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Parasitoids (Hymenoptera) of leaf-spinning moths (Lepidoptera) feeding on *Vaccinium uliginosum* L. along an ecological gradient in central European peat bogs

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Lozan, A. I., Spitzer, K., Jaroš, J., Khalaim, A., Rizzo, M. C., Guerrieri, E. & Bezděk, A. 2010: Parasitoids (Hymenoptera) of leaf-spinning moths (Lepidoptera) feeding on *Vaccinium uliginosum* L. along an ecological gradient in central European peat bogs. — Entomol. Fennica 21: 243–253.

Parasitoids of leaf-spinning Lepidoptera associated with two isolated central European peat bogs were investigated. Five families of parasitoid Hymenoptera (Braconidae, Ichneumonidae, Eulophidae, Pteromalidae and Encyrtidae) were recorded. Three categories were recognised: (1) primary parasitoids, (2) facultative hyperparasitoids and (3) obligatory hyperparasitoids. Ten species of Braconidae, five species and seven marked morphospecies among Ichneumonidae, and three species of Chalcidoidea were identified. Despite of some niche-specific (but less host-specific) parasitoids, all these hymenopterans are likely to be generalists and none of them were confirmed to be habitat and/or host specialists. Unlike their eurytopic (opportunistic tyrphoneutral) parasitoids, the Lepidoptera hosts associated with peat bogs are partially highly stenotopic (tyrphobionts and tyrphophiles). The occurrence of parasitoids compared to their potential hosts was structured along an ecological (mesoclimatic) gradient, so most parasitoids were recorded from margins while stenotopic (narrow habitat adaptation) moths were mostly distributed near the centre of the bog habitat.

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Received 26 January 2009, accepted 2 June 2010

1. Introduction

Parasitoids of an ecological guild of Lepidoptera feeding on relict boreo-montane plant *Vaccinium uliginosum* L., a deciduous circumboreal shrub characteristic of peaty soils of coldlands, in two isolated central European peat bogs (Spitzer *et al.* 2003) were studied. The moths reared from leaf spinnings belong to four families (Tortricidae, Gelechiidae, Chimabachidae and Geometridae) and include both stenotopic (tyrphobiontic and tyrphophilous taxa), closely associated with peat bogs, and opportunistic (tyrhoneutral) species not related to the bogs.

Peat bogs of central Europe, which developed under isolation, are true habitat islands for a unique insect diversity of highly stenotopic taxa ("relicts") among Lepidoptera and parasitoid Hymenoptera (Spitzer & Danks 2006, Lozan *et al.* 2010). The Lepidoptera community of central European peat bogs has been well studied under the long-term monitoring programmes, but the parasitoids have not been subject of such investigations. This paper is based on previous investigations of Lepidoptera (Spitzer *et al.* 2003) and aims at assessing parasitoid diversity along an ecological (mesoclimatic) gradient in two different peat bog systems. This mesoclimatic gradient is characterised by extreme temperatures and expressed by local vegetation of "forest-tundra" formations between bog centres and bog margins (including "lagg", see Material and methods, and Bezděk *et al.* 2006). These two central European bogs are isolated ancient habitats of distinct climatic and edaphic conditions close to the forest-tundra biome with a high proportion of local cold-adapted species.

There is an identified distinct micro-climatic gradient from lagg (the ecotone of outer parts of the bog) to margins and centres of peatbogs, including intermediate zones, where we collected our field samples for ecological analysis. The bog habitat affinity (association or relation to bog habitat) of both moths and parasitoids from our samples was correlated with available reliable records of levels of host specialisation in order to reveal the degree of their stenotopy and eurytopy. Previous preliminary investigations in one of the studied peat bogs under the same ecological gradient (centre versus margins) showed that hyme-

nopteran parasitoids (Braconidae), collected by light traps (Lozan 2002), were not restricted to the bog as reported for stenotopic Coleoptera and Lepidoptera (cf. Bezděk *et al.* 2006).

