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Photo
The cover picture shows male of *Aradus angularis*
J. Sahlberg, 1886 – Photo Gerhard Strauß.

See paper of **Gossner et al.** (2018) From the South and from the North? – *Quilnus marcosi* Heiss & Baena and *Aradus angularis* J. Sahlberg, two flat bug species new for Central Europe (Hemiptera, Heteroptera, Aradidae).

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Amended description and new combination for *Entomophthora nebriae* Raunkiaer, (1893), a little known entomopathogenic fungus attacking the ground beetle *Nebria brevicollis* (Fabricius, 1792)

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Abstract

A fungus attacking the ground beetle *Nebria brevicollis* (Fabricius, 1792) (Coleoptera, Carabidae) was collected in north-western Germany. The fungus was identical to *Entomophthora nebriae* Raunkiaer, 1893 (Entomophthoromycotina, Entomophthoraceae), described in 1893 from Denmark and so far only known from the type collection. We provide an amended description of *E. nebriae* based on the new collection and transfer the species to the genus *Erynia* as *Erynia nebriae* **comb. n.**

Zusammenfassung

Eine grössere Anzahl verpilzter Laufkäfer von *Nebria brevicollis* (Fabricius, 1792) wurden im Spätherbst 2016 in Nordrhein-Westfalen, Deutschland, gesammelt. Der Pilz wurde unter Beizug von Typusmaterial als *Entomophthora nebriae* Raukiaer, 1893 (Entomophthoromycotina, Entomophthoraceae) identifiziert. Dieser Pilz wurde 1893 in Dänemark beschrieben und seither nie mehr nachgewiesen. In der vorliegenden Arbeit geben wir eine erweiterte Beschreibung der Art, die wir auf Grund der morphologischen Merkmale in die Gattung *Erynia* transferieren als *Erynia nebriae* **comb. n.** Angesichts der Häufigkeit und der weiten Verbreitung von *N. brevicollis* in der Schweiz ist zu erwarten, dass *E. nebriae* auch hier vorkommt.

Introduction

Raunkiaer (1893) described *Entomophthora nebriae* as a pathogen of the ground beetle *Nebria brevicollis* F. (Coleoptera, Carabidae). Since its description in 1893, the fungus has not been reported in the literature. Recently, it was observed from near Bochum in Germany by Keller (2013). In the last three years (2014–2016) infected individuals of *N. brevicollis* were encountered regularly in a forest in the vicinity of Witten between November and January. But only at the end of 2016 was sufficient fresh material collected to enable examination of the fungus more thoroughly. In the present paper we report data of these new collections of *Entomophthora nebriae* upon which we base an amended description and propose a new combination, *Erynia nebriae*.

At the time, when Raunkiaer (1893) described *E. nebriae*, all entomophthoralean species were placed either in the genus *Entomophthora* Fresenius (1856) or in the genus *Empusa* Cohn (1855) the latter subsequently became a synonym of the former. Today the family Entomophthoraceae consists of three subfamilies, the Entomophthoroideae (four genera including *Entomophthora*) and the Erynioideae (six genera including *Erynia*) being the most important (Keller and Petrini 2005). They differ mainly by the conidiophores and the number of nuclei in the conidia. The former has unbranched conidiophores and multinucleate conidia, the latter has branched conidiophores and uninucleate conidia. In addition to that the genus *Entomophthora* Fres. (1856) has campanulate primary conidia, a single type of secondary conidia, and cystidia are absent when conidia are produced. On the other hand the genus *Erynia* (Nowakowski ex Batko) Remaudière & Hennebert (1980) has ovoid to elongate primary conidia and two types of secondary conidia produced on short conidiophores, and long and thick cystidia.

Material and methods

Eighteen beetles with recently sporulating fungus were collected between November 19 and December 16, 2016 along a forest path in a deciduous forest dominated by beech (*Fagus sylvatica* L.) and oak (*Quercus robur* L.). The forest belongs to the recreation area Hohenstein near Witten, Nordrhein-Westfalen, Germany, situated at an altitude of about 130 m. The collection site is defined by the coordinates 51.432241N and 7.353456E.

During the collection period the day temperatures varied between 2 and 14°C and the night temperatures between minus 6 and 12°C. Freshly collected beetles with sporulating fungus were individually placed in humid chambers with a slide placed 1–2 mm above the cadaver to collect the projected primary conidia. Some of these slides with primary conidia were subsequently placed in humid chambers with a second slide 1–2 mm above the one with primary conidia to collect the projected secondary conidia. The cadavers with sporulating fungus were placed in 70% ethanol. Additionally further examination of the fungal material was achieved by removing small portions of the fungus and carefully dissecting them into thread-like pieces.

The fungal material was mounted in lactophenol-cotton blue (LPCB) or in lactophenol-aceto-orcein (LPAO) as described by Keller (1987). All measurements were based, if not otherwise stated, on 25 structures per individual host, designated as one series. From each structure, usually more than one series was studied to assess variation. The number of series is given after the range of the mean values, the range of the extreme values (in brackets) and the ratio length/diameter (L/D).

Type material, labelled "Museum Botanicum Hauniense C-F-70834" was obtained from the University of Copenhagen. The paper envelop was labelled by hand: "Entomophthora Nebriae sp. n., på Nebria brevicollis Fab., Dyrehaven 11-1888, leg. C. Raunkiaer". It contained fragments of the exoskeleton of a beetle and dust-like material adhering to the paper. Small pieces of the exoskeleton and dust-like material scratched from the paper were mounted in LPCB and microscopically examined.

Results

The infected beetles were found on bare soil (about 85%), on wood sticks, on fallen leaves or on stones (Fig. 1). The abdomina of the sporulating cadavers were extremely swollen with the forewings spread and the hindwings lifted upwards (Fig. 2). Fresh mycelium was white (Fig. 2), older mycelium yellowish (Fig. 3). The mycelium covered the entire abdomen and the posterior part of the thorax. The cadavers could easily be removed from the substrate which infers that the rhizoids did not fix them strongly to the surface.

Only a few rhizoids were encountered. They were monohyphal with a diameter ranging from 14 to 30 µm (n = 7) ending with short root-like branches (Fig. 4). The conidiophores were densely packed, hyaline and branched. The spherical nuclei had a diameter of 7.0 (6–8.5) µm. The primary conidia measured 29.6–32.4 (27–37) µm × 9.7–11.5 (8–13) µm. They were uninucleate, bitunicate, elongate subcylindrical to slightly ellipsoidal to fusiform, sometimes slightly asymmetrical, with a large central vacuole. The papilla was rounded and joined smoothly the conidial body (Figs. 6 and 7). The L/D ratio ranged from 2.82–3.11 (5 series). Secondary conidia measured 23.2 (21–26) µm × 11.7 (11–13) µm, L/D = 1.98 (1 series). Young resting spores with simple wall were spherical and measured 33.9–35.0 (31–41) µm (2 series). The number of nuclei in young resting spores varied between 7 and 16 with an average of 11.1 (Fig. 8). However, since the nuclei only stained faintly and were not clearly demarcated from the surrounding material, this number may be slightly inaccurate. Mature resting spores were spherical and measured 32.4–35.6 (27–40) µm (5 series). The spore wall was 3.5–5.0 µm thick, yellow to slightly brown and smooth (Fig. 9). Resting spores were present in all examined cadavers. The cystidia were long and thick, the diameter above the conidial layer was 23.8 (14–39) µm (1 series). They distinctly towered above the conidial layer (Figs 2, 4) and contained many nuclei (Fig. 4). More details are given in Table 1. The fungal material was deposited at the herbarium ZT, accession number ZT Myc 58425.

Table 1. Dimensions of the fungal structures (pc = primary conidia, sc = secondary conidia, yRS = young resting spores, mRS = mature resting spores, s.d. = standard deviation).

Structure	Length (L) (s.d.) min-max	Diameter (D), (s.d.), min-max	Ratio L/D	Stain
pc 1	30.8 (2.21) 27-37	10.4 (1.18) 9-13	3.11	LPAO
pc 21	29.6 (1.75) 27-33	10.2 ((0.88) 8-12	2.90	LPAO
pc 22	30.2 (1.27) 28-33	9.7 (0.85) 8-12	3.11	LPAO
pc 23	31.7 (1.61) 28-35	10.5 (0.62) 9-12	3.01	LPCB
pc 24	32.4 (2.46) 28-37	11.5 (0.64) 11-13	2.82	LPCB
sc 25	23.2 (1.52) 21-26	11.7 (0.62) 11-13	1.98	LPCB
yRS 7		35.0 (2.09) 31-41		LPAO
yRS 8		33.9 (1.81) 31-38		LPAO
mRS 4		32.4 (2.41) 28-37		LPAO
mRS 6		33.1 (2.54) 27-39		LPAO
mRS 9		33.9 (1.62) 29-37		LPAO
mRS 14		35.6 (2.36) 31-40		LPAO
mRS 15		34.2 (2.04) 31-39		LPAO
Cystidia		23.8 (6.32) 14-39		LPAO

Figures 1–3. 1. *Nebria brevicollis* at an early stage of fungus sporulation. At this stage the beetle is still able to move it's legs and antennae (nat. length of the beetle about 13 mm). **2.** Beetle with fully sporulating fungus showing the extremely swollen abdomen. The strong cystidia are clearly visible at the edge of the fungus mass. **3.** At the end of the sporulating period the mycelium turns yellowish (Photos: T. Hülsewig).

The slide with type material contained some resting spores but no other fungal material. The resting spores were spherical, smooth-walled and measured 33.6 (29–41) µm (n=35).

Discussion and conclusion

Raunkiaer (1893) found *E. nebriae* on the ground beetle *Nebria brevicollis*. He described the conidia as ellipsoidal to fusiform, asymmetrical, often slightly curved, 28–37 µm long, 10–13 µm broad, hyaline and smooth, and the resting spores as spherical, 35–50 µm diameter, hyaline to pale brown developing outside the host. Our measurements and observations match Raunkiaer's data though minor differences to the original description were noted concerning the dimensions of the resting spores. Own measurements of resting spores of the type material, however, completely matched the dimensions of resting spores present in the material collected in Germany. The place of the formation of the resting spores (outside the host) was not examined in the present study. Considering the correspondence of all comparable data (symptoms, dimensions of conidia and resting spores, host species, season of the collections) we are convinced that the examined fungus is identical with the one described by Raunkiaer.

Present data also clearly show that *E. nebriae* is not a species of *Entomophthora* but is a typical member of the genus *Erynia*. This was already recognized by Humber and Ben-Ze'ev (1981) who proposed the new combination *Erynia nebriae* but did not publish it validly (ICN 2011, Melbourne Code, Art. 45.1; see also MycoBank number 111468).

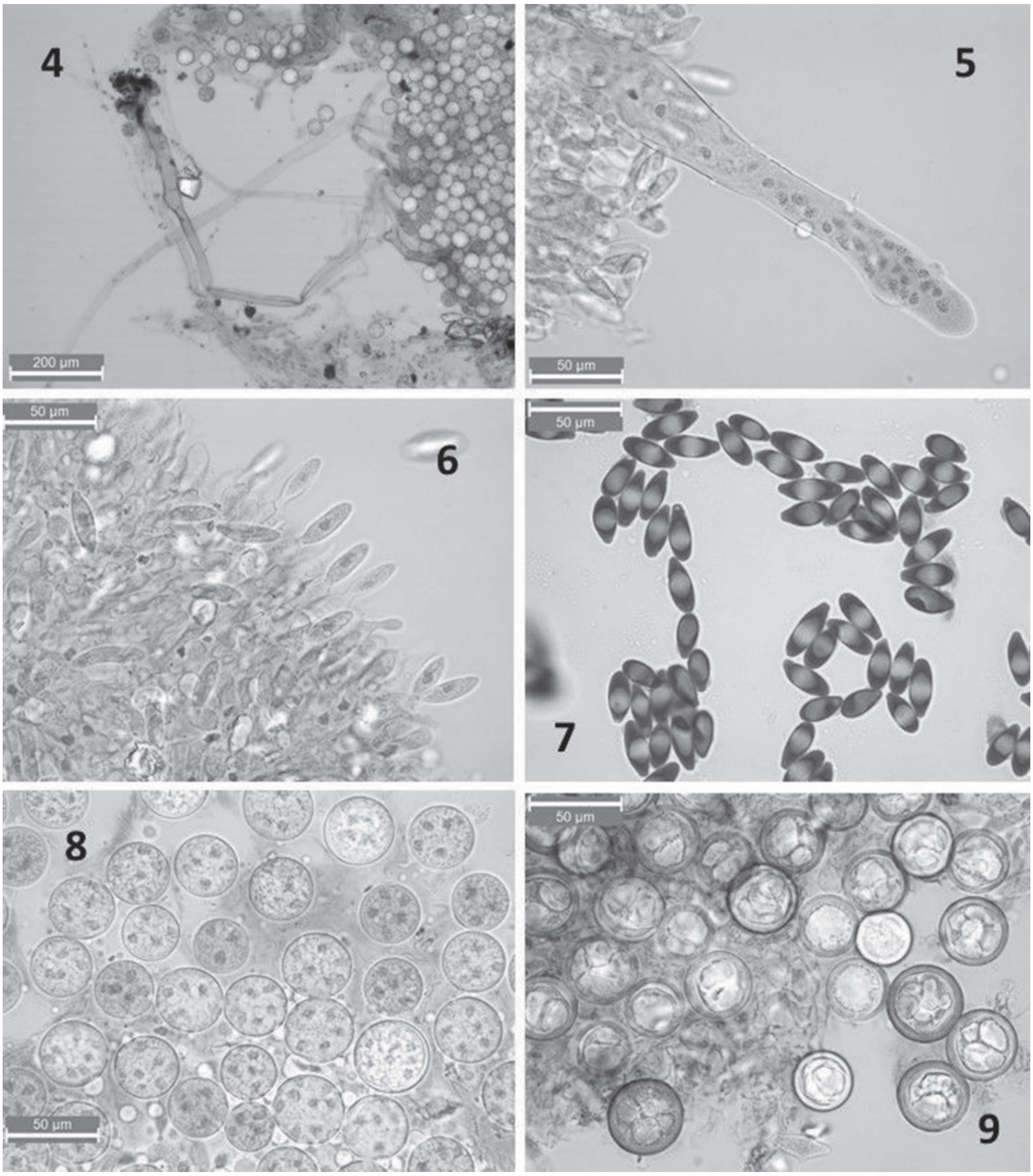
Therefore, we validate the name as

***Erynia nebriae* (Raunkiaer) S. Keller, comb. n.**
MB822120

Basionym: *Entomophthora nebriae* Raunkiaer, 1893, Bot. Tidsskr. 18: 109-110.

Syn.: *Zoophthora nebriae* (Raunkiaer) Batko (1966) MycoBank number 341184.

An aspect of the presented findings is noteworthy. The fungus was found at an epizootic level (in addition to the examined 18 individuals, there were more fungus-killed beetles, but in late state of sporulation or post sporulation) at the end of the seasonal activity of the host beetle. Even low temperatures at night, including below zero, did neither impede the epizootic nor kill the fungus. It is likely that the beetles at this time of year (late in the season) are more susceptible to the attack of the fungus. Another



Figures 4–9. 4. Rhizoid with dark and sparsely branched ending together with resting spores (LPAO). **5.** Cystidium with numerous nuclei (LPAO). **6.** Dense layer of conidiophores with developing primary conidia (LPAO). **7.** Primary conidia with prominent central vacuole (LPCB). **8.** Young resting spores with nuclei (LPAO). **9.** Mature resting spores with thick walls and one to several vacuoles depending on the stage of maturation (LPAO).

explanation is that the beetles became infected earlier in the season, before moving to their overwintering habitats. It is plausible that the fungus developed slowly within the beetles located in overwintering habitats at the low temperatures and that just prior to sporulation the fungus altered the host behaviour causing the infected beetles to leave the overwintering sites in order to die in the open environment. It is well established that many species of Entomophthorales manipulate the behaviour of their hosts to benefit their own survival and transmission (Roy et al. 2006).

Ground beetles are hosts of only two species of Entomophthorales with known taxonomic position. *Erynia nebriae* is the only one known to attack adult beetles while *Furia zabri* attacks larvae of *Zabrus tenebrioides.* The reason for this rareness may be the strong exoskeleton of the adults on one hand and the subterranean life of the larvae of most carabid species. Another species of Entomophthorales with unknown taxonomic position, *Tarichium jaczewskii* Zaprometov, was described from *Zabrus gibbosus*. According to Ben-Ze'ev and Kenneth (1982) *T. jaczewskii* is possibly the resting spore state of *F. zabri*.

Nebria brevicollis is among the best known, most widely distributed, and most frequently encountered carabid beetles in Europe. It prefers hedgerows, field borders and deciduous forests (Luka et al. 2009). In Switzerland the species is very common and widely distributed up to altitudes of about 1200 m (Luka et al. 2009). Under these circumstances we can expect the presence of *E. nebriae* in Switzerland. Unfortunately, most coleopterists are not interested in "mouldy" beetles but it would be advantageous to encourage recording of diseased beetles. This would improve our ecological knowledge of these fascinating fungi, particularly for antagonists such as Entomophthorales, and additionally contribute to improved understanding of the population dynamics of their hosts.

