzerland.

Family Subfamily	Genus	Described species of APE	
		World-wide	Switzerland*
Ancylistaceae	<i>Conidiobolus</i>	11	3 (27 %)
Entomophthoraceae		205	78 (38 %)
Entomophthoroideae	<i>Batkoa</i>	10	8 (80 %)
	<i>Entomophaga</i>	19	10 (53 %)
	<i>Entomophthora</i>	21	15 (71 %)
	<i>Eryniopsis</i>	4	2 (50 %)
Erynioideae	<i>Erynia</i>	16	10 (63 %)
	<i>Furia</i>	14	2 (14 %)
	<i>Orthomyces</i>	1	0
	<i>Pandora</i>	34	14 (41 %)
	<i>Strongwellsea</i>	3	2 (67 %)
	<i>Zoophthora</i>	35	15 (43 %)
Massosporoideae	<i>Massospora</i>	11	0
Form-genus	<i>Tarichium</i>	37	0
Neozygitaceae	<i>Apterivorax</i>	2	0
	<i>Neozygites</i>	17	7 (41 %)
Meristacraceae	<i>Meristacrum</i>	1	0
Total		236	88 ( 37.3%)

\* In parenthesis: Proportion of species recorded from Switzerland.

It should be emphasized that this high number of records was not gathered on sophisticated sampling tours but mainly in localities where professional and private activities took place. This indicates that many more species unknown to science may be detected in future. Based on the existing records we have good reasons to assume that Switzerland is a hot spot for arthropod-pathogenic Entomophthorales.

A similar species richness is known from Poland. Bałazy (1993) listed 81 species without including the numerous species of *Tarichium* mainly collected from mites. On the other hand, specific investigations on arthropod-pathogenic Entomophthorales in Spain revealed 26 species (Niell & Santamaria 2001), while Gustafsson (1965) recorded 24 species in Sweden. From Norway, Kligen *et al.* (2002) listed 12 species of Entomophthorales; 13 species are reported from eastern Austria (Barta *et al.* 2005) and 35 species are recorded from the United Kingdom ([www.mapmate.co.uk/checklist](http://www.mapmate.co.uk/checklist)). From outside Europe there are only two recent check-lists of arthropod-pathogenic Entomophthorales. Ben-Ze'ev (1993) listed 31 species from Israel and Villacarlos & Mejia (2004) mentioned 20 species from the Philippines, however, only nine of them are unequivocally identified. Older check-lists report 10 species from Australia (Glare & Milner, 1987) and 14 species from Mexico (Remaudière & Latgé 1985). In his monograph on the Entomophthoraceae from the USA, Thaxter (1888) listed 27 species, but in the meantime an unknown number of species from this country was recorded. Based on the ARSEF culture collection:

[http://arsef.fpsnl.cornell.edu/mycology/ARSEF\\_Culture\\_Collection.html](http://arsef.fpsnl.cornell.edu/mycology/ARSEF_Culture_Collection.html)  
and recent publications at least 54 species are known from the USA.

From these data we may indeed conclude that central Europe has the highest known species diversity of arthropod-pathogenic Entomophthorales. However, we must be aware that only a few researchers were and are active in this field and that their investigations were mainly limited to temperate climates. But also in these climate zones there are still neglected habitats like wet places, forests (ground, bush and tree level) and hill and mountain areas. Further reasons for the species richness in central Europe could be: climatic conditions optimal for these fungi, high diversity of habitats, highly structured landscape connected with a careful landscape management and agricultural practises based on environmental friendly and sustainable methods.

Most arthropod-pathogenic Entomophthorales are highly specialised and those with a broader host range may turn out to be species-complexes like *Zoophthora radicans* (Bałazy 1993; Keller, in prep.). Considering this fact and that more than a million potential host species exist, one can assume that the number of known species represents only a very small proportion of the actually existing species.

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