2. Material and methods

2.1. Sites of investigations

Leaf spinnings on *Vaccinium uliginosum* were collected during June 1998–2001 from two montane isolated peat bogs of the core zone of the Šumava National Park, SW Bohemia, Czech Republic; details are given by Spitzer *et al.* (2003):

- a) Mrtvý luh near Volary (740 m a.s.l., 310 ha) represents a montane oligotrophic valley peat bog more or less closed by the forest. Open treeless areas are covered by *V. uliginosum* (and other *Vaccinium* spp.), *Eriophorum vaginatum* and *Calluna vulgaris* with a gradual transition to dwarf forest of *Pinus mugo s. lat.* around the bog.
- b) Chalupská slat' bog near Borová Lada (900 m a.s.l., 116 ha) is a montane oligotrophic raised bog with a central bog-lake and mountain pine forest around, with large patches of *V. uliginosum* (including other *Vaccinium* spp.) and *Betula pubescens* (the gradient between the centre and margins is not gradual like in the Mrtvý luh bog).

2.2. Sampling

For collecting the hosts, leaf-spinnings were sampled along an ecological gradient between the outer margins, lagg (inner margins) and the centres of each investigated bog system. The cover of *V. uliginosum* was higher near the treeless areas of the bogs and the stenotopic host taxa (i.e. tyrphobionts+tyrphophiles) were most abundant in the centres (edaphic "tundra-like" formation) when compared with the pine forested margins (including the lagg ecotone, which is an integral part of the bog) of the bogs. It was not possible to identify exactly which parasitoid species emerged from the particular host spinning. The attempt for host larvae identification by head cap-

sules was not successful and not sufficiently reliable.

2.3. Lepidoptera

The complete list of moth species with quantitative data (species, reared specimens and leaf spinings per site) is given by Spitzer *et al.* (2003), here we supply only the list of species where stenotopic taxa are marked with an asterisk (tyrphobionts and tyrphophiles), as follow:

Diurnea lipsiella (Denis et Schiffermüller) and *Dasytoma salicella* (Hübner) (Chimabachidae); *Athrips pruinosella* (Lienig & Zeller)* (Gelechiidae); *Acleris laterana* (Fabricius), *Acleris maccana* (Treitschke)*, *Acleris lipsiana* (Denis & Schiffermüller)*, *Cnephasia stephensiana* (Doubleday), *C. asseclana* (Denis & Schiffermüller), *Argyrotaenia ljugiana* (Thunberg), *Pandemis cinnamomeana* (Treitschke), *P. heparyana* (Denis & Schiffermüller), *Clepsis senecionana* (Hübner), *Adoxophyes orana* (Fischer von Röslerstamm), *Apotomis sauciana* (Frölich)*, *Celypha lacunana* (Denis & Schiffermüller), *Phiaris bipunctana* (Fabricius)*, *Rhopobota naevana* (Hübner) and *Pammene luedersiana* (Sorhagen)* (Tortricidae); *Rhinoprora (Pasiphila) debiliata* (Hübner) (Geometridae).

The rearing of a total of 19 species (18 species of typical leaf-spinning microlepidopteran species and one macrolepidopteran leaf-spinning species) was conducted under laboratory conditions, where larvae were kept and fed on *V. uliginosum* in glass boxes.

2.4. Hymenoptera

All reared hymenopterans were initially preserved in 80% ethanol, then dried up with the help of filter paper and mounted into collections. Taxonomic analysis was done by using the most recent keys (e.g., Graham 1959, Askew 1968, Huddleston 1980, 1984, Bouček & Rasplus 1991, Belokobylskij & Tobias 1998, 2000, Guerrieri & Noyes 2005), and by comparing the specimens with authoritatively identified specimens and with other material deposited in institutional collections.

Table 1. No. of reared specimens/species from the four families of leaf-spinning Lepidoptera (Chimabachidae, Gelechiidae*, Tortricidae*, Geometridae*; include specialist/stenotopic taxa: tyrphobionts + tyrphophiles) in two peatbogs.

Parasitoid family	Specimens reared	Species reared
Ichneumonidae	26	12
Braconidae	56	10
Eulophidae	4	1
Pteromalidae	4	1
Encyrtidae	14	1
Unidentified (Chalcidoidea)	3	?
Total	107	25

All Braconidae and Chalcidoidea specimens were identified at the species level except for three damaged ones (presumably Chalcidoidea). Most of the collected Ichneumonidae were identified at the species level, some only at the genus level.