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From the South and from the North? – *Quilnus marcosi* Heiss & Baena and *Aradus angularis* J. Sahlberg, two flat bug species new for Central Europe (Hemiptera, Heteroptera, Aradidae)

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biogeography
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Abstract

The flat bug fauna of Switzerland is still insufficiently studied. We describe the first records of *Aradus angularis* J. Sahlberg, 1886 and *Quilnus marcosi* Heiss & Baena, 2006 (Heteroptera: Aradidae) in Switzerland from a burnt forest area in the canton Valais. These are also the first records for Central Europe. With these new records, the number of Aradidae species recorded in Switzerland increases to 21, and in the canton Valais to 16. A cantonal record list of aradid species in Switzerland and photographs of the two recently new recorded species are provided. The pyrophilous *A. angularis* shows a disjunct distribution pattern, disconnected from its known distributional range from Fennoscandia to Northeast China, which suggests that the species is a relict of the Ice Age in Central Europe. In contrast, the sub-Mediterranean *Q. marcosi* seems to have expanded its distributional range to the north-east or has previously gone unnoticed in Switzerland. The host plants of *Q. marcosi* include *Pinus nigra* and *P. sylvestris*.

Zusammenfassung

Die Rindenwanzen der Schweiz sind noch ungenügend erforscht. Wir beschreiben den ersten Nachweis von *Aradus angularis* J. Sahlberg, 1886 und *Quilnus marcosi* Heiss & Baena, 2006 (Heteroptera: Aradidae) für die Schweiz, von einer Waldbrandfläche im Kanton Wallis. Diese beiden Nachweise sind zugleich die ersten für Mitteleuropa. Dadurch erhöht sich die Zahl der für die Schweiz bekannten Aradidenarten auf 21, für das Wallis auf 16. Eine kantonale Liste der Aradidenarten der Schweiz und Photos der neu gemeldeten Arten werden vorgestellt. Der pyrophile *A. angularis* zeigt ein, von seinem bekannten Verbreitungsgebiet von Fennoskandinavien bis nach Nordost-China, disjunktes Vorkommen. Dies lässt vermuten, dass es sich bei der Art in Mitteleuropa um ein Eiszeitrelikt handelt. Im Kontrast dazu sieht es so aus, als dass die sub-mediterrane *Q. marcosi* ihr Verbreitungsgebiet nach Nordosten ausdehnt oder sie bisher in der Schweiz übersehen wurde. Das Wirtsbaumspektrum von *Q. marcosi* umfasst *Pinus nigra* und *P. sylvestris*.

Introduction

Flat bugs (Heteroptera: Aradidae) represent the most species-rich family of saproxylic Hemiptera, besides Achilidae and Derbidae (both Fulgoromorpha) (Gossner and Damken 2018). All aradids feed on the hyphae of wood-decomposing fungi, with only a few exceptions, such as *Aradus cinnamomeus* Panzer, 1806, which sucks on living pines. The bodies of juveniles as well as of adults are strongly widened and flattened, with the upper side featuring many pointed excrescences, humps and warts. Most species are highly specialized, living on specific decomposing fungi of certain woody plants, hidden under the bark or in the wood (Heiss and Péricart 2007). Some rather black-coloured species show an adaptation to forest fires, being able to rapidly detect burnt deadwood infested by a particular host fungi, e.g. *Aradus lugubris* Fallén, 1807 on *Daldinia loculata* (Lév.) Sacc. (Xylariaceae) (Wikars 2001). Their hidden way of life and the low amount of deadwood, in particular large dimensions, in Central European forests, explains the relatively few records of most flat bug species in this region (Gossner et al. 2007).

In the Palaearctic region, 241 species and nine subspecies from 28 genera of flat bugs are known to occur (Aukema and Rieger 2001, Aukema et al. 2013). Of these, 31 species, of which one is divided in two subspecies, of the four genera *Aneurus*, *Aradus*, *Calisius* and *Mezira* have been recorded in Central Europe (Günther and Schuster 2000, Heiss and Péricart 2007, Aukema et al. 2013), and 18 species, one comprising two subspecies, of this subset have been observed in Switzerland (Table 1). Due to losses of older collections, in particular that of Frey-Gessner (Anonymous 1866), and to unclear author names, historical records sometimes cannot be verified. Furthermore, some records are very questionable, such as *Aradus annulicornis* Fabricius, 1803 commented as the "most common Aradidae species in Switzerland" (Frey-Gessner 1864). In addition, a qualitative investigation on aradids in Switzerland has not been conducted so far. Based on that, the knowledge on the Aradidae of Switzerland is still very limited irrespective of the canton. However, 17 of the 19 known aradid species were also found after 1990 (Table 1). The record list for the canton Valais alone comprises 14 species and thus can be considered a hotspot of Aradidae diversity in Switzerland.

In this study, we present records of two species new to Central Europe, sampled in a forest stand in the canton Valais that was heavily affected by wild fire on 300 ha in 2003 (Wohlgemuth et al. 2005). The species *Aradus angularis* J. Sahlberg, 1886 was sampled during a post-fire invertebrate succession survey ten years after the fire. *Quilnus marcosi* Heiss & Baena, 2006 was sampled during a field excursion in 2017, 14 years after the fire.

Table 1. Cantonal list of Swiss records of Aradidae. The information refers to Heiss and Péricart (2007), supplemented by [1] = Records of the Swiss Federal Research Institute WSL (det. Heckmann), [2] = Wyniger (1999), Wyniger and Burckhardt (2003), [3] = Heckmann and Blöchlinger (in prep.), [4] = Di Giulio et al. (2000), [5] = Göllner-Scheiding (1988), [6] = Simonet (1954), [7] = present study, [8] = leg. det. coll. MMG, [9] = Records of the Swiss Federal Research Institute WSL (det. Grimm), [10] = Records of the Swiss Federal Research Institute WSL (det. Jenser), [11] = Records of the Swiss Federal Research Institute WSL (det. Stöcki); [12] = Hollier (2012); Canton = license plate abbreviations of cantons are used. ! = Occurrence after 1990 confirmed. ? = no evidence after 1990, with the year of the last record, if known. Older bibliographical references are not included in this table because many museum records (Entomological Collection of the Muséum d' histoire naturelle de Genève MHNG, Entomological Collection of the Muséum d' histoire naturelle de Lyon MHNL, Entomological Collection of the Swiss Federal Institute of Technology Zurich ETHZH) have been verified by Heiss and Péricart (2007) and some of them are references to these older bibliographical quotations. Many data on the cantonal occurrences in Heiss and Péricart (2007) do not include the dates of the records, and thus the differentiation into historical, older and current evidence is not possible in many cases.

Species	Canton	Current
Aneurus (Aneurodes) avenius (Dufour, 1833)	BL[2] BS[2] GE[12] SO[9] TI[1,2]	!
Aneurus (Aneurus) laevis (Fabricius, 1775)	AG[10] GE[6, 12] SO[9] TG[3] TI VD	!
Aradus angularis J. Sahlberg, 1886	VS[7]	!
Aradus aterrimus Fieber, 1864	GE VS[1]	!
Aradus betulae (Linnaeus, 1758)	TI[8] VS	!
Aradus betulinus Fallén, 1807	GL[1] GR SG[1] VS	!
Aradus cinnamomeus Panzer, 1806	GE GR LU[4] SO VD VS ZH[1]	!
Aradus conspicuus Herrich-Schaeffer, 1835	BE SO[9] TI VD VS	!
Aradus corticalis (Linnaeus, 1758)	GE[12] GR VD VS	!
Aradus crenaticollis R.F. Sahlberg, 1848	GL TI VS	!
Aradus depressus depressus (Fabricius, 1794)	AG BE[11] BL GE GL GR SH SG SO TG TI VS	!
Aradus krueperi Reuter, 1884	GE[12]	
Aradus lugubris Fallén, 1807	GR TI VS[1]	!
Aradus obtectus Vásárhelyi, 1988	GR SG VS	!
Aradus pallescens frigidus Kiritshenko, 1913	GR VS	!
Aradus pallescens pallescens Herrich-Schaeffer, 1840	GE VS	!
Aradus reuterianus Puton, 1875	VS	!
Aradus ribauti Wagner, 1956	VS	!
Aradus truncatus Fieber, 1860	GE GR	? 1974
Aradus versicolor Herrich-Schaeffer, 1835	AG[10] BE GE[12] SH SO SZ[5] TI VD ZH[8]	!
Quilnus marcosi Heiss & Baena, 2006	VS[7]	!

Methods

Sampling area

The sampling area is located within a large area of burnt forest in the Swiss Central Alps near Leuk (canton Valais; 46°20'N, 7°39'E) along a south-facing slope ranging from 800 to 2200 m a.s.l. close to the upper timber line (Fig. 1). The climate is continental with cold winters and dry summers (Zumbrunnen et al. 2009). Mean annual temperature decreases from 8.6°C at 640 m a.s.l. to 5.2°C at 1500 m a.s.l., while annual precipitation ranges from 600 mm at 640 m a.s.l. to 1000 mm at 1500 m a.s.l. (1961–1990) (Aschwanden et al. 1996). The wildfire (arson) occurred on 13 August 2003 and burnt 300 ha. The burnt area encompasses a gradient in vegetation ranging from a xerothermic mixed forest of oak (*Quercus pubescens* Willd.) and Scots pine (*Pinus sylvestris* L.) at 800–1200 m a.s.l., to spruce (*Picea abies* (L.) H.Karst.) at 1200–1800 m a.s.l., to larch (*Larix decidua* Mill.) mixed with woodland pasture at 1800–2000 m a.s.l. The forest is homogeneous within each vegetation type, but forest density and canopy coverage decrease with increasing altitude. Small gaps of former pasture activity and rock outcrops shape the forest structure at high altitudes (Wohlgemuth et al. 2008).

Sampling of the specimens

Aradus angularis was found during post-fire invertebrate succession surveys carried out by the Swiss Federal Research Institute WSL in 2004, 2005, 2006, 2008 and 2013 (e.g. Moretti et al. 2010). In these surveys true bugs were sampled using Combi-Traps (Fig. 1C), a yellow water pan (funnel) combined with a window trap, with two plexiglass screens at right angles to avoid the influence of wind direction, and one pitfall trap (13 cm diameter) at each trapping site (for details, see Duelli et al. 1999). Eighteen traps of each type were set along transects at three distinct altitudes (six traps per type and per altitudes at 1200, 1450, and 1700 m a.s.l.), and in three distinct areas: A) unburnt area, with ca. 150 m distance from the margin of the burnt area, B) burnt margin, within the burnt area, ca. 50 m from the forest margin, and C) a central burnt area within the burnt area, ca. 250 m from the forest margin. Along each transect, two trap sites per area were set, for a total of 6 trap sites per transect and 18 trap sites in total. During each sampling year, the traps were

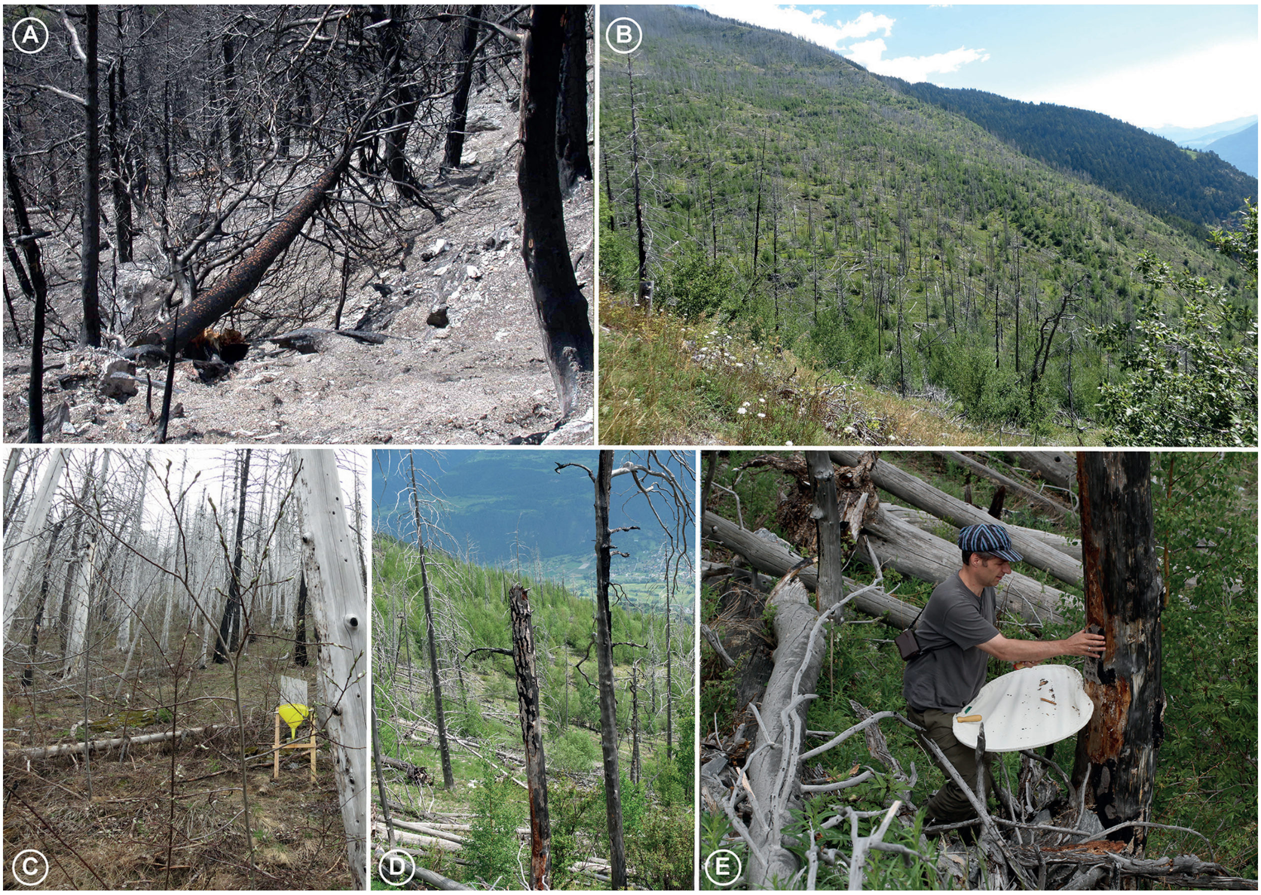

Figure 1. Photographs of the burnt site in Leuk, Valais, Switzerland: (**A**) Detail of the forest in 2003, one month after the fire; (**B**) Overview in August 2013 and (**C**) Detail of the site incl. Combi-trap in April 2013 (*Aradus angularis* J. Sahlberg, 1886 was sampled in June 2013); (**D**) Surrounding and (**E**) detail of the burnt pine tree (*Pinus sylvestris*) on which *Quilnus marcosi* Heiss & Baena, 2006 was detected in 2017 under one of a few remaining bark pieces. Photo credits: **A**: Marco Moretti, **B, E**: Beat Wermelinger, **C**: Martin Obrist, **D**: Martin M. Gossner.

emptied weekly from mid-April to early September. The insects were conserved in 70% alcohol.

During an excursion on 1 June 2017 to the burnt area two snags of burnt *Pinus sylvestris* trees were checked for Aradidae, one at 1480 m a.s.l. and the other at 1670 m a.s.l.

Results

During the post-fire invertebrate succession surveys by the WSL, two aradid species were recorded for the first time in Central Europe. *Aradus angularis* J. Sahlberg, 1886 occurred at a distance of 2177 km from the closest known record in Fennoscandia, and *Quilnus marcosi* Heiss & Baena, 2006 occurred 278 km from the closest record in southern France.

First detections and diagnoses

Aradus angularis J. Sahlberg, 1886

VS, Leuk, Thel, forest fire area, 1730 m a.s.l., 46°20’05”N, 7°39’28”E, 1 ♂ in Combi-trap, 19 June 2013. Voucher specimen is stored in the collection of R. Heckmann, Konstanz.

The species differs from other smaller, very dark species of the genus by its elongated body, almost-parallel outer margins of the wings and very thin antennas (Fig. 2A). To confirm identification of the specimen, the genitalia were dissected: The paramere has a typical distal basal tooth, distinct for *angularis*. Furthermore the 9th tergite shows a pointed shape, as shown in Heiss and Péricart (2007).

Quilnus marcosi Heiss & Baena, 2006

VS, Leuk, Thel, forest fire area, 1480 m a.s.l., 46°19’56”N, 7°38’51”E, 1 ♂, 1 juv., below one of a few remaining bark pieces on a sun-exposed burnt *Pinus sylvestris* snag, with a diameter at breast height of 35 cm (Fig. 1D, E). 1 June 2017, leg., det. M.M. Gossner, 19 June 2013. Voucher specimens are stored in the private collection of MMG, Fronreute, Germany.

The species (Fig. 2B) differs from other larger *Quilnus* species by rounded apical corners of the pronotum, the shorter second antennal segment and the structure of the genitalia (paramere, parandria, tergit IX), as shown in Heiss and Péricart (2007) and Heiss (2010).