2.5. Data analysis

We used the same community data analysis scheme as in Spitzer *et al.* (2003). The Canonical Correspondence Analysis (CCA; CANOCO version 3.12 software) by Ter Braak (1987) was used to determine the habitat preferences of parasitoids in relations to the centers and the margins of the two investigated bogs.

3. Results

A total of 107 specimens of parasitoids (Table 1) were reared under laboratory conditions from 19 species of leaf-spinning Lepidoptera feeding on typical bog plant *V. uliginosum* in two central-European peat bogs of the Šumava Mountains. All identified parasitoid species can be classified as tyrphoneutral taxa, being generalists and more or less polyphagous parasitoids of Lepidoptera or oligophagous species associated with smaller numbers of biologically similar Lepidoptera (Table 2). None of them was confirmed to be a habitat and/or host specialist, despite that some of their leaf-spinning Lepidoptera hosts were bog specialists.

Table 2. Known geographic range and host range for parasitoid Hymenoptera (Ichneumonoidea, Chalcidoidea) reared from leaf-spinning Lepidoptera feeding on *Vaccinium uliginosum* L. in two central European peat bogs (Šumava Mts.).

Taxa	Geographic range	Number of Lepidoptera recorded in literature per:	
		Families	Species
Ichneumonoidea: Braconidae			
<i>Hormius moniliatus</i>	Holarctic, Oriental	5	at least 17
<i>Hormius similis</i>	Transpalaeartic, Oriental	Probably as <i>H. moniliatus</i>	
<i>Oncophanes minutus</i>	Transpalaeartic	10	>50
<i>Bracon erraticus</i>	Transpalaeartic	4	5
<i>Charmon extensor</i>	almost Cosmopolitan	13	>75
<i>Meteorus ictericus</i>	Palaeartic, Australian	13	>90
<i>Meteorus colon</i>	Transpalaeartic	10	25
<i>Earinus gloriatorius</i>	West Palaeartic	6	12
<i>Orgilus pimpinellae</i>	Transpalaeartic	9	25
<i>Ascogaster bidentula</i>	Transpalaeartic	2	2
Ichneumonoidea: Ichneumonidae			
<i>Itoplectis tunetana</i> *	Transpalaeartic	6	13
<i>Glypta ceratites</i>	Europe, Mongolia	6	183
<i>Tranosema carbonellum</i>	Holarctic	First record on Lepidoptera	
<i>Chorinaeus funebris</i>	Holarctic	7	17
<i>Exochus tardigradus</i>	Palaeartic	Unknown	Unknown
Chalcidoidea: Eulophidae			
<i>Elachertus artaeus</i>	Palaeartic, Nearctic	5	11
Chalcidoidea: Pteromalidae			
<i>Termolampa pinicola</i>	Transpalaeartic	1	2
Chalcidoidea: Encyrtidae			
<i>Copidosoma filicorne</i>	Holarctic	2	17

* Facultative hyperparasitoid.

According to their known foraging activity, they are either primary parasitoids (Braconidae and Chalcidoidea, partially Ichneumonidae) of Lepidoptera and rarely of other insect groups, or obligatory and facultative hyperparasitoids (among Ichneumonidae) (see Table 3).

Being widely distributed with a wide host range (Ichneumonoidea) or partially with a narrower host spectrum among Lepidoptera only (Chalcidoidea), they have comparatively low host specificity and a wide coverage of various habitats, being not restricted to the bog habitat at all.

Quantitatively, most parasitoids were recorded from margins in the Mrtvý Luh bog, i.e. 55 specimens belonging to twelve species versus only 21 specimens and nine species from the centre+intermediary parts. The number of parasitoids reared from hosts of the Chalupská slat'

bog was almost equal in both parts, i.e. 15 specimens and seven species in centre and 16 specimens and six species in margins (Table 4).

Table 3. No. of reared specimens and species per parasitoid category from the four families of leaf-spinning Lepidoptera (Chimabachidae, Gelechiidae*, Tortricidae*, Geometridae; * include specialist/stenotopic taxa: tyrphobionts + tyrphophiles) in two peat bogs.