Discussion

The records of the two new species increase the number of flat bug species in Switzerland to 21 species, with canton Valais being the most species-rich canton with 16 species. The frequent fires in south-facing regions, such as Valais and Grisons, as well as Ticino, which contribute to a large amount of deadwood, combined with warm and

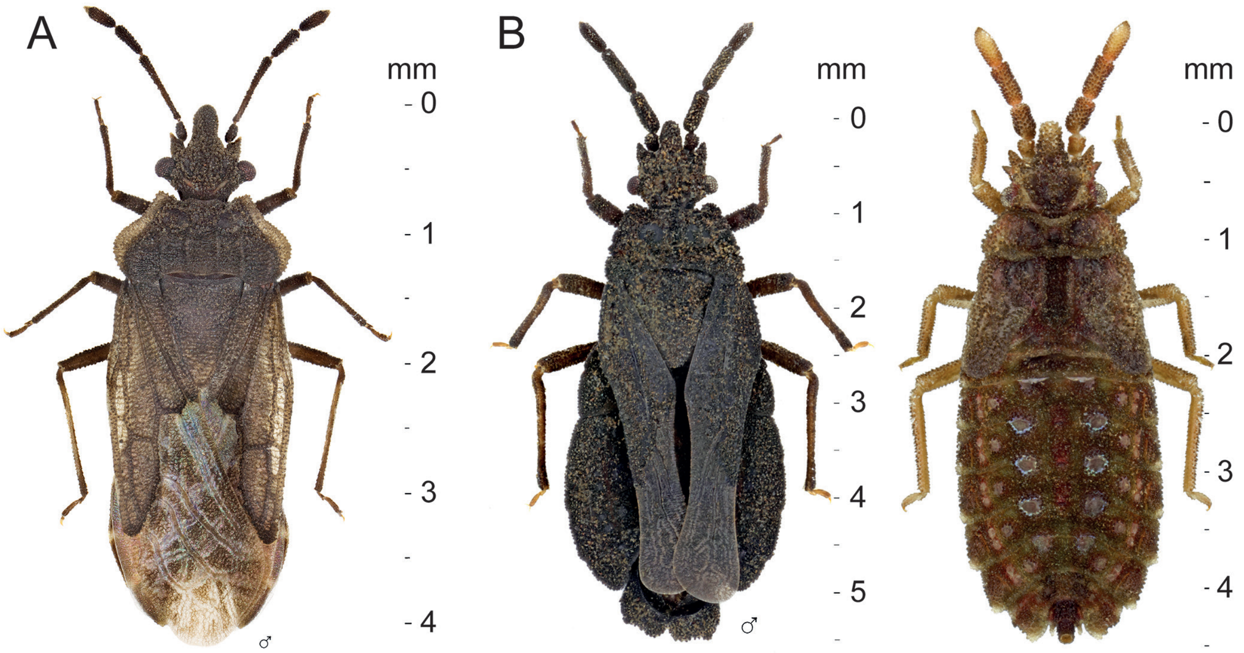

Figure 2. Two flat bug (Aradidae) species new to Central Europe, sampled in the burnt forest site in Leuk, Valais, Switzerland. (**A**) Male of *Aradus angularis* J. Sahlberg, 1886, sampled with a “Combi-trap” at 1730 m a.s.l. in June 2013 (sampling period 21 May to 23 June), leg. MM, det. coll. RH. Characteristic for the species are the size, the very thin antennae and the elongated body with the almost parallel outer margins of the wings and the form of the male genital structures. (**B**) Stenoptere male and juvenile of *Quilnus marcosi* Heiss & Baena, 2006, sampled under the bark of a burnt pine (*Pinus sylvestris*) tree at 1480 m a.s.l. on 1 June 2017, leg. det. coll. MMG. Characteristic for the species within the genus are the small size, the rounded apical corners of the pronotum and the form of the male genital structures. Photo credits: Gerhard Strauß.

dry climatic conditions, might be a main reason for such high diversity of Aradidae in Switzerland. Although the aradids are not well studied across cantons in Switzerland, data on saproxylic beetles also support the idea of Valais and Ticino being hotspots of saproxylic species diversity (Chittaro and Sanchez 2016, Sanchez et al. 2016). In the German federal states of Baden-Württemberg and Bavaria, 18 and 16 aradid species have been identified, respectively, which means that Switzerland, which is the same size but is not as well studied, already exceeds the number of species in Baden-Württemberg and Bavaria (Simon et al. 2018).

The record of *Aradus angularis* J. Sahlberg, 1886 in Switzerland is remarkable. In Europe, the species is distributed in Fennoscandia (Finland, Sweden) and European Russia (Fig. 3), but also occurs further east in Siberia and Mongolia (Heiss and Péricart 2007). More recently, it was also found in Northeast China (Bai et al. 2010). The vastly disconnected, rather disjunct occurrence in Switzerland at high altitude (Figs 3, 4) suggests that the species might be a relict of the last Ice Age. These relicts are cold-adapted species originating from the arctic or high alpine regions, which dispersed to lower elevation and to the south during cold periods and survived in higher elevations or "cooling holes" during later warmer periods (Hewitt 1999, Habel and Assmann 2010). Other examples of such Ice Age relicts among Heteroptera are the Corixidae *Arctocorisa carinata* (C. Sahlberg, 1819) (Jansson 1986), the Lygaeidae *Geocoris lapponicus* Zetterstedt, 1838 (Péricart 1998), and the Saldidae *Micracanthia fennica* (Reuter, 1848) (Günther and Strauß 2006).

Aradus angularis lives on dead burnt conifer trees, in particular *Picea* (Helioevaara and Vaisanen 1983), a tree species also found in the sampling area. It is listed as vulnerable in the Red Lists of Sweden and Finland (Gärdenfors 2000, Rassi et al. 2001). In Sweden and Finland the species has been found on charred tree trunks up to three years after forest fires (Helioevaara and Vaisanen 1983, Pettersson and Nilsson 1986, Heiss and Péricart 2007, Hagglund et al. 2015, Heikkala et al. 2017) (Fig. 4) and

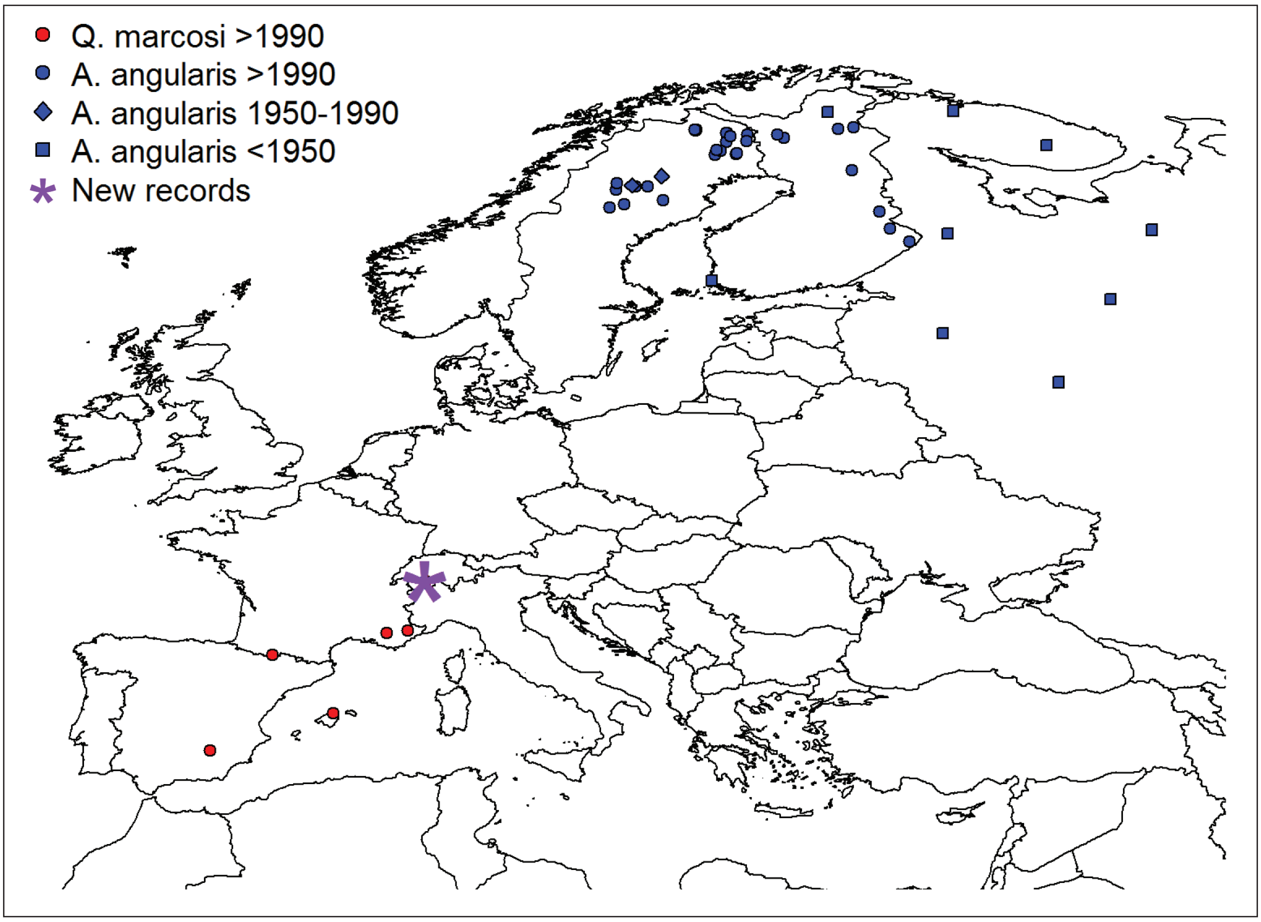

Figure 3. Records of *Aradus angularis* J. Sahlberg, 1886 (blue, n=46) and *Quilnus marcosi* Heiss & Baena, 2006 (red, n=7) in Europe, and new records of both species in Switzerland (star). Data are based on Heiss and Péricart (2007), Brustel (2009), Heiss (2010), Esser (Mallorca, unpubl., leg. Esser, det. coll. MMG) and the website of the Muséum national d'histoire naturelle Paris (https://science.mnhn.fr/institution/mnhn/collection/eh/item/eh18974?lang=en_US) for *Q. marcosi* and Reuter (1900), Helioevaara and Vaisanen (1983), Pettersson and Nilsson (1986), Lammes and Rinne (1990), Roth and Coulianos (2014), Hagglund et al. (2015), Heikkala et al. (2017), Heikkala (pers. com.), Martikainen (pers. com.), Artportalen Sveden (https://artfakta.artdatabanken.se/taxon/100379) and Kirishenko (1951) for *A. angularis*. Please note that data points in the European part of Russia represent the centre of each Oblast in which the species has been recorded.

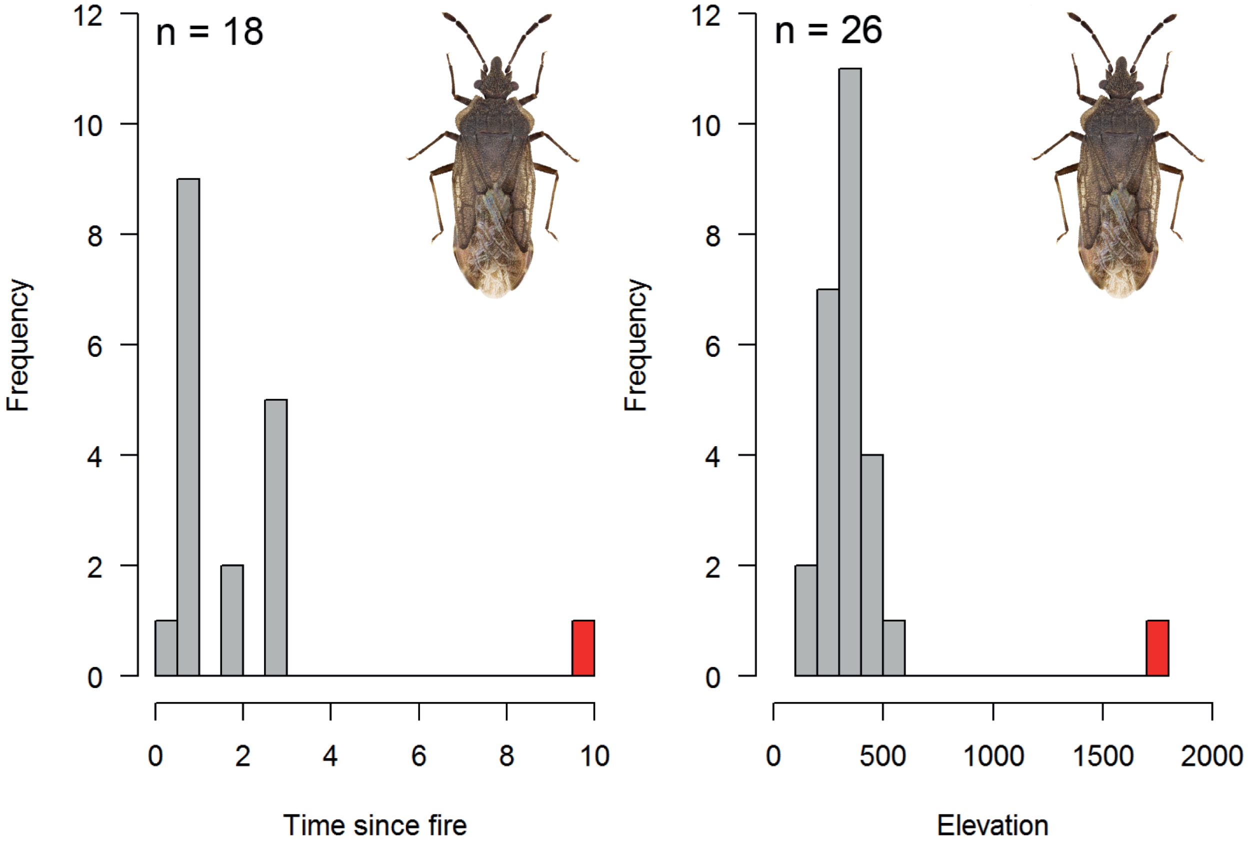

Figure 4. Frequency of occurrences of *Aradus angularis* J. Sahlberg, 1886 with respect to time since fire (left) and elevation (right), based on previous records in Fennoscandia (grey) and the new record in Switzerland (red). Please note that data were available for a subset of records only.

therefore is classified as a pyrophilous species by Wikars (1992, 1997). It is assumed that the pyrophilous Aradidae depend on pioneer fire-related ascomycete fungi that arrive early on competition-free substrates but are rapidly outcompeted by other fungi (Wikars 1997). The host fungi of *A. angularis* remains unknown. Surprisingly, we found only a single specimen of this species, 10 years after the fire, although sampling started in the year after the fire and continued two, three and five years after the fire occurred. This finding does not support the classification as a pyrophilous species, at least not as an obligatory one. In contrast, several individuals of another pyrophilous species, *Aradus lugubris* Fallén, 1807, and two pyrophilous longhorn beetle species (Pradella et al. 2010) were caught in the year after fire, in the same trap where *A. angularis* was captured, and at several other sampling sites. This suggests that the trapping method is suitable for catching pyrophilous species. It is still unclear how pyrophilous species survive during periods without forest fires. They might persist hidden in old burnt forests or in matrix forests with a large amount of deadwood (Saint-Germain et al. 2008), or they might extend their diet to other fungi that are not dependent on fire. Alternatively, being generally highly mobile species, the pyrophilous specimen reported here might have dispersed from a nearby burnt forest stand, such as that in Visp (21 km distance), where a large intensive forest fire occurred in 2011, and become caught in the trap. Similar to our observations regarding flat bug species, tens of individuals of one carabid (ground beetle) species (*Pterostichus quadrifoveolatus* Letzner, 1852), which is pyrophilous according to Wikars (1997), was found in the burnt forest in Leuk in 2013, while other pyrophilous beetles were only found in the first years after fire (Pradella et al. 2010). This suggests that some species are obligatory pyrophilous, while others might have a higher flexibility in terms of feeding or habitat requirements.

The record of *Quilnus marcosi* Heiss & Baena, 2006 is less surprising, as it has already been detected 279 km away in southern France in the West Alps (Heiss 2010). *Quilnus marcosi* has a sub-Mediterranean distributional range, expanding to the mountain range of the Alps. The species seems to be rare, as it was discovered only eleven years ago and not more than seven sites of occurrences of this species are known so far (Fig. 3). All previous records have described occurrences in southern Europe, including Spain and France. Thus, the present record might show its range expansion to Central Europe or a general wider distribution for the first time. Heiss (2010) already suggested that this species might further spread to the north and east, in particular with climate warming. However, Heiss (2010) predicted only colonisation of dead *Pinus nigra*, within its disjunct distributional range from the Iberian Peninsula south of the Alpine mountain range up to the relict site at the eastern border of the Alps in Austria. The present record is the second one from *Pinus sylvestris*, following a record from Vallée du Rioumajou (Hautes-Pyrénées) (Brustel 2009). As a larva was also found in the tree in the present study, it is likely that this tree species can also be used as a host, which would allow further spread within the distributional range of *P. sylvestris*. The host fungi of *Q. marcosi* is the polyporous *Antrodia xantha* (Fr.) Ryvarden, 1973, which occurs on several *Pinus* species (Brustel 2009). There are no indications that *Q. marcosi* is associated with burnt deadwood. Thus, the large supply of deadwood resources after forest fires most likely promotes the occurrence of this species, as has been shown for other Aradidae species (Seibold et al. 2014).

Conclusions

The overall high number of flat bug species that have been recorded previously in Valais, Switzerland (Heiss and Péricart 2007) and the two recent species records suggests that this region may be a hot spot of flat bug diversity in Central Europe. This is also supported by other taxa that depend on deadwood such as saproxylic beetles (Chittaro and Sanchez 2016, Sanchez et al. 2016). The canton Valais has an unexpected long fire history (see Gimmi et al. 2004) and burnt areas and hotspots similar to the study area Leuk might exist in the region. The large amount of deadwood created by frequent forest fires most likely generates suitable habitats for pyrophilous as well as non-pyrophilous species. We strongly encourage entomologists to conduct a qualitative and even standardized quantitative assessment (see Gossner et al. 2007, Marchal et al. 2013, Morkel 2017) of aradids across Switzerland to evaluate the diversity distribution of this highly specialised saproxylic family with many endangered species.

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PENSOFT.