Parasitoid category	Specimens reared	Species reared
Primary	95	22
Facultative hyperparasitoids	1	1
Obligatory hyperparasitoids	8	2
Unidentified (Chalcidoidea)	3	?
Total	107	25

Table 4. Number of reared parasitoids (Hymenoptera: Ichneumonoidea, Chalcidoidea) from leaf-spinning moths (Lepidoptera) on *Vaccinium uliginosum* L. per each investigated bog site (Šumava Mts.).

Taxa	Position along the gradient [#]					
	Mrtvý luh				Chalupská slat'	
	Cntr	Inter	Marg	Lagg	Cntr	Marg+Lagg
Ichneumonoidea: Braconidae						
<i>Hormius moniliatus</i>	3	0	0	0	0	0
<i>Hormius similis</i>	1	0	0	0	0	0
<i>Oncophanes minutus</i>	1	0	0	2	0	0
<i>Bracon erraticus</i>	0	0	0	5	0	0
<i>Charmon extensor</i>	0	0	0	1	0	0
<i>Meteorus ictericus</i>	0	0	8	1	1	3
<i>Meteorus colon</i>	0	0	0	2	0	0
<i>Earinus gloriatorius</i>	0	0	0	0	1	0
<i>Orgilus pimpinellae</i>	1	0	0	0	3	3
<i>Ascogaster bidentula</i>	0	0	9	11	0	0
Ichneumonoidea: Ichneumonidae						
<i>Itoplectis tunetana</i> *	0	0	1	0	0	0
<i>Glypta ceratites</i>	0	0	0	0	0	3
<i>Glypta</i> sp.	0	0	1	1	0	0
<i>Campoplex</i> sp. 1	0	0	1	3	0	0
<i>Campoplex</i> sp. 2	0	0	0	0	0	1
<i>Campoplex</i> sp. 3	0	0	0	0	0	2
<i>Campoletis</i> sp.	0	0	0	2	0	0
<i>Tranosema carbonellum</i>	0	0	0	0	1	0
<i>Chorinaeus funebris</i>	0	1	0	0	0	0
<i>Exochus tardigradus</i>	0	1	0	0	0	0
<i>Mesochorus</i> sp. 1**	0	0	3	3	1	0
<i>Mesochorus</i> sp. 2**	0	0	0	1	0	0
Chalcidoidea: Eulophidae						
<i>Elachertus artaeus</i>	3	0	0	0	1	0
Chalcidoidea: Pteromalidae						
<i>Termolampa pinicola</i>	0	0	0	0	0	4
Chalcidoidea: Encyrtidae						
<i>Copidosoma filicorne</i>	7	0	0	0	7	0
Other Chalcidoidea (damaged)	3	0	0	0	0	0
Total	19	2	23	32	15	16

* Facultative hyperparasitoid.

** Obligatory hyperparasitoid.

Abbreviations: Cntr – centre, Marg – margins, Inter – intermediate zone, Marg+Lagg – margins and lagg ecotone.

The stenotopic tyrphobiotic species of leaf spinning Lepidoptera were mostly associated with shrubs of *V. uliginosum* near the centre of the investigated bogs, while tyrphoneutral taxa were distributed in the margins of the bog habitat. Species spectra of parasitoids recorded from bog centres and bog margins were irregularly dispersed (Fig. 1a), so that only few species were present in two or more investigated habitats along the

microclimatic gradient. On the contrary, the stenotopic species spectra of Lepidoptera of both bog centres were very similar, but very different in bog margins (Fig. 1b). The gradient is characterised by the near ground temperatures which were extremely low near the bog centres and gradually increasing to the bog margins, e.g. the minimum temperatures in July–August reach often -4°C near the centres (-2°C at the