Alpine Entomology

On the genus *Chaetocladius* s. str. Kieffer, 1911 from Switzerland with descriptions of five new relic species occurring in glacial alpine springs and streams (Diptera, Chironomidae)

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conservation

Abstract

A description of the male adults of five *Chaetocladius* s. str. species (*C. castellae* **sp. n.**, *C. lencioniae* **sp. n.**, *C. lodscrozetae* **sp. n.**, *C. macunensis* **sp. n**. and *C. muttensis* **sp. n.**) is provided based on material collected in some glacial alpine springs and cold streams located in the Swiss Alps (altitude 1800–2700 m). Male adult of the nearest *Chaetocladius* species known from Europe and neighbouring areas belong to: *C. aedeagolobatus* Rossaro, Magoga & Montagna, 2017; *C. insolitus* Caspers, 1987; *C. gracilis* Brundin 1956; *C. antipovae* Makarchenko & Makarchenko, 2011; *C. dissipatus* (Edwards, 1929), *C. holmgreni* (Jacobson, 1998), *C. egorych* Makarchenko & Makarchenko, 2017. Although some resemblance can be found between the five diagnosed and described species and other related members of the *Chaetocladius* genus, the taxonomic position cannot be clarified until current comprehensive work on the genus is complete. Geographical distribution of the five new species is currently restricted to the two Alpine Swiss glacial catchments: upper basins of the Rhône River and Muttbach streams; streams and lakes delimited by the Macun area. This highlights the importance of some high mountain ranges, considered as cold glacial enclaves and hotspots of endemism, in the preservation and persistence of autochthonous alpine relic species. Such species are considered as relevant biogeographic representative and their loss would be biologically indicative of global warming and climate change. Currently, there are only seven recorded *Chaetocladius* species from Switzerland: *C. coppai* Moubayed-Breil, 2017; *C. laminatus* Brundin, 1947; *C.* cf. *longivirgatus* Stur & Spies, 2011; *C. melaleucus* (Meigen, 1818); *C. perennis* (Meigen, 1830); *C. piger* (Goetghebuer, 1913); *C. suecicus* (Kieffer, 1916). Consequently, the description of the five new species increases the total number in the genus *Chaetocladius* to twelve for this country. Remarks and comments on the taxonomic position, ecology and geographical distribution of the new described species, with key to known male adults from the upper catchment of Rhône River (including Muttbach valley) are provided..

Introduction

Alpine freshwaters areas occurring in mountainous landscapes and high elevation are characterized by severe environment (Ward 1994). The relatively harsh environmental conditions prevailing, such as long winters, thick snow and ice cover, low temperature and limited water productivity, contribute to the settlement of highly specialized aquatic fauna (especially aquatic insects). Furthermore, the insular nature of alpine landscapes constrains the dispersal and distribution of species in reinforcing and maintaining high level of endemism. Alpine freshwater habitats thus harbour a plethora of highly specialized species that exhibit a comparably small distributional range, making them particularly susceptible to environmental change.

The Chironomidae family (Diamesinae and Orthocladiinae in particular) predominates in the high alpine ponds/lakes and stream network with a large number of species compared to the other macroinvertebrates such as other Diptera, Ephemeroptera, Plecoptera, Trichoptera, Oligochaeta (Milner and Petts 1994, Ilg et al. 2001, Lods-Crozet et al. 2001, Hieber et al. 2005, Robinson et al. 2007, 2016, Lods-Crozet et al. 2012). Most of the alpine studies in hydrobiology were focused on macroinvertebrates inhabiting glacial streams (Milner et al. 2001), which revealed that Chironomidae were predominant and characterized by cold adapted species (Kownacki et al. 2000; Lods-Crozet et al. 2001; Moubayed-Breil and Lods-Crozet 2016; Robinson et al. 2007, 2016; Moubayed-Breil and Dia 2017). Non-glacial aquatic systems, such as springs were also well represented in high alpine landscapes (Lencioni et al. 2012) but have not received much attention so far. High mountain rheocrenes located in the Swiss Alps mostly consist of sensitive and vulnerable habitats, which give shelter, refuge and sanctuary for populations and species potentially rich in divergent genetic lineages and thus resembling diversity hotspots of global significance (Monaghan et al. 2005). Some cold crenobiontic relic species were found in the pristine headwaters in the Alps including two new recently described species (*Chaetocladius coppai* Moubayed-Breil, 2017; *Heleniella helvetica* Moubayed-Breil & Lods-Crozet, 2016) from remote areas in small groundwater resurgences and spring-fed streams located in the upper basin of the Rhône River.

Based on knowledge provided on the taxonomy, geographical distribution and ecology of the known *Chaetocladius* species from Europe and the Palaearctic Region (Brundin 1947, 1956; Pankratova 1970; Sæther 1980, 1990; Caspers 1987, Cranston et al. 1989, Bhattacharyay et al. 1993, Lods-Crozet 1998, Moubayed 1989, Makarchenko and Makarchenko 2001, 2004, 2007, 2011a-b, Langton and Pinder 2007, Lencioni et al. 2007, 2012, Zelentsov 2007, Stur and Spies 2011, Ashe and O'Connor 2012, Kobayashi 2012, Wang et al. 2012, Sæther and Spies 2013, Makarchenko et al. 2017, Moubayed-Breil 2017, Rossaro et al. 2017), the genus *Chaetocladius* Kieffer, 1911 currently comprises worldwide about 79 valid species.

Based on material collected between 1997–1998 and 2013 in high alpine springs and small cold streams located in the Swiss Alps, we here describe five new species of *Chaetocladius* s. str for which we discuss the taxonomic position, ecology and geographical distribution. A key to the known male adults from the catchment of the upper Rhône (including Muttbach glacier), with remarks on some related species from the Palaearctic Region are also provided.

Material and methods

Study sites

Numerous sampling sites are located along some glacial streams and streamlets delimited by the three Alpine Swiss glacial catchments: - the Muttbach valley and the Rhône River alluvial plain "Gletschboden" in the Central Alps (46°34'12.258"N; 8°22'45.623"E); - the Macun streams and lakes in the Swiss National Park, Eastern Alps (46°43'39.678", 10°07'55.764"E).

The Mutt stream (length: 3600 m) originating from the Mutt glacier (area 0.6 km^2, altitude 2582–3000 m) represents the major tributary of the upper Rhône catchment. It joins the Rhône River at the upper limit of a floodplain and contributes approximately 10 % (0.62 m^3.s^{-1} in 1997) to the Rhône discharge (Knispel and Castella 2003). The upper parts of the Mutt catchment are composed mainly of moraines and bare rocks including a carbonate outcrop. Alpine grasslands are found in the lower parts while *Salix* spp. and *Alnus viridis* thickets, together with herbaceous alpine vegetation, are predominant in the floodplain (Lods-Crozet et al. 2001).

The Rhône River alluvial plain "Gletschboden" is located in the upper catchment of the Rhône River. The major water source is the Rhône glacier (area 10.2 km^2). Below the glacier snout, situated at an altitude of 2210 m, the Rhône River flows down a 400 m high granite cliff (slope 63 %) and enters an alluvial plain (length: 2000 m). During the last century, the retreat of the Rhône glacier has left valley moraine deposits and a braided channel pattern. The upper part of the Rhône is a kryal segment (Ward 1994) where water temperature rarely exceeds 4 °C. Mean annual discharge of the Rhône in 1998 was 2.88 m^3.s^{-1} and its hydrograph reveals a discharge peak in summer with large daily flow fluctuations (Knispel and Castella 2003). Highly diverse thickets of *Salix* spp. and *Alnus viridis* and herbaceous alpine vegetation are predominant in the alluvial plain, with some *Larix decidua*.

The Macun cirque site is a high alpine cirque (> 2600 m), which is located in the Eastern Alps (Swiss National Park). It was annexed to the park in 2000 and currently is an area designed for long-term monitoring of alpine water bodies (springs, streams, ponds, lakes). The region comprises more than 35 small lakes or permanent ponds and around 10 small temporary ponds scattered within two sub-basins. A north basin is fed mostly by snowmelt and groundwater, whereas the south basin is fed by glacial melt from a number of rock glaciers. Precipitation is low, typically being around 850 mm per year. Bedrock geology is crystalline (ortho-gneiss) rock. The area is above the tree line and the drainage area of each pond is characterised by a mixture of two types of land cover, rock and alpine grassland (Robinson and Oertli 2009, Lods-Crozet et al. 2012).

The sites in the Central Alps were investigated three times a year between 1996 and 1998, during the three major annual hydrological phases: in June during snowmelt, in August during ice melt and in September at low water level. The field protocols followed closely those established in the EU-project 'AASER' (Brittain and Milner 2001, Lods-Crozet et al. 2001, Knispel and Castella 2003, Lods-Crozet 2012).

Sampling procedure

Ten sampling points were chosen randomly within each site. Depth, flow velocity and bed sediment composition were recorded at each of the 10 points before benthic sampling. The fauna was then collected into a 250-mm-mesh pond net at these points by kick sampling within a 30 × 30-cm area for 30 s. Adult material was collected using Malaise traps which were set up for a minimum of five days. In the Eastern Alps, during summer 2013, a supplementary survey was conducted to complete the standardized monitoring of small water bodies and streams within the Macun cirque (Lods-Crozet et al. 2012). Adult material of the five new described *Chaetocladius* species was collected for fifteen days using Malaise trap placed in the surrounding area of three lakes (altitude 1800–2700 m). Pupal exuviae were collected with a drift net from the shore.

All samples were preserved in 70 % Ethanol. Material of male adults were cleared of musculature in 90 % lactic acid (head, thorax, abdomen and anal segment) for about 60 to 80 minutes, which can be left overnight at room temperature without any detrimental effect or damage. The specimens were checked under a binocular microscope after 20 minutes in lactic acid to determine how the clearing was progressing. When clearing was complete the specimens were washed in two changes of 70 % Ethanol to ensure that all traces of lactic acid were removed. Compared to clearing with potassium hydroxide, or other clearing solutions, no deterioration of the typical “original” structure is reported by using lactic acid. All examined material was mounted in polyvinyl lactophenol, remaining material including paratypes were preserved in 70 % Ethanol. The eye on one side was dissected from the head, which ensures that the hairs on the inner margin of the eye are more clearly visible. Before the final slide mountings (dorsally) of the type and paratype material, the hypopygium including the IXth tergum, the anal point, the gonocoxite and the gonostylus, were viewed ventrally and laterally to examine and draw from both sides all the necessary details of the species. In particular, the ventral view of hypopygium was illustrated when anal point and tergite IX were removed. Morphological terminology and measurements largely follow Sæther (1980) and Cranston et al. (1989) for the imagines.

Results

Taxonomy

Chaetocladius castellae Moubayed-Breil, sp. n.

http://zoobank.org/A9B87258-1379-46EE-878B-B0850B31EEDF

Material examined. Holotype. **Switzerland**: Gletschboden alluvial plain, streamlet and springs located close to the upper catchment of the Rhône River, upstream to the Mutt stream confluence (station U2), altitude 1800 m, 30.IX.1998; 46°34’15.466”N, 8°22’47.054”, 1 male adult, leg. B. Lods-Crozet. Environmental data of Rhône water are: crystalline water, conductivity 3.3–17.8 µS/cm; temperature 2–4 °C during late spring to late summer (June-September).

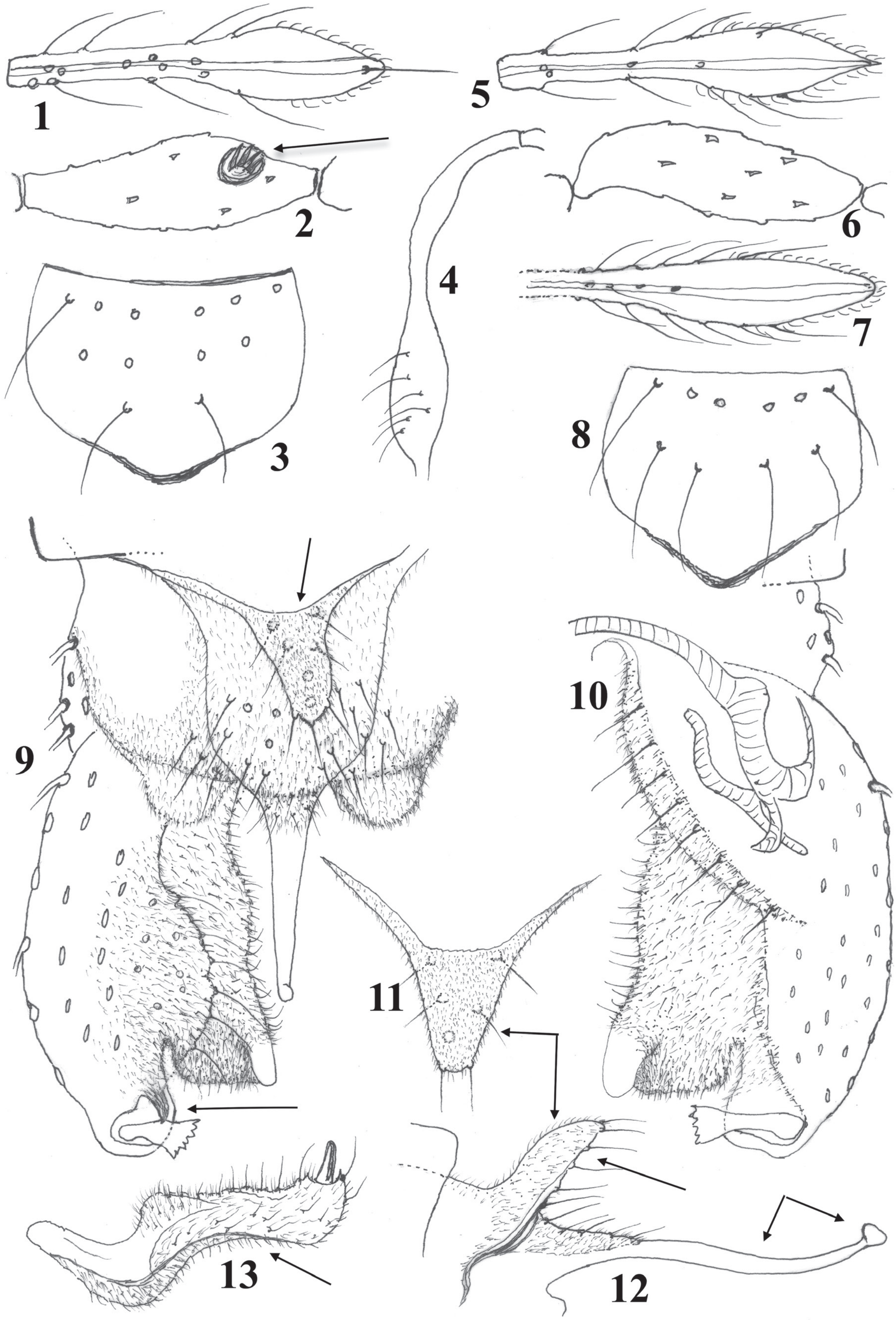
Paratypes. **Switzerland**: Mutt stream (Station M4), altitude 2100 m. 07.VIII.1997, 46°34’04.946”N, 8°24’17.159”E, 2 male adults, leg. B. Lods-Crozet. Environmental data of Mutt stream water are: crystalline water, conductivity: 61–183 µS/cm; temperature: 1–8 °C during late spring to late summer (June-September). In the streamlet and rheocrenes located close to station M4, conductivity ranged between 103 to 253 µS/cm; temperature 4.4. to 14.8 °C (Ilg et al. 2001).

Holotype (mounted on 1 slide; GBIFCH 00460692) and one paratype (on slide) are deposited in the collections of the ‘Musée cantonal de Zoologie, Palais de Rumine, 6 place de la Riponne, CH-1014 Lausanne, Switzerland. Remaining paratype (on slide) is deposited in the collection of the senior author.

Diagnosis. *C. castellae* sp. n. is separated from its nearest species (*C. insolitus* and *C. muttensis* sp. n.) by the following main characters: nearly similar shape of tergite IX, which bears a long nose-like dorsally projecting lamella-like structure; long triangular anal point; large inferior volsella; sinuous gonostylus. However, *C. castellae* sp. n. can be separated from the two previously cited species in having: palpomere 3 bearing 3–4 sensilla clavata (tubule-like) grouped in a ring; dorsal projecting lamella on tergite IX (more strongly projecting upwards), which bears 5–6 setae on ventral side; anal point long and triangular bearing 13–15 dorsal setae on its basal area and 5–6 smaller setae placed on proximal part; gonocoxite markedly swollen medially and bearing 1 row of 7–8 setae on inner dorsal margin, apex of inner dorsal margin with (or without) a distinct triangular to sub-rectangular tubercle; inferior volsella long, tongue-like, downwardly extending to distal part of gonocoxite; gonostylus nearly linear and typically sinuous.

Description. Male imago (n = 3 male adults; Figs 1–4, 9–18). Small sized *Chaetocladius* species. Total length 3.00–3.10 mm. Wing length 1.87–1.88 mm (markedly short). General colouration contrasting brown to dark brown. Head dark brown, antennae pale; thorax contrasting brown to dark brown, mesonotal stripes distinctly dark brown; wing pale; legs brown. Tergites I-VIII brown; anal segment brown to dark brown.