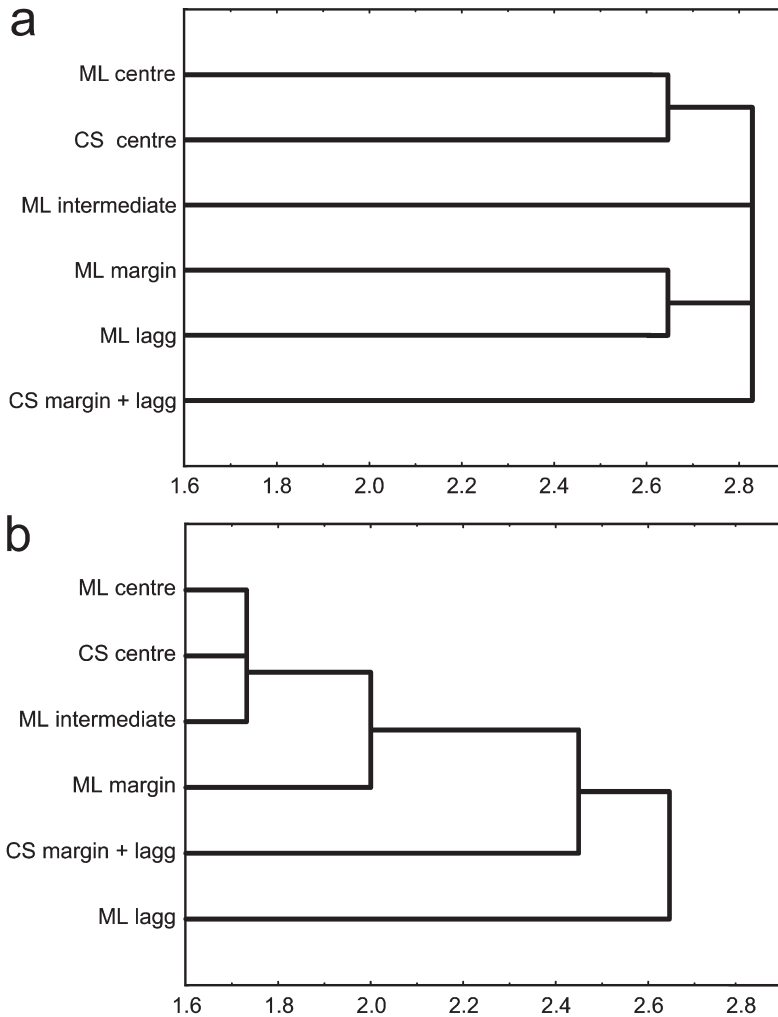


Fig. 1. Similarities (presence-absence data, single linkage, Euclidean distance) of different parts, from centres to margins (including inner margins=lagg), of Mrtvý luh (ML) and Chalupská slat' (CS) peat bogs. – a. Parasitoids (number of species and morphospecies) of leaf-spinning moths. – b. Leaf spinning moth communities; data from Spitzer *et al.* (2003).

same time period) (for basic temperature data of the bog sites see Spitzer *et al.* 2003).

4. Ecological data on parasitoids

The data below have been summarized in Table 2, accompanied by the geographic ranges of the parasitoid species.

4.1. Primary parasitoids

4.1.1. *Ichneumonoidea*

Braconidae

Hormius moniliatus (Nees, 1811)

Idiobiont ectoparasitoid of Lepidoptera (e.g. Co-

leophoridae, Tortricidae, Pyralidae) (Belokobylskij & Tobias 1998).

Hormius similis Szépligeti, 1896

Idiobiont ectoparasitoid, very close to previous species sharing, probably, same habitat requirements and host range (Belokobylskij & Tobias 1998).

Oncophanes minutus (Wesmael, 1838)

Idiobiont ectoparasitoid of Lepidoptera. The parasitism on Coleoptera (Cerambycidae, Bostrichidae) and Hymenoptera, Symphyta (Tenthredinidae) is not counted and require confirmation (Belokobylskij & Tobias 1998, Diaconu & Lozan 2000).

Bracon erraticus (Wesmael, 1838)

Idiobiont ectoparasitoid covering a wide spectrum of hosts, mainly among Lepidoptera (Tortricidae, Geometridae, Gelechiidae etc.) (Tobias 1986). The species is both morphologically and ecologically very variable (or there are several species in fact), so parasitism on Coleoptera (Chrysomelidae), Diptera (Tephritidae) and Hymenoptera (phytophagous taxa of Eurytomidae) is not excluded.