Head. Eyes bare, hairs present on median part of inner eye margin. Temporals consist of 10 setae including 6 inner and 4 outer verticals. Antenna 650–660 µm long, 13-segmented; length (µm) of segments: 1, 50; 2–12, 30–35 (nearly sub-equal); last flagellomere 150–160; apex of last flagellomere (Fig. 1) moderately clubbed, bearing 1 pre-apical seta and numerous sensilla chaetica; antennal groove beginning on segment 3 and reaching ultimate flagellomere; AR 0.30–0.40. Clypeus (Fig. 3) broad, nearly rectangular, cup-like in shape with rounded sides and bearing 12 setae in 3 rows. Palp 5-segmented; length (µm) of segments 1–5: 40, 45, 115, 120, 135; palpomere 3 (Fig. 2) with sensilla clavata including: 4–5 sparsely distributed and 3–4 (tubule-like) grouped in a ring which



Figures 1–13. Male adult of *Chaetocladius* spp. *C. castellae* sp. n.: **1**, last flagellomere; **2**, sensilla clavata on palpomere 3; **3**, clypeus; **4**, antepronotum, left side. *C. muttensis* sp. n.: **5**, last flagellomere; **6**, palpomere 3; **8**, clypeus. *C. insolitus*: **7**, apex of last flagellomere. Hypopygium of *C. castellae* sp. n.: **9**, dorsal; **10**, ventral with anal point and tergite IX removed; **11**, dorsal lamellae of tergite IX; **12**, anal point and tergite IX in lateral view; **13**, left gonostylus in dorsal view.

is placed on distal part. Thorax. Antepronotum (Fig. 4) well developed with fused lobes, lateral antepronotals 4–5 grouped close together; acrostichals consist of 15–16 short setae starting close to antepronotum and placed in 1–2 rows; dorsocentrals 10–11 placed in 1–2 rows; humeral pit ovoid, without contrasting spots; prealars 4–5 in 1 row; supralars absent. Scutellum with 6 uniserial setae. Wing. Brachiolum with 1 seta. Membrane densely covered with coarse punctuation. Distribution of setae on veins: R, 15–17; R_1, 2–3; R_{2+3} 12–16; remaining veins bare. Squama with 5 uniserial setae. Legs. Tibial spurs of PII and PIII are *Chaetocladius*-type, with prominent and projecting apicolateral denticles. Sensilla chaetica present on: tibia and tarsomeres ta_1-ta_2 of PI; tibia and tarsomeres ta_1-ta_3 of PII; tibia and tarsomere ta_1 of PIII. Length (µm) and proportions of legs as in Table 1.

Hypopygium in dorsal, ventral and lateral view as in Figs 9–10; ventral view (Fig. 10) with tergite IX and anal point removed. Tergite IX broadly sub-rectangular with nearly straight posterior margin; basal median area with a characteristic lamella-like structure which is orally directed and markedly visible in lateral view (Figs 9, 11, 17–18); dorsal lamella-like structure is cup-like in dorsal view and a long nose-like shape in lateral view, bearing 5–7 setae place on ventral side (dorsal side lacking setae); presence of 6–8 setae near the posterior margin (3–4 on each side of base of anal point). Anal point (Figs 9, 12, 17) about 90–95 µm long, maximum width at base 30 µm, reaching base of lobe of inferior volsella; basal part large, cup-like, bearing 13–15 dorsal setae including 5–6 smaller and placed on proximal part; median and distal part uniformly elongated and distinctly parallel-sided between base and apex, with an average of 15 µm wide; distance between base of the lamella and base of anal point 35 µm. Laterosternite IX with 5 lateral setae on each side, posterior margin distinctly bi-lobed (lobes visible on each side of the base of anal point). Transverse sternapodeme arc-like, with a distinct rounded oral projection on each side; lateral sternapodeme broad; phallapodeme slender and sinuous medially at joint with lateral sternapodeme. Virga indistinct. Gonocoxite 240–250 µm long, markedly broad medially where maximum width is about 85–90 µm; slightly truncate apically; inner dorsal margin (Fig. 9, 15, 17) markedly swollen medially and with 1 row of 7–8 curved setae, apex of inner dorsal margin bearing a characteristic conspicuous tubercle (triangular to sub-rectangular); ventral inner margin (Fig. 10) with 7–8 inwardly directed setae. Inferior volsella 160 µm long, 75 µm maximum width, clearly visible in both dorsal and ventral view; tongue-like and posteriorly extending from base of gonocoxite till its distal part; posterior margin distinctly straight, apical inner part nose-like and entirely hyaline in both dorsal and ventral sides; distal outer margin weakly separated from inner margin of gonocoxite. Gonostylus (Figs 13, 16) 140–145 µm long, maximum width 40–45 µm; nearly linear with both anterior and posterior margins markedly sinuous; crista dorsalis low and distinct, bearing several short orally directed setae; megaseta 18–20 µm long, conspicuous and slightly bent outwards.

Table 1. *Chaetocladius castellae* sp. n. Length (µm) and proportions of legs PI, PII and PIII.

	fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV	BR
PI	850	940	570	320	220	140	120	0.61	2.95	3.14	2.50
PII	835	830	330	230	170	110	100	0.40	3.27	5.05	2.00
PIII	940	950	550	280	220	120	100	0.58	3.38	3.43	2.40

Taxonomic position. *C. castellae* sp. n. keys near *C. insolitus* and *C. muttensis* sp. n. based on the following resembling characters: presence of dorsal long projecting lamella-like structure; long triangular anal point; large inferior volsella; sinuous gonostylus. However, *C. castellae* sp. n. can be separated from the two previously cited species by the following main differentiating features: dorsal lamella-like structure on tergite IX is more strongly projecting and bearing setae on ventral side (Figs 9, 11, 12, 17–18), while it is entirely bare in *C. insolitus* (Caspers 1987, Figs 3–4) and *C. muttensis* sp. n. (Figs 58, 62, 65); distal part of inferior volsella differently figured in *C. muttensis* sp. n. (Figs 58–59, 65); gonostylus typically sinuous anteriorly and posteriorly (Figs 13, 16), while it is narrowing distally and bearing a typical nose-like expansion placed posteriorly in *C. muttensis* sp. n. (Figs 58, 63–65).

Etymology. The new species is named *castellae* in honour to our colleague Dr. Emmanuel Castella, who worked closely together with B. Lods-Crozet on the AASER project (AASER: Alpine and Arctic of Streams Ecosystem Research) during three years (from 1996 to 1998). He is currently senior research scientist at the University of Geneva and at the head of a research group, which focuses on aquatic invertebrate ecology.

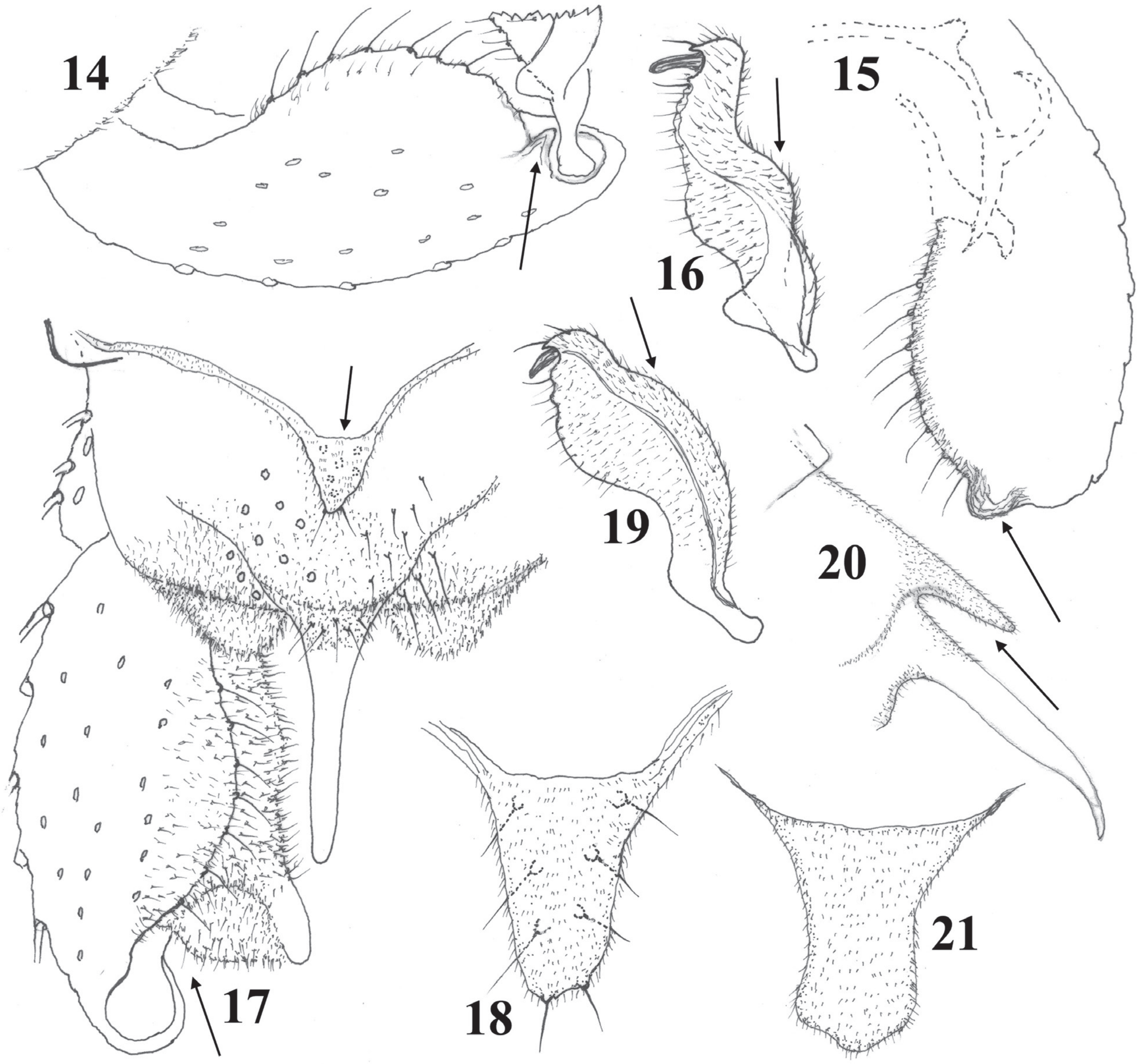
Ecology. Crenophilous species inhabiting cold mountain springs and cold streams with crystalline to calcareous water. Emergence: from July to early September.

Geographical distribution. Only known from its type locality: Central Swiss Alps.

Chaetocladius lencioniae Moubayed-Breil, sp. n.

http://zoobank.org/AD97AFCF-EC91-4DF2-9E8B-6AEEA45E560B

Material examined. Holotype. **Switzerland**: Mutt stream (station M4), altitude 2100 m, 09.VIII.1997; 46°34'04.946"N, 8°24'17.159"E, 1 male adult, leg. B. Lods-Crozet. Environmental data of Mutt stream water are: crystalline/calcareous water, conductivity 61–183 µS/cm; temperature: 1–8 °C during late spring to late summer (June-September). In the streamlet and rheocrenes located near station M4, conductivity ranged between 103 to 253 µS/cm; temperature 4.4. to 14.8 °C (Ilg et al. 2001).



Figures 14–21. Male adult of *Chaetocladius* spp. *C. castellae* sp. n. (paratype-1): **14–15**, gonocoxite, lateral and dorsal; **16**, gonostylus in dorsal view. *C. castellae* sp. n. (paratype-2): **17**, hypopygium in dorsal view; **18**, dorsal lamellae of tergite IX. *C. insolitus*: **19**, gonostylus in dorsal view; **20**, anal point and tergite IX in lateral view; **21**, dorsal lamellae of tergite IX.

Paratype. 1 male adult, same locality and data as for holotype.

Holotype (mounted on 1 slide; GBIFCH 00460691) is deposited in the collections of the 'Musée cantonal de Zoologie, Palais de Rumine, 6 place de la Riponne, CH-1014 Lausanne, Switzerland. The single paratype is deposited in the collection of the senior author.

Diagnosis. *C. lencioniae* sp. n. keys near the following two species: *C. gracilis*, based on the shape of both tergite IX and the anal point; *C. antipovae*, based on the shape of the inferior volsella. However, *C. lencioniae* sp. n. can be distinguished in having: tergite IX semi-circular; sternite IX typically circle-like in shape; anal point markedly pointed apically and bearing setae on proximal part; virga faint, consists of 2 long teeth; gonostylus massively spherical to bulb-shaped, anterior margin swollen medially, ending in 3 characteristic small teeth comb-like placed close to the base of megaseta, posterior margin rounded, projecting downwards and terminating in a pointed sclerotized apical tooth; crista dorsalis large tooth-like, sclerotized and spherical, smooth with rounded apex, placed pre-apically close to megaseta (clearly visible in dorsal and ventral view).

Description. Male imago (n = 2 male adults; Figs 22–31). Small sized species. Total length 3.75 mm. Wing length 2.15 mm. General colouration contrasting pale brown to dark brown except for the mesonotal stripes, which are reddish dark brown. Head brownish, antennae pale brown, thorax brown with dark brown mesonotal stripes. Wing transparent. Legs brown with dark brown tarsus. Tergites I-V brownish, tergites VI-VIII yellowish, anal segment hyaline to yellowish; gonostylus dark brown in its proximal and median part, dark brown to blackish in its distal part, megaseta and surrounding area dark brown.

Head. Eyes bare, hairs on inner eye margin absent. Temporals consist of 9–10 uniserial setae including 7–8 inner and 2 outer verticals. Antenna 1370 µm long, 12-segmented; last flagellomere (Fig. 22) 820 µm long, preceding segment 85 µm long; last flagellomere distinctly clubbed, lacking pre-apical seta and bearing a brush of curved sensilla chaetica apically; antennal groove extending from segments 3 to the ultimate flagellomere, becoming broader on last flagellomere; AR 1.50. Clypeus (Fig. 23) trapezoidal to cup-like in shape with rounded posterior margin, bearing 10 setae placed in 3 rows. Palp 5-segmented; first and second palpomeres faintly fused; length (µm) of segments: 65, 75, 205, 215, 325; 5–6 sensilla clavata are present on third palpomere. Thorax. Lateral antepronotals 3 uniserial, acrostichals 10–11 uni-biserial, dorsocentrals 14–16 uniserial, prealars 3–4 in 1 row, supraalars absent; humeral pit ovoid, nearly indistinct and lacking contrasting spots. Scutellum (Fig. 24) with 14 setae placed in 1 row along an arc line (7 on each side of the median area). Wing. Brachiolum with 1 seta. Membrane densely covered with coarse punctuation. Distribution of setae on veins: R, 13; R_1, R_{2+3}, R_{4+5} and remaining veins bare. Squama with 12 uniserial setae. Legs. Tibial spurs of PII and PIII are *Chaetocladius*-type, with prominent apicolateral denticles. Tarsomere ta_4 of PII and PIII distinctly shorter than ta_5; sensilla chaetica present only on tarsomeres ta_1-ta_3 of PI, PII and PIII (well represented on hind leg). Length (µm) and proportions of legs as in Table 2.

Table 2. *Chaetocladius lencioniae* sp. n. Length (µm) and proportions of legs PI, PII and PIII.

	fe	**ti**	**ta_1**	**ta_2**	**ta_3**	**ta_4**	**ta_5**	**LR**	**BV**	**SV**	**BR**
PI	810	1020	710	430	260	165	140	0.70	2.55	2.58	3.10
PII	840	850	390	230	150	85	100	0.46	3.68	4.33	2.75
PIII	910	1060	560	315	240	100	125	0.43	3.24	3.52	3.40

Hypopygium in dorsal, ventral and lateral view as in Figs 25–31; ventral view (Fig. 26) with tergite IX and anal point removed. Tergite IX semi-circular and broad with 10–11 setae placed posteriorly between base of anal point and the posterior margin (5–6 on each side). Anal point about 85–90 µm long, 65–70 µm maximum width at base, overreaching notch of inferior volsella; triangular and uniformly narrowed and sharply pointed in both dorsal (Figs 25) and lateral view (Fig. 28); base with 11–12 setae including 5–6 inserted dorsally and 6 placed on the lateral margin (3 on each side, occasionally 1 seta is inserted near the median area). Laterosternite IX typically circle-like in shape with 6–7 setae on each side. Transverse sternapodeme rounded with distinct oral projections; phallapodeme strongly broadened distally at joint with lateral sternapodeme. Virga (Figs 25, 27) faintly visible, consists of 2 long teeth about 23 µm long and fused at base. Gonocoxite 250 µm long, maximum width 95–105 µm, markedly swollen at base; inferior volsella (dorsal, Fig. 25; lateral, Fig. 31) 90–95 µm long, 30–35 µm maximum width, entirely hyaline, consists of 3 lobes; distal lobe smooth and rounded, the 2 basal lobes are strongly dented and separated by a distinct notch; posterior inner margin markedly swollen. Gonostylus (Figs 29–31) 105 µm long, maximum width 40–45 µm; massively spherical to bulb-shaped; anterior margin swollen medially, ending in 3 small characteristic pre-apical teeth, which are comb-like and pointed (clearly visible: dorsally, Fig. 29; ventrally, Fig. 30; laterally, Fig. 31); posterior margin markedly swollen distally and terminating in a pointed sclerotized apical tooth, bearing 2–3 stout orally directed setae; crista dorsalis (Figs 29–30) large tooth-like, smooth and located pre-apically close to megaseta; megaseta 20–22 µm long, 9 µm wide, conspicuous and slightly bent inwards.

Taxonomic position. *C. lencioniae* sp. n. keys near *C. gracilis*, based on the shape of both tergite IX and the anal point (Brundin 1956, fig. 87) and *C. antipovae*, based on the shape of the inferior volsella (Makarchenko and Makarchenko, Figs 3–4). However, the new species can easily be separated from other members of the *Chaetocladius* genus in having: tergite IX semi-circular; sternite IX typically circle-like in shape; anal point markedly pointed apically and bearing setae on proximal part; virga with 2 distinct long teeth; gonostylus spherical to bulbous; anterior margin ending with 3 characteristic pointed teeth (Figs 29–31), comb-like and placed close to megaseta area (clearly visible in both dorsal, ventral and lateral view); posterior margin markedly swollen distally and terminating in a pointed sclerotized apical tooth; crista dorsalis strong tooth shaped, smooth and placed pre-apically close to megaseta.

Etymology. The new species is named *lencioniae* in honour of our colleague Dr. Valeria Lencioni from the Museum of Trento (Italy), who is active as curator 'Conservatore' and hydrobiologist in contributing to preserve the biological and ecological quality of water and environment in Trento and surrounding areas.