Charmon extensor (Linnaeus, 1758)

Larval koinobiont endoparasitoid covering a wide spectrum of Lepidoptera hosts (typically from families Gelechiidae, Geometridae, Tortricidae, Yponomeutidae etc.) (Billups 1897, Achterberg 1979, Belokobylskij & Tobias 1998). Parasitism on Coleoptera (Cerambycidae, Bostrichidae) and/or Hymenoptera, Symphyta (Tenthredinidae) require confirmation.

Meteorus ictericus (Nees, 1811)

Solitary koinobiont larval endoparasitoid covering a wide spectrum of Lepidoptera (Huddleston 1980, Tobias 1986). A record on a diprionid sawfly requires confirmation.

Meteorus colon (Haliday, 1835)

Solitary koinobiont larval endoparasitoid of Lepidoptera (Huddleston 1980, Tobias 1986).

Earinus gloriatorius (Panzer, 1809)

Solitary koinobiont endoparasitoid of Lepidoptera (Nixon 1986).

Orgilus pimpinellae Niezabitowski, 1910

Solitary koinobiont larval endoparasitoid of many Lepidoptera (Taeger 1988, Belokobylskij & Tobias 1998).

Ascogaster bidentula Wesmael, 1835

Solitary koinobiont egg-larval endoparasitoid of only Lepidoptera (typically families Geometridae and Tortricidae) (Huddleston 1984, Tobias 1986).

Ichneumonidae

Chorinaeus funebris (Gravenhorst, 1829)

Larval-pupal koinobiont endoparasitoid covering

a wide spectrum of only Lepidoptera (Aeschlimann 1975).

Glypta ceratites Gravenhorst, 1829

Solitary koinobiont endoparasitoid of a wide spectrum of Lepidoptera (Aubert 1978).

Glypta sp.

Members of the genus *Glypta* are koinobiont endoparasitoids covering a wide spectrum of microlepidopteran hosts living in concealment (Tortricidae, Gelechiidae, Geometridae etc.) or other Lepidoptera (Lasiocampidae, Lymantriidae, Lycanidae etc.). There are records of their parasitism on other insect orders as Hymenoptera-Symphyta (Cephalidae, Diprionidae) and Coleoptera (Cerambycidae, Scarabaeidae, Curculionidae) (Dasch 1988), however these require confirmation.

Exochus tardigradus Gravenhorst, 1829

Host unknown. Members of the metopiine genus *Exochus* are primary koinobiont larval-pupal endoparasitoids of a wide range of microlepidopterous larvae in leaf rolls or similar situations (Gelechiidae, Tortricidae, Geometridae, Yponomeutidae etc.) (Gauld 2002, Tolkanitz 2007). Records on Coleoptera and Hymenoptera-Symphyta (Tenthredinidae) are probably erroneous.

Tranosema carbonellum (Thomson, 1887).

Mentioned as koinobiont endoparasitoid of sawfly *Arge pagana* Panzer (Argidae) by Hedwig (1939). This is the first record of this species from Lepidoptera. Members of the genus are generally known as endoparasitoids of various small Lepidoptera, especially the family Tortricidae.

Campoletis sp. and *Campoplex* spp. (three unidentified species).

Members of these Campopleginae genera are known as primary koinobiont larval (rarely larval-pupal) parasitoids of small and medium-sized Lepidoptera of various families (Townes 1969, Kasparyan 1981, Gauld 1991, Shaw & Aeschlimann 1994, Wagener *et al.* 2006). Records of their parasitism on other insect groups (Coleoptera) and/or their hyperparasitism on other Ichneumonidae require confirmation (Townes 1945).

4.1.2. Chalcidoidea

Eulophidae

Elachertus artaeus (Walker, 1839)

Gregarious ectoparasitoid of various Lepidoptera (Gelechiidae, Gracillariidae, Noctuidae, Notodontidae, Tortricidae), attacking larvae of free-moving leaf spinning/rollers, or larvae of leaf-miners which spin cocoons in their last stage often by rolling the edge of the leaf (Bouček & Askew 1968, Noyes 2003).

Pteromalidae

Termolampa pinicola Bouček, 1961

Known as a primary parasitoid of *Retinia resinella* (L.) (Lepidoptera, Tortricidae) on *Pinus thunbergii* (Parl.) and *Pinus* sp. (Noyes 2003). Our results show this species is probably associated with a tortricid or gelechiid moth other than the only known host, which can be considered a new host record. The species is therefore likely to be at least oligophagous.