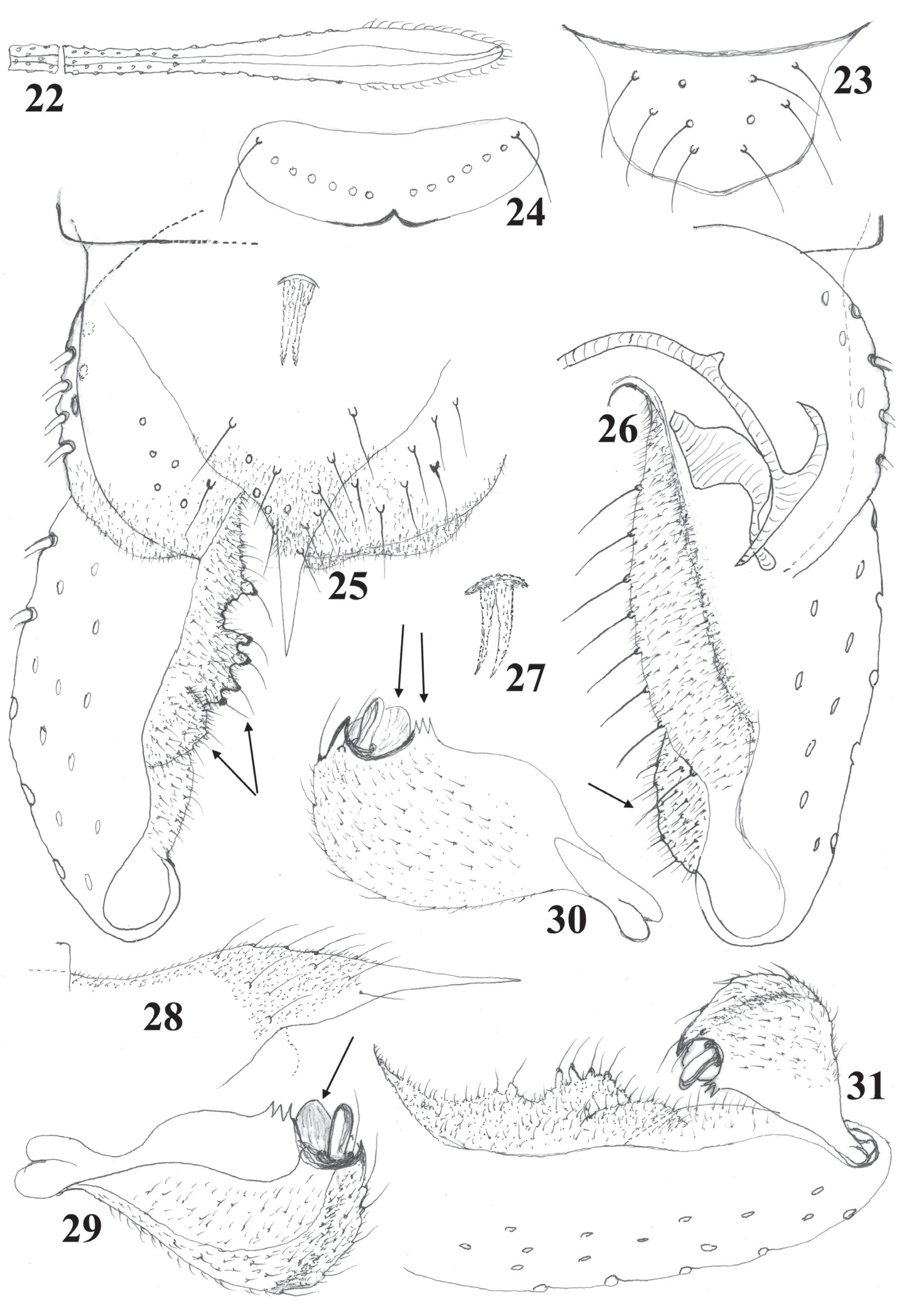
Ecology. High mountain springs and cold streams with crystalline to calcareous water. Emergence: from July to early September.

Geographical distribution. *C. lencioniae* sp. n. is only known from its type locality. It can be considered as a typical biogeographic representative of high mountain rheocrenes and cold streams delimited by some Swiss Alpine glaciers.

Chaetocladius lodscrozetae Moubayed-Breil, sp. n.

http://zoobank.org/F348A75E-E4DF-4351-B48A-2C9356133165

Material examined. Holotype. **Switzerland**: Gletschboden alluvial plain, streamlet and springs located



Figures 22–31. Male adult of *Chaetocladius lencioniae* sp. n.: **22**, last flagellomere and preceding segment; **23**, clypeus; **24**, scutellum. Hypoygium: **25–26**, dorsal (**25**) and ventral (**26**) with anal point and tergite IX removed; **27**, virga; **28**, anal point and tergite IX in lateral view; **29**, left gonostylus, dorsal; **30**, right gonostylus, ventral; **31**, gonocoxite and gonostylus in lateral view.

close to the upper catchment of the Rhône River, upstream of the Mutt stream confluence (station U2), altitude 1800 m, 08.IX.1998, 46°34'15.466"N, 8°22'47.054", 1 male adult, leg. B. Lods-Crozet. Environmental data of Rhône water are: crystalline water, conductivity 3.3–17.8 µS/cm; temperature 2–4 °C during late spring to late summer (June-September).

Paratypes (all leg. B. Lods-Crozet). **Switzerland.** 1 male adult, same locality and data as for holotype. 2 male adults, Gletschboden, upstream, altitude 1800 m, 30.IX.1999. 1 male adult, Mutt stream (station M4), altitude 2100 m, 07.VIII.1997, Swiss coordinates: 2'674'059, 1'157'904. Environmental data of Mutt stream water are: crystalline/calcareous water; conductivity: 61–183 µS/cm; temperature: 1–8 °C during late spring to late summer (June-September). In the streamlet and rheocrenes located near the station M4, conductivity ranged between 103 to 253 µS/cm; temperature 4.4. to 14.8 °C (Ilg et al. 2001).

Holotype (mounted on 1 slide; GBIFCH 00460693) and 1 male paratype (on 1 slide; GBIFCH 00460694) are deposited in the collections of the 'Musée cantonal de Zoologie, Palais de Rumine, 6 place de la Riponne, CH-1014 Lausanne, Switzerland. Remaining paratypes are deposited in the collection of the senior author.

Diagnosis. The nearest species to *C. lodscrozetae* sp. n. are *C. dissipatus*, *C. holmgreni*, *C. egorych* and *C. aedeagolobatus* Rossaro, Magoga & Montagna, 2017 from which it can be separated in having: clypeus half diamond-like, with V-shaped posterior side, bearing 6 setae placed in 2 rows; palpomere 4 distinctly truncate apically, sensilla clavata present on segment 3 including 5 sparsely distributed and 3 (tubule-like) grouped on a ring placed distally; ultimate flagellomere 465–475 µm long, distinctly clubbed, AR about 1; tergite IX broad and semi-circular with 16–22 dorsal setae placed on its posterior part; anal point long, triangle-like, nearly parallel-sided and distinctly thin between base and apex, dorsally bearing a characteristic massive lamella-like orally directed structure which is markedly visible in lateral view, lamella is cup-like in dorsal view, composed of 2 well separate margins, inner margin linear and bare, outer margin markedly undulated and bearing 7–8 dorsolateral setae, inside area bare; virga typical inversed V-shaped, composed of 6–7 posteriorly directed spines; gonocoxite broad basally and narrowed distally, abruptly tapering before apex; inferior volsella extending from base of gonocoxite to its distal part, consist of 2 lobes (dorsal lobe markedly projecting medially and beak-like in shape, distal part distinctly swollen and pouch-like in shape; ventral lobe swollen basally and tapering distally, ending nearly at tip of gonocoxite, inner ventral margin bearing about 11 strong setae; gonostylus half bulb-shaped ending with a distinct hyaline rounded distal area, anterior side with orally directed small setae, posterior margin markedly rounded bearing a double inner apical margin, anterior margin varies from straight to convex, crista dorsalis low and indistinct.

Description. Male imago (n = 4 male adults; Figs 32–44). Medium sized species. Total length 3.80–3.90 mm. Wing length 2.00–2.13 mm. General colouration contrasting brown to dark brown. Head dark brown, antennae pale brown, thorax brown to dark brown, mesonotal stripes distinctly dark brown; wing pale; legs contrasting brown to dark brown. Tergites I-VI/VII brown, tergites VII-VIII and anal segment entirely dark brown.

Head. Eyes bare, hairs present anterior part of inner eye margin. Temporals consist of 11–12 setae including 7–8 uniserial inner and 4 outer verticals. Antenna 915–920 µm long, 13-segmented; ultimate flagellomere 465–475 µm long, distinctly clubbed distally and bearing a dense brush of curved sensilla chaetica apically, apex (Fig. 34) lacking pre-apical setae; antennal groove beginning on segments 3–4 and reaching ultimate flagellomere; AR 1.02. Clypeus (Fig. 35) about 105 µm maximum height and 120 maximum width, half diamond-like, with V-shaped posterior side, which is rounded apically, bearing 6 setae placed in 2 rows: 4 near the basal margin, 2 on median part. Palp 5-segmented, first and second palpomeres fused; palpomere 4 distinctly truncate apically; length (µm) of segments: 38, 75, 150, 130, 175–180; palpomere 3 (Figs 32–33) with sensilla clavata including 5 sparsely distributed and 3 grouped on a characteristic ring placed distally. Thorax. Antepronotum well developed, with fused lobes. Lateral antepronotals 5 grouped close together apically; acrostichals 10–11 uniserial; dorsocentrals 8–9 in 1 row, prealars 3; humeral pit ovoid, lacking contrasting spots. Scutellum with 8 setae in 1 row (4 placed on each side of median area). Wing. Brachiolum with 1 seta. Membrane densely covered with coarse punctuation. Distribution of setae on veins: R, 10–11; R_1, 0–1; remaining veins bare. Squama with 5–10 uniserial setae. Legs. Tibial spurs of PII and PIII are *Chaetocladius*-type, with projecting apicolateral denticles. Sensilla chaetica present on: tibia and tarsomere ta_1 of PI and PII; tarsomeres $ta_{1-}ta_3$ of PIII. Length (µm) and proportions of legs as in Table 3.

Hypopygium in dorsal, ventral and lateral view as in Figs 36–44; ventral view (Fig. 37) with tergite IX and anal point removed. Tergite IX broad and semi-circular with 16–22 dorsal setae placed on the posterior part (7–8 setae on each side of base of anal point); presence of a characteristic massive rounded prominence extending from the median area to base of anal point; prominence is cup-like in shape in dorsal view (Fig. 36) and orally directed in lateral view (Fig. 40), outer margin is markedly undulated and bearing 8–10 dorsolateral setae (4–5 placed on each side), inside area bare. Anal point (Figs 36, 40) about 80–85 µm long, maximum width 40–45 µm at base, markedly elongated and reaching inner lobe of inferior volsella; in dorsal view (Fig. 36), median and distal part linear to parallel-sided with an average of 3–5 µm wide; in lateral view (Fig. 40), distinctly thicker on proximal half, becoming thinner on its distal half, often bent downwards, apex slightly curved upwards. Laterosternite IX with 5 setae on each side. Transverse sternapodeme arc-like, with distinct

Table 3. *Chaetocladius lodscrozetae* sp. n. Length (µm) and proportions of legs PI, PII and PIII.

	fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV	BR
PI	790	885	560	320	240	150	110	3.63	2.73	2.99	2.20
PII	820	830	370	230	180	110	100	3.45	3.26	4.46	2.90
PIII	890	980	585	325	260	145	110	3.60	3.43	3.20	2.30

rounded oral projections; lateral sternapodeme slender and distinctly short; phallapodeme sinuous medially at joint with lateral sternapodeme. Virga (Fig. 38) inversed V-shaped, composed of 6–7 posteriorly to laterally directed spines. Gonocoxite 280–285 µm long, markedly broad basally, maximum width 85–90 µm, narrowed and abruptly tapering distally, apex rounded and bearing 4–5 apical setae; inner ventral margin with about 11 strong setae; apical margin with 2–3 stout setae. Inferior volsella 120 µm long, maximum width 45 µm, extending from base of gonocoxite to its distal part (about 65 µm distance from apex of gonocoxite); similarly shaped in both dorsal, ventral and lateral view (Figs 36–37, 39, 41); median inner margin terminating in a nose-like lobe which is hyaline, bare and bent downwards; distal part pouch-like in shape. Gonostylus (Figs 41–44) 100–110 µm long, 40–45 µm maximum width, nearly semi-circular, distal part of posterior margin bare and hyaline; anterior side smooth in general, varies from straight (Figs 42–43) to convex (Fig. 44), bearing numerous orally directed small setae; crista dorsalis low and indistinct; megaseta 18–20 µm long, conspicuous, occasionally with pointed apex, slightly bent inwards.

Taxonomic position. *C. lodscrozetae* sp. n. keys close to *C. dissipatus*, *C. holmgreni*, *C. egorych* and *C. aedeagolobatus* from which it can be separated in having: sensilla clavata present on palpomere 3 including 5 sparsely distributed and 3 grouped on a characteristic ring placed distally; tergite IX broad and nearly semi-circular with 10–11 setae on its posterior area, presence of a characteristic massive rounded prominence extending from the median area to base of anal point; anal point elongated and parallel-sided which is distinctly thicker on its proximal half; virga inversed V-shaped, composed of 6–7 posteriorly directed spines; gonocoxite broad basally and narrowed distally, abruptly tapering before apex; inferior volsella extending from base of gonocoxite to its distal part, consist of a large lobe which is pouch-like in shape, inner margin terminating in a hyaline nose-like lobe which is bare and bent downwards; gonostylus nearly semi-circular, distal part of posterior margin hyaline and bare, anterior side with orally directed small setae, anterior margin varies from straight to convex.

Etymology. The new species is named *lodscrozetae* in honour of Dr. Brigitte Lods-Crozet from the Cantonal Museum of Zoology of Lausanne (Switzerland), who is still active as researcher and hydrobiologist in contributing to preserve the biological and ecological quality of water and environment in Switzerland.

Ecology. Glacial springs and cold mountain streams with crystalline to calcareous water. Emergence: from July to early September.

Geographical distribution. *C. lodscrozetae* sp. n. is only known from rheocrenes and lotic habitats delimited by the Gletschboden floodplain, the Mutt stream and streamlet, Swiss Alps, altitude 1800–2100 m.

Chaetocladius macunensis Moubayed-Breil, sp. n.

http://zoobank.org/75DA3760-22C8-4357-8DF7-ABD7E9F98E42

Material examined. Holotype. **Switzerland**: Macun cirque, streamlet and rheocrenes, left shore of Immez Lake, alt. 2616 m, 27.VII.2013; 46°43’39.678”, 10°07’55.764”E, 1 male adult, leg. B. Lods-Crozet. Environmental data from inlet of Immez Lake: crystalline water, conductivity 5.9 µS/cm; temperature 11.6 °C, pH 6.7 (Robinson and Oertli 2009).

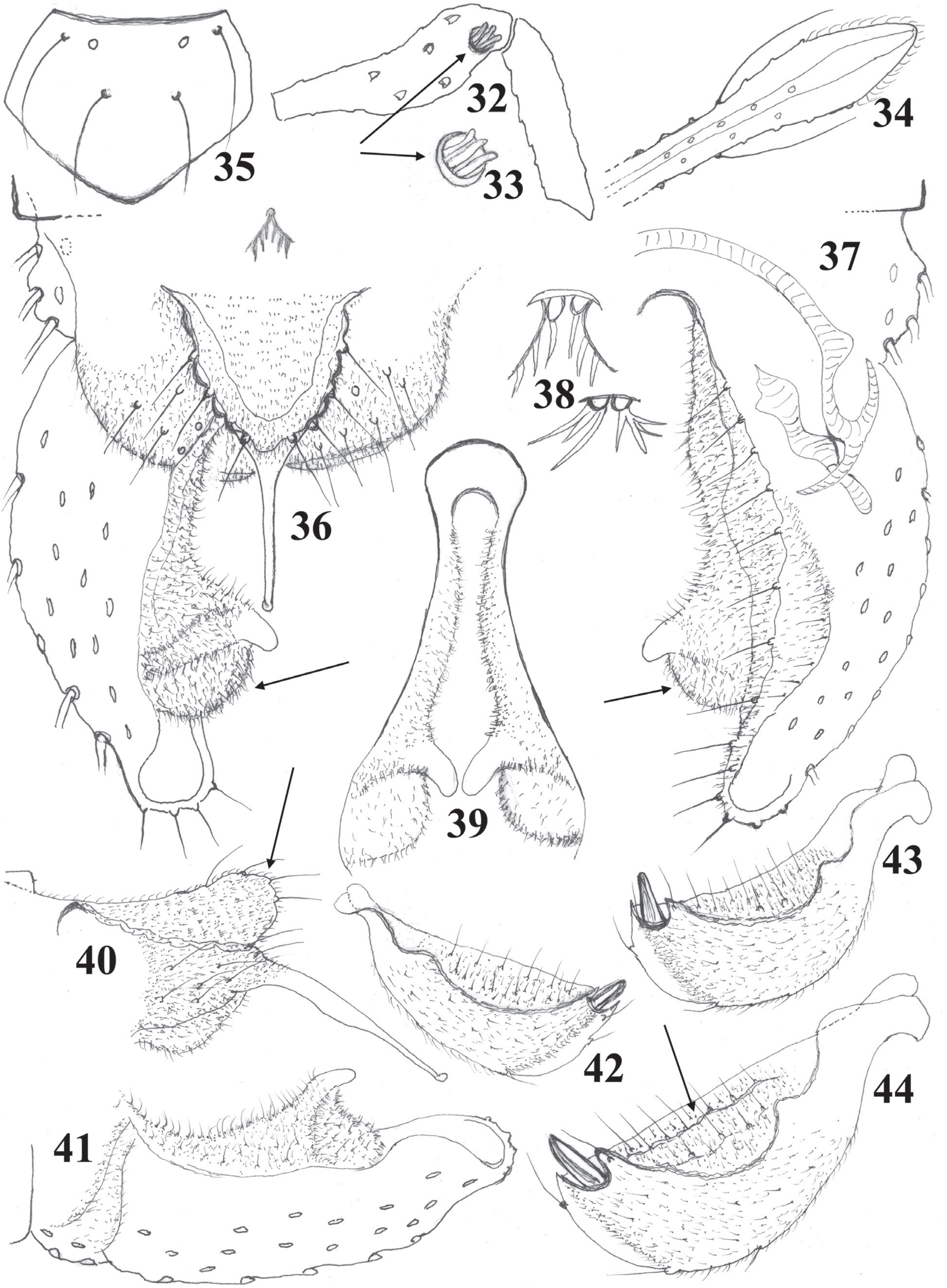
Paratypes. 3 male adults, same locality and data as for holotype.

Holotype (mounted on 1 slide; GBIFCH 00460690) is deposited in the collections of the ‘Musée cantonal de Zoologie, Palais de Rumine, 6 place de la Riponne, CH-1014 Lausanne, Switzerland. Paratypes are deposited in the collection of the senior author.

Diagnosis. Based on the unusual and unique shape of the inferior volsella, *C. macunensis* sp. n. can be easily separated from other members of the *Chaetocladius* genus by the following characters: clypeus semi-circular bearing 7 setae placed in 1 row along an arc line; antenna and ultimate flagellomere relatively short (respectively 600–660 and 130–200 µm long), apex distinctly clubbed and bearing 1 pre-apical seta, AR markedly low (0.25–0.35); tergite IX sub-triangular and lacking dorsal setae; anal point triangular, uniformly narrowed, apex rounded, base with 6 setae inserted dorsolaterally (3 on each side); virga horseshoe-shaped, median tooth sinuous and S-like in shape; gonocoxite markedly swollen medially and distally, inner dorsal margin without stout setae, inner ventral margin swollen medially; inferior volsella consists of 1 single large and typical lobe, which bears numerous strong stout setae on its inner margin; gonostylus elongated and nearly linear, anterior side covered with setae, posterior margin nearly straight.

Description. Male imago (n = 2 male adults; Figs 45–57). *C. macunensis* sp. n. is one of the smallest species of *Chaetocladius*. Total length 3.55–3.65 mm. Wing length 1.35 mm. General colouration contrasting brown to dark brown. Head yellowish to brown; antennae and pedicel dark brown; thorax contrasting brown to dark brown, mesonotal stripes distinctly dark brown; wing transparent; legs brownish with tarsomeres ta_5 dark brown. Abdomen including anal segment entirely brownish.

Head, thorax and tergite I as in Fig. 45. Eyes mostly bare, extreme posterior part with few hairs; inner mar-



Figures 32–44. Male adult of *Chaetocladius lodscrozetae* sp. n.: **32–33**, palpomeres 3–4 with sensilla clavata on palpomere 3; **34**, last flagellomere; **35**, clypeus; **36–37**, hypopygium, dorsal (**36**) and ventral (**37**) with anal point and tergite IX removed; **38**, virga, two aspects; **39**, ventral view of inferior volsella; **40**, anal point and tergite IX in lateral view; **41**, left gonocoxite in lateral view; **42–44**, gonostylus, lateral (**42**), dorsal (**43**) and dorso-lateral (**44**).

gin bare. Temporals consist of 4 uniserial setae comprising only inner verticals, outer verticals absent. Antenna 730–800 µm long, 13-segmented; ultimate flagellomere (Fig. 46) 130–200 µm long, relatively short; apex of last flagellomere distinctly clubbed, bearing 1 pre-apical seta and curved sensilla chaetica; segments 11 and 12 each about 20 µm long; antennal groove beginning on segments 3 and reaching ultimate flagellomere; antennal ratio markedly low, AR 0.25–0.35. Clypeus (Fig. 48) 125 µm maximum width and 75 µm high, nearly rectangular with rounded sides, bearing 7 setae placed anteriorly in 1 row along an arc line. Palp 5-segmented; first and second palpomeres nearly fused; length (µm) of segments: 15, 55, 105, 115, 160; palpomere 4 distinctly broadened (37 µm maximum width); palpomere 3 (Fig. 47) with 4–5 sensilla clavata. Thorax. Antepronotum (Fig. 49) well developed with gaping lobes, lateral antepronotals 4–5; acrostichals 12–13, short and starting close to the antepronotum; dorsocentrals, 15–16 in 1 row; prealars 4–5; humeral pit ovoid, indistinct. Scutellum with 7 uniserial setae placed along an inversed arc-like (1 medially and 3 on each side of it). Wing. Brachiolum with 1 seta. Membrane densely covered with coarse punctuation. Distribution of setae on veins: R 11; R1 3; R2+3 6–7 placed distally; R4+5 0. Squama composed of 38–41 alternate long and short setae placed in 1 row. Legs. Tibial spurs of PII and PIII are *Chaetocladius*-type, with prominent apicolateral denticles. Sensilla chaetica (Fig. 50) present on tarsomeres ta_1-ta_4 of PI, PII and PIII. Length (µm) and proportions of legs as in Table 4.

Hypopygium in dorsal, ventral and lateral view as in Figs 52–57; ventral view (Fig. 53) with tergite IX and anal point removed. Tergite IX broadly triangular and narrowed posteriorly till base of anal point, lacking dorsal setae. Anal point (Figs 51–52, 57) about 60–65 µm long, 15-20 µm maximum width at base, reaching half of inferior volsella length; triangular, uniformly narrowed towards apex which is slightly pointed; base markedly truncate bearing an obtuse prominence which is only visible in lateral view (Fig. 51, 57), presence of 6 setae inserted dorsolaterally (3 on each side). Laterosternite IX with 5 setae on each side, posterior margin with 1 lobe placed near the base of anal point. Transverse sternapodeme rounded with distinct oral projections placed laterally, lateral sternapodeme distinctly short; inner margin of phallapodeme with a median triangular projection, outer margin weakly swollen at joint with lateral sternapodeme. Virga (Fig. 52, 54) distinctly horseshoe-shaped, 15–17µm maximum width; base sub-circular, 15 µm maximum width; median tooth about 20–22 µm long, sinuous and S-like in shape. Gonocoxite 210–215 µm long, maximum width 80–85 µm; in dorsal view (Fig. 52) markedly swollen medially and distally, inner dorsal margin lacking strong stout setae; in ventral view (Fig. 53), the inner margin is swollen medially and bearing 7 stout setae; inferior volsella (Fig. 52, 57) 60–65 µm long, 15–18 µm maximum width, consists of 1 single large lobe, swollen medially and slightly narrowed distally (distinctly visible in dorsal and lateral view, Figs 52, 57), with numerous setae placed on its inner margin. Gonostylus (Figs 55–57) 105–110 µm long, maximum width 25 µm; uniformly elongated, anterior side covered with small setae; posterior margin nearly straight, ending with distinct tooth; crista dorsalis low to nearly absent; megaseta 21–23 µm long, conspicuous and slightly bent inwards.

Table 4. *Chaetocladius macunensis* sp. n. Length (µm) and proportions of legs PI, PII and PIII.

	fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV	BR
PI	550	650	410	290	210	120	100	0.63	2.24	2.93	2.40
PII	675	655	290	160	140	91	82	0.44	3.42	3.24	2.10
PIII	725	775	420	220	190	120	98	0.54	3.06	3.57	2.30

Taxonomic position. *C. macunensis* sp. n. can be easily separated from its nearest species (*C. tenuistylus*, sensu Makarchenko and Makarchenko 2004, Fig. 10) by the following main distinguishing characters: ultimate flagellomere relatively short (130–200 µm long), apex clubbed and bearing 1 pre-apical seta (Fig. 5), antennal ratio markedly low (0.25–0.35); tergite IX sub-triangular and lacking dorsal setae; anal point triangular with a truncate prominence (obtuse angle) placed near the base which is only visible in lateral view (Figs 51, 57); virga typically horseshoe-shaped, base circular with its 2 apices distinctly curved inwards, median tooth S-like in shape; anal point triangular and tapering distally; inferior volsella consists of a large lobe which is typically swollen medially and slightly narrowed distally; gonostylus elongated and nearly linear, anterior side covered with setae, posterior margin nearly straight.

Etymology. The new species is named *macunensis* after the Swiss Alpine cirque of Macun, which was annexed to the Swiss National Park in 2000 (canton of Graubunden).

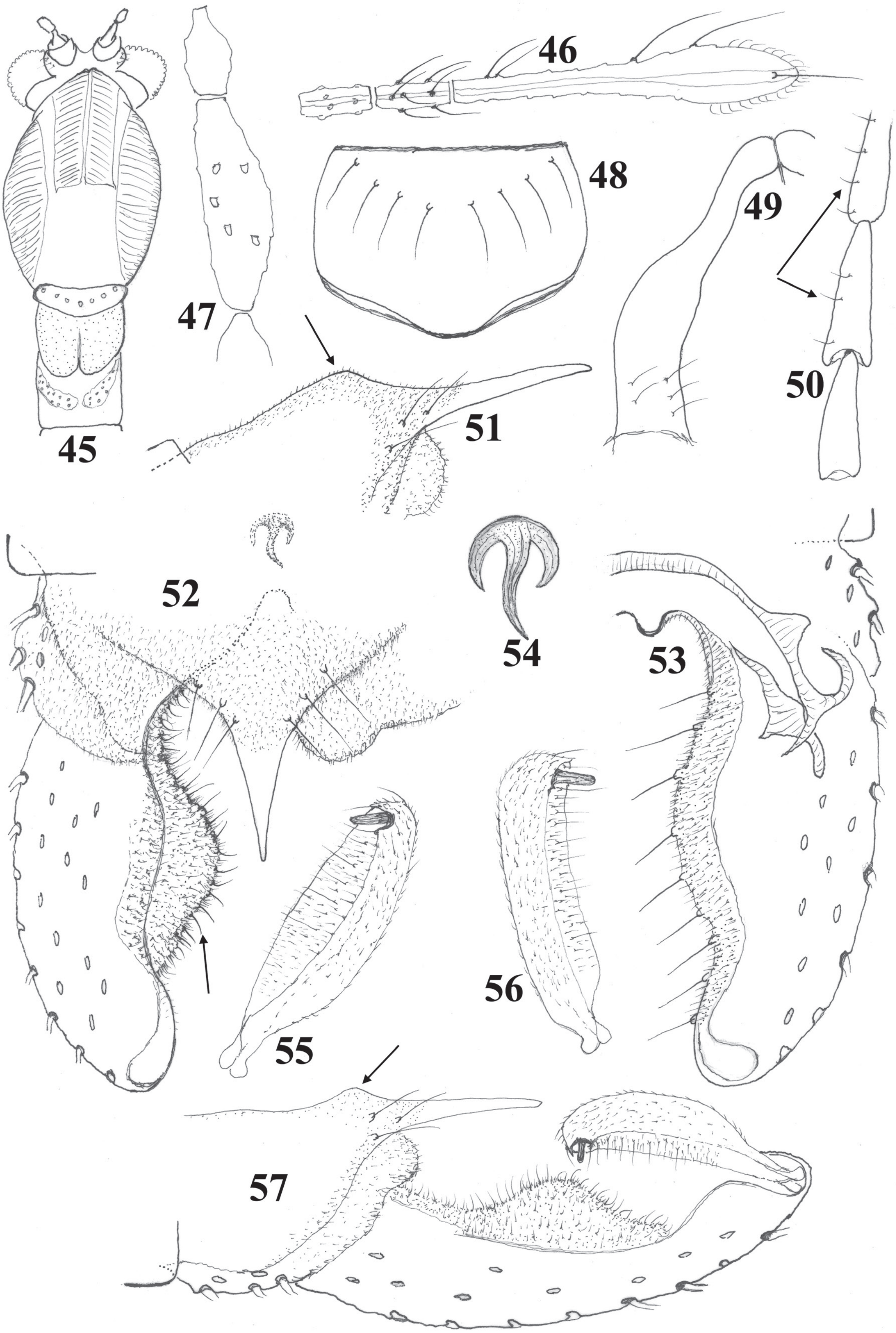
Ecology. *C. macunensis* sp. n. is apparently confined to cold glacial streams and the inflow section of lakes delimited by the Macun cirque where water is typically crystalline. Emergence is recorded from July to early September.

Geographical distribution. A typical biogeographic representative of Alpine high mountain springs and glacial streams located in the eastern Swiss Alps area. Currently, *C. macunensis* sp. n. is only known from the Macun cirque.

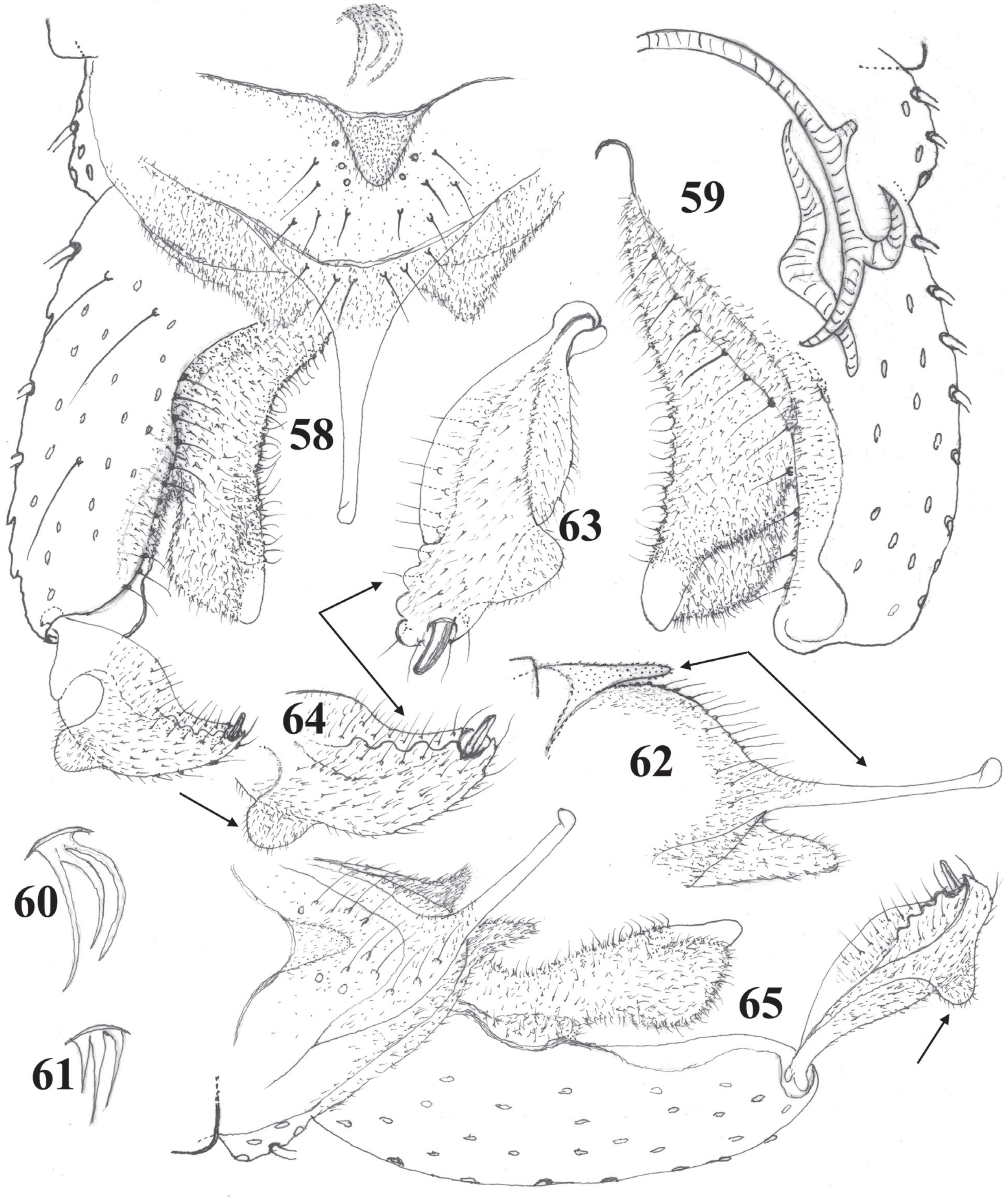
Chaetocladius muttensis Moubayed-Breil, sp. n.

http://zoobank.org/13D2E7A8-EFB6-47F0-85C7-3BD46B5F3DB7

Material examined. Holotype. **Switzerland**: upper basin of the Mutt glacial stream (station M5), altitude 1800 m, 03.VIII.1997, 46°34’12.347”N, 8°22’51.363”, 1 male adult, leg. B. Lods-Crozet. Environmental data of Mutt stream water are: crystalline to calcareous water, conductivity 61–183 µS/cm; temperature: 1–8 °C during late spring to late summer (June-September).



Figures 45–57. Male adult of *Chaetocladius macunensis* sp. n.: **45**, palpomeres 2–3; **46**, last flagellomere and the two preceding segments; **47**, clypeus; **48**, head, thorax and first abdominal segment; **49**, antepronotum, left side; **50**, tarsomeres 2–4 of PIII; **51**, anal point and tergite IX in lateral view; **52–53**, hypopygium, dorsal (**52**) and ventral with anal point and tergite IX removed (**53**); **54**, virga; **55**, left gonostylus, dorsal; **56**, right gonostylus, lateral; **57**, anal point, gonocoxite and gonostylus in lateral view.