Encyrtidae

Copidosoma flicorne (Dalman, 1820)

Egg-larval endoparasitoid, one of the most common species of the genus in Europe with a relatively narrow host spectrum, limited to the families Gelechiidae and Tortricidae (Lepidoptera) (Guerrieri & Noyes 2005).

4.2. Facultative hyperparasitoids

Ichneumonoidea: Ichneumonidae

Itopectis tunetana (Schmiedeknecht, 1914)

Primary parasitoids of various Lepidoptera (Acrolepiidae, Choreutidae, Gelechiidae, Plutellidae, Tortricidae, Yponomeutidae) and hyperparasitoids of other parasitoid Hymenoptera (Braconidae: *Aleiodes rossicus*) (Kasparyan 1981).

4.3. Obligatory hyperparasitoids

Ichneumonoidea: Ichneumonidae

Mesochorus spp. (two unidentified species). Members of this large genus are endoparasitic hyperparasitoids of either Hymenoptera (e.g. parasitoids of the families Braconidae, Ichneumonidae) or tachinid parasitoids (Diptera: Tachinidae) (Wahl 1993, Schwenke 1999).

5. Discussion

5.1. Parasitoid diversity

Parasitoids in our samples can be classified as shown in Table 3. The members of the family Braconidae were the most numerous and they were only primary parasitoids. The Ichneumonidae were twice less numerous than the Braconidae and were more diversified, e.g. primary and secondary (obligatory and facultative) parasitoids. Identified species of Chalcidoidea (Pteromalidae, Encyrtidae and Eulophidae) were all reported as primary parasitoids. For the list of species see Table 2.

Primary parasitoids of families Braconidae and Ichneumonidae can be classified as polyphagous species associated with various Lepidoptera (except probably *Bracon erraticus*, which in literature is also recorded from other insect orders (see below)). Primary parasitoids of family Chalcidoidea are often more niche-specific than taxon-specific, with a moderate host range of biologically similar host taxa belonging to a more or less large taxonomic range (Askew & Shaw 1986, Lawton 1986).

The only one facultative hyperparasitoid species (*Itopectis tunetana*, Ichneumonidae) is not very habitat selective and generally polyphagous, with wide geographic range. The obligatory ichneumonid hyperparasitoids of the genus *Mesochorus* attack probably a series of other primary parasitoids, e.g. among parasitoid Hymenoptera and Diptera (Wahl 1993). Although hyperparasitic intraguild strategy frequently occurs in parasitoid Hymenoptera, it is difficult to reveal and detect such connections in the field samples. The multitrophic parasitism in our samples is undoubtedly only a small part of the

intrinsic and almost unknown parasitoid food web of peat bogs.

Most parasitoid species recorded in this study are considered to be widely distributed in the Palearctic (except *Earinus gloriatorius*, recorded recently only from Europe) and several species with almost cosmopolitan range (some taxa introduced). All such species seem to be characteristic in various biotopes, including peatlands, but having no specific requirements to bog habitats.

A huge amount of host records has thoroughly been analysed (for example, Taxapad) in order to be able to assess the real host range and distribution of each parasitoid species we managed to identify in our samples. However, many published records of parasitism on a large spectrum of lepidopteran families and/or on other insects than Lepidoptera (such as Hymenoptera-Symphyla (Tenthredinidae, Cephidae, Diprionidae) and Coleoptera (Cerambycidae, Scarabaeidae, Curculionidae etc.)) might be wrong and, at minimum, all these published connections would require confirmation. Ultimately, only a number of more limited and more reliable sources were considered, by judging the host ranges as a context that has reasonable boundaries (e.g. ‘generalist’ versus ‘specialist’ parasitoid, see Shaw 1994) and by using data from taxonomic collections that we managed to examine elsewhere (see also Acknowledgements).

5.2. Association with bog Lepidoptera

It was really difficult to reveal the precise relationships of emerged parasitoids to the reared host(s) in our leaf spinning samples. The braconid endoparasitoid *Charmon extensor*, which attacks a large spectrum of insects throughout the world, is known from a strictly tyrophilous tortricid moth *Acleris maccana* (Billups 1897). The same host species is recorded for a polyphagous endoparasitoid braconid, *Meteorus ictericus*, which is a widely distributed species not only in the Palearctic region. Another braconid endoparasitoid, *Orgilus pimpinellae*, which is Lepidoptera host oriented and widely distributed in the Palearctic, has been recorded from the tyrophobiotic gelechiid moth *Athrips pruinosa* associated with the host plant *V. uliginosum*

(Taeger 1988), consistently with our samples. All these species of Lepidoptera and Hymenoptera (Braconidae) were represented in our samples and were also encountered during our previous studies in the investigated bog sites (e.g. Lozan 2002, Spitzer *et al.* 2003, Bezděk *et al.* 2006).

Many of the obtained parasitoids are known also as true bioregulators operating in orchards and forests (*Oncophanes minutus*, *Charmon extensor*, genus *Meteorus* etc.), and some of their potential tyrophoneutral hosts were abundant in the investigated peat bogs.

6. Conclusions

In the two isolated central European peat bogs studied here, the diversity of parasitoids (superfamilies Ichneumonoidea and Chalcidoidea) is slightly higher compared with their lepidopteran hosts. The overall “tyrpho-association” of both leaf-spinning Lepidoptera and their potential parasitoids (Ichneumonoidea + Chalcidoidea) represents:

- a) 19 species of Lepidoptera, of which seven stenotopic taxa (tyrphobionts+tyrphophiles) and 12 tyrophoneutrals (cf. Spitzer *et al.* 2003, Spitzer & Danks 2006);
- b) 25 species of multitrophic parasitoids; none of the identified species was a bog stenotopic taxon, therefore, all of them are tyrophoneutrals (eurytopic components of various ecosystems).

Associated with peat bogs, there are a few known stenotopic taxa among Braconidae (Lozan & Tobias 2002, Lozan *et al.* in press) and Ichneumonidae (Tereshkin 1996) so far. However, none of them matched our data of rearings from leaf spinings. Investigations of parasitoid Hymenoptera associated only with peat bogs were generally neglected and not many data are available (cf. Krogerus 1960, Spitzer & Danks 2006).

The ability of parasitoids (including multitrophic levels) to populate a wide range of habitats and hosts (i.e. eurytopy) contrasts with that of stenotopic leaf-spinning Lepidoptera species. The historical patterns of evolution of parasitoids are more important determinants than current

ecological characteristics in an ‘isolated habitat’, which reflects a certain degree of environmental tolerance (cf. Hawkins 1994, Hawkins & Mills 1996, Tschamtko *et al.* 2002). It may also suggest that any single perturbation in the peat bog environment might shift the host-parasitoid evolutionary relationships not in favour of Lepidoptera hosts which seem to be much more habitat dependent (often cold-adapted “relict” taxa) than their opportunistic parasitoids (Spitzer & Danks 2006). All parasitoids are therefore only eurytopic taxa when compared with the stenotopic+eurytopic combination of leaf-spinning Lepidoptera hosts. From the conservation point of view, the complex of the isolated peat bog habitats, hydrological conditions and the very specific local micro- and mesoclimate might prevent the potential impact of the population outbreak or/and invasion of common opportunistic parasitoids unless human and climatic impacts are excluded.

Acknowledgements. Field and laboratory studies (rearing, identification, habitat comparative analysis) were supported by the Czech Academy of Sciences (Grant IQS500070505) and partially by the EU Synthesys (grant GB-TAF-4159) and European Science Foundation (BEPAR Grant Nr.1667). We thank D. R. Kasparyan, V. I. Tobias and S. A. Belokobylskij (Zoological Institute, Saint Petersburg) for identification of some Ichneumonidae and allowance of Braconidae collection; G. Broad (Natural History Museum, London) and C. van Achterberg (Nationaal Natuurhistorisch Museum, Leiden) for the access to the Braconidae collections; our technical assistant H. Zikmundová (Biology Centre, České Budějovice) who helped us with laboratory rearing of both Lepidoptera and Hymenoptera. We are thankful to Mark Shaw for his helpful comments and valuable suggestions on early draft of the MS. Last but not least we are grateful to the two anonymous reviewers for their useful comments.

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