Figures 58–65. Male adult of *Chaetocladius muttensis* sp. n. **58–59**, hypopygium, dorsal (**58**) and ventral with anal point and tergite IX removed (**59**); **60–61**, virga, two aspects; **62**, tergite IX and anal point in lateral view; **63**, right gonostylus, lateral; **64**, left gonostylus, distal part (dorsal); **65**, anal point, gonocoxite, tergite IX and gonostylus in lateral view.

Paratype. **Switzerland**: upper basin of Mutt stream (station M4), altitude 2100 m, 09.VIII.1997, 46°34'04.946"N, 8°24'17.159"E, 1 male adult, leg. B. Lods-Crozet. Environmental data of Mutt stream water are: crystalline to calcareous water, conductivity 61–183 µS/cm; temperature: 1–8 °C during late spring to late summer (June-September). In the streamlet and springs located close to station M4, conductivity ranged between 103 to 253 µS/cm; temperature 4.4 to 14.8 °C (Ilg et al. 2001).

Holotype (mounted on 1 slide; GBIFCH 00460695) is deposited in the collections of the 'Musée cantonal de Zoologie, Palais de Rumine, 6 place de la Riponne, CH-1014 Lausanne, Switzerland. The single paratype is deposited in the collection of the senior author.

Figure 66. The Mutt stream valley with the Mutt glacier in the back and in the foreground station M4 (Photo, B. Lods-Crozet).

Diagnosis. *C. muttensis* sp. n. can be separated from its nearest species (*C. insolitus* and *C. castellae* sp. n.) by the following characters: tergite IX bearing a characteristic dorsal lamella-structure which is bare and slightly projecting close to the dorsal side of tergite IX; anal point triangular, widely broad at base and bearing 6 setae at base

Figure 67. Cirque of Macun, Eastern Alps, Swiss National Park, altitude 2616–2700 m (photo © *hepia*).

(3 on each side); virga faint but present, consists of 3 long spines; inferior volsella tongue-like with distal outer margin well separated from inner margin of gonocoxite; inner margin of gonocoxite not swollen medially and lacking row of strong setae; gonostylus gradually narrowing distally, anterior area with a characteristic undulate line placed distally and reaching base of megaseta, posterior margin with a typical lob-like expansion placed medially and directed downwards.

Description. Male imago (n = 2 male adults; Figs 5, 6, 8, 58–65). A medium sized species, total length 2.90–3.00 mm. Wing length 1.60–1.75 mm (markedly short). General colouration faintly contrasting brown to dark brown. Head including palpomeres, clypeus and antennae brown to pale brown; thorax brown to dark brown, mesonotal stripes distinctly dark brown; wing pale; legs brown to dark brown. Tergites I-VIII and anal segment brown to dark brown.

Head. Eyes bare, hairs absent on median part of inner eye margin. Temporals consist of 8 setae including 5 inner and 3 outer verticals. Antenna 575–585 µm long, 13-segmented; last flagellomere (Fig. 5) 135–145 µm long, well clubbed, pointed apically, bearing numerous sensilla chaetica apically and lacking pre-apical seta; antennal groove beginning on segment 3 and reaching ultimate flagellomere; AR 0.30–0.35. Clypeus (Fig. 8) trapezoidal with straight sides, bearing 8–10 setae in 2 rows. Palp 5-segmented; length (µm) of segments 1–5: 30, 35, 105, 125, 180; palpomere 3 (Fig. 6) with 4–5 sparsely distributed sensilla clavata. Thorax. Lateral antepronotals 4–5; acrostichals 8–9, short and starting close to antepronotum; dorsocentrals 12–13 in 1–2 rows; prealars 4–5; humeral pit ovoid, lacking contrasting spots. Scutellum with 8 setae placed in 1 row. Wing. Brachiolum with 1 seta. Membrane densely covered with coarse punctuation. Distribution of setae on veins: R, 14–15; R_1, 1–2; R_{2+3} 12–13; remaining veins bare. Squama with 5–6 uniserial setae. Legs. Tibial spurs of PII and PIII are *Chaetocladius*-type, with projecting apicolateral denticles. Sensilla chaetica present on: tibia and tarsomeres ta_1- ta_4 of PI; tibia and tarsomres ta_1-ta_3 of PII; tarsomres ta_1- ta_4 of PIII. Length (µm) and proportions of legs as in Table 5.

Hypopygium in dorsal, ventral and lateral view as in Figs 58–65; ventral view (Fig. 59) with tergite IX and anal point removed. Tergite IX broad, sub-rectangular with nearly semi-circular to straight posterior margin; basal median area with a characteristic lamella-like structure which is weakly projecting and markedly vis-

Figure 68. Malaise trap set up at Immez Lake (Macun cirque, Eastern Alps, Swiss National Park, altitude 2616 m (photo J.L. Lods).

Table 5. *Chaetocladius muttensis* sp. n. Length (µm) and proportions of legs PI, PII and PIII.

	fe	ti	ta_1	ta_2	ta_3	ta_4	ta_5	LR	BV	SV	BR
PI	840	895	550	310	205	120	100	0.62	3.11	3.15	1.50
PII	815	790	370	215	160	105	95	0.47	3.45	4.34	2.20
PIII	890	925	520	290	210	115	95	0.56	3.29	3.49	3.25

ible in lateral view (Fig. 62); dorsal lamella-like projection 45–50 µm long, maximum width 55–60 µm at base, wide cup-like in dorsal view (Figs 58, 65) and long finger-like shape in lateral view (Fig. 62), bare in both dorsal and lateral sides; presence of 14–15 setae placed medially and near the posterior margin. Anal point (Figs 58, 62, 65) about 80–90 µm long, maximum width at base 16–18 µm, uniformly elongated and reaching distal part of inferior volsella; horizontally straight (Figs 58, 62) or occasionally projecting upwards (Fig. 65); basal part wide cup-like bearing 6 setae (3 on each side); parallel-sided medially and distinctly narrowing between median part and apex. Laterosternite IX with 5 lateral setae on each side, posterior margin distinctly bi-lobed (lobes visible on each side of the base of anal point). Transverse sternapodeme arc-like, with distinct tubercle-like oral projections; lateral sternapodeme relatively short; phallapodeme projecting inwards medially. Virga (Figs 59, 60–61) faintly present, consist of 3 long curved spines. Gonocoxite about 250 µm long, broad medially where maximum width is about 80 µm; apex of inner margin distinctly rounded and projecting inwards; ventral side (Fig. 59) wider at base and narrowed distally, inner margin with 10–11 inwardly directed setae. Inferior volsella about 110–115 µm long, 55–60 µm maximum width; long rectangle-shaped and extending from base of gonocoxite to its distal part which is markedly truncate; distal part tongue-like, well separated from the inner margin of gonocoxite (separating part is well visible in both dorsal and ventral view, Figs 58–59); posterior margin bent inwards; apical inner part nose-like, bare and entirely hyaline in both dorsal and ventral sides. Gonostylus (Figs 58, 63–65) 120–125 µm long, maximum width 40–45 µm; narrowing distally, anterior area with a characteristic undulate line extended from median part to base of megaseta, posterior margin rounded and bearing a typical lobe-like expansion which is placed medially and directed downwards; crista dorsalis weekly developed, swollen proximally and becoming gradually lower distally; megaseta 15–18 µm long, conspicuous and slightly bent outwards.

Taxonomic position. *C. muttensis* sp. n. keys near *C. insolitus* and *C. castellae* sp. n. from which it can be separated in having: tergite IX with a characteristic dorsal cup-like lamella-structure, bare and slightly projecting (Fig. 62); anal point widely broad at base which bears about 6 setae; virga faint but present, consists of 3 long curved spines; inferior volsella tongue-like with distal outer margin well separated from inner margin of gonocoxite; inner margin of gonocoxite not swollen medially and lacking row of strong setae; gonostylus (Figs 58, 63–65) gradually narrowing, anterior area with a characteristic undulate line, posterior margin with a typical lobe-like expansion placed medially and directed downwards.

Etymology. The new species is named *muttensis* after the Swiss Alpine glacial Mutt stream, which is located in the upper basin of the Rhône River in the central Swiss Alps.

Ecology. *C. muttensis* sp. n. only occurs in the Mutt glacial stream where larvae are apparently confined to the lotic part of springs and the rhithral (crystalline to calcareous water). Emergence from July to early August. Associated species found in the same locality include: *C. laminatus* Brundin, 1947; *C.* cf. *longivirgatus* Stur & Spies, 2011; *C. suecicus* (Kieffer, 1916); *Heleniella helvetica*.

Geographical distribution. *C. muttensis* sp. n. is only known from its type locality, which is delimited by the upper basin of the Mutt glacial stream.

Key to known adult males of *Chaetocladius* species from the upper catchment of Rhône River including Muttbach valley (Central Swiss Alps)

1 Tergite IX with a dorsal lamella structure located on median area (Figs 9, 17, 58) 2

– Tergite IX without such dorsal lamella structure 3

2 Gonostylus gradually narrowing distally, anterior area with a typical undulate line extended from median part to base of megaseta, posterior margin rounded and bearing a characteristic lobe-like expansion directed downwards (Figs 58, 63–65); lamella structure on tergite IX without setae (Fig. 58).................... *C. muttensis* sp. n.

– Gonostylus linearly elongated, both anterior and posterior margin sinuous (Figs 13, 16); anterior area without undulate line; lamella structure on tergite IX with stout setae on ventral side and posterior margin (Figs 11–12, 18) ...... *C. castellae* sp. n.

3 Gonostylus bulbous and spherical (Figs 29–31) 4

– Gonostylus not as above, slender, semi-circular with rounded posterior margin (Figs 42–44) or linear and uniformly elongated with straight posterior margin (Figs 55–57) 5

4 Inferior volsella (Figs 25, 31) weekly developed, consists of 3 lobes, basal lobe smooth and rounded, the 2 basal lobes are markedly dented and separated by a distinct notch; posterior margin of gonostylus bearing 3 small pre-apical teeth; crista dorsalis large tooth shaped, smooth with rounded apex and placed pre-apically close to megaseta (Figs 29–30).... .... *C. lencioniae* sp. n.

5 Tergite IX bearing a dorsal elevated massive hump, located distally (Figs 36, 40) which is spherical and clearly visible in lateral view (Fig. 40); basal margin of anal point undulated (Fig. 36) and bearing setae; inferior volsella composed of a large spherical lobe bearing medially a nose-like lobe and ending distally in a typical marsupial pouch-like expansion (Figs 36–37, 39), virga inversed V-shapaed, consists of 6–7 spines (Figs 36, 38).................... *C. lodscrozetae* sp. n.

– Tergite IX without such elevated dorsal hump (Fig. 52); base of anal point truncate (clearly visible in lateral view, Fig. 51); inferior volsella composed of 1 large swollen lobe (Figs 52, 57); virga typically horseshoe-like, composed of 3 spines ....*C. macunensi* sp. n.

Discussion

The nearest *Chaetocladius* species to the five diagnosed and described species include: *C. insolitus* for *C. castellae* sp. n.; *C. gracilis* and *C. antipovae* for *C. lencioniae* sp. n.; *C. dissipatus*, *C. holmgreni*, *C. egorych* and *C. aedeagolobatus* for *C. lodscrozetae* sp. n. Based on some specific characters found in the male adult of *C. macunensis* sp. n (shape of anal point, inferior volsella and virga), this new species can be placed near *C. tenuistylus* Brundin, 1947 (sensu Makarchenko and Makarchenko 2004, Fig. 10). Although some resemblance can be found between the five new described species and other related members of the *Chaetocladius* genus, the taxonomic position cannot be clarified until current comprehensive work on the genus is complete.

Worldwide there are actually about 79 known *Chaetocladius* species, which include the hitherto listed 69 species by Ashe and O'Connor (2012) and the recently described 10 species by: Makarchenko et al. (2017), Moubayed-Breil (2017), Moubayed-Breil and Dia (2017), Rossaro et al. (2017). Consequently, the updated previous list of 79 species is upgraded to 84, which currently include the five new described species in this paper.

Currently, only seven *Chaetocladius* species are known from Switzerland: *C. coppai* Moubayed-Breil, 2017; *C. laminatus* Brundin, 1947; *C.* cf. *longivirgatus* Stur & Spies, 2011; *C. melaleucus* (Meigen, 1818); *C. perennis* (Meigen, 1830); *C. piger* (Goetghebuer, 1913); *C. suecicus* (Kieffer, 1916). Consequently, the description here of the five new *Chaetocladius* species increases the total number in the genus to 12 known valid species for this country.

Geographical distribution of the five new described species is currently restricted to the two Alpine Swiss glacial catchments (Figs 66–68): upper catchment of the Rhône River and Muttbach streams; streams and lakes delimited by the Macun area. Type localities of *C. castellae* sp. n., *C. lencioniae* sp. n., *C. lodscrozetae* sp. n. and *C. muttensis* sp. n. are delimited by stenothermic springfed rivulets located close to glacial streams (Rhône River, Mutt stream) and the upper Rhône catchment (central Switzerland, alt. 1800–2000 m). *C. macunensis* sp. n. only occurs in a high-alpine catchment in the Swiss National Park (Macun region, Eastern Swiss Alps, alt. 2550–2700 m).

It is of interest to note that none of the new described species in the present work is identical to any of those described recently from southern side of the Alps (Stur and Spies 2011, Rossaro et al. 2017). This may contrast with a previous statement that the faunae on the two sides of the Alps are similar (Reiss 1968). Nevertheless, it is not really surprising, as the Chironomidae still are quite incompletely known with new species being described continuously from various parts of the word, including from Europe.

Conclusion

The presence of the five new species in some high mountain Alpine ranges of Switzerland highlights the importance of some cold glacial enclaves, considered as hotspots of endemism, in the preservation and persistence of autochthonous and sensitive alpine relic species. Such species are considered as relevant biogeographically representative and their loss would be biologically indicative of the global warming and climate change.

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PENSOFT.

Alpine Entomology

Reinstatement of *Leuctra biellensis* Festa, 1942 (Plecoptera, Leuctridae)

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Abstract

Both molecular and morphologic characters support the reinstatement of *Leuctra biellensis* Festa, 1942 as a valid species distinct from *Leuctra nigra* (Olivier, 1811). Genetic distances between *L. biellensis* and the different populations of *L. nigra* are around 9%, while intraspecific distances among *L. nigra* haploclades are less than 1%. Morphologically, the two species can be separated in male adult specimens by the shape of the two teeth on tergite VIII, by the lateral edges of tergites and by the distal expansion of the paraprocts. *Leuctra biellensis* occurs on the southern slope of the Alps in Italy and Switzerland (Ticino and Graubünden), while *L. nigra* has a wide distribution in Central and Northern Europe. As the type material of *L. biellensis* was lost, and to avoid future confusion between the two species, we designate as neotype a male imago collected at the type locality.

Introduction

The SwissBOL (Swiss Barcode of Life) is an ongoing Project, started in 2011, which aims at inventorying the genetic biodiversity of all taxa occurring in Switzerland. Against the background of global warming and other anthropogenic pressures that are threatening freshwater aquatic biodiversity, Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are considered as particularly vulnerable groups (Tierno de Figueroa et al. 2010, Conti et al. 2014, Errochdi et al. 2014). Between 2013 and 2015, DNA barcode sequences were obtained for 90 of the 112 stonefly species reported from Switzerland (Gattolliat et al. 2016). Complementary field searches were done in 2015 and 2016 to elucidate several cases of isolated specimens on the gene tree. First results showed high intraspecific genetic distances between some populations preliminary identified as *Leuctra nigra* (Olivier, 1811). It was hypothesized that two species were involved, one in the North of the Alps and one in the South (Gattolliat et al. 2016).

Leuctra biellensis Festa, 1942 was originally described from Val Chiobbia in the Piedmont, Northern Italy. This taxon was subsequently considered as a junior synonym of *L. nigra* by Consiglio (1967). The present reinstatement of *L. biellensis* is based both on genetic evidence and on distinctive morphological characters shared by all the specimens occurring along the southern slope of the Alps. New detailed comparative descriptions are given for *L. biellensis* and *L. nigra*.

The original description of *Leuctra biellensis* was based on a single male imago collected by F. Capra. Type material was reportedly deposited at Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italia

(Festa 1942). However, we were unable to locate the type. According to the present curator of the entomological collection, it may be lost or may have never been deposited (Maria Tavano, comm. pers. 2015). In order to stabilize the nomenclatural concept of *L. biellensis* and to avoid future confusion between *L. biellensis* and *L. nigra*, we designate a neotype for *L. biellensis,* collected as close as possible to the type locality (article 75.3, ICZN 1999). The neotype and some of the topotypes were deposited at the Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italy.

Material and methods

Molecular study: DNA was extracted from specimens stored in the collection of the Museum of Zoology in Lausanne, using a non-destructive method allowing *a posteriori* morphological identification. 658 bp of the mitochondrial protein-coding gene cytochrome c oxydase subunit I (CO1) was amplified using the primers LCO1490 and HCO2198 (for details see Gattolliat et al. 2016).

Additional sequences were downloaded from the Barcode of Life Data System (BOLD) database, notably four sequences from Bavaria, projects Barcoding Fauna Bavarica (Hendrich et al. 2010) and Germany Malaise Trap 05 [GMGRC] (Geiger et al. 2016), two Belgian and four Norwegian sequences from the project 'Norwegian Barcoding of Life [NorBOL] – Freshwater Insects' (Boumans and Brittain 2012), and one more Swiss sequence from the project 'West Palaearctic Plecoptera [WPPLE]'. All specimens are listed in Table 1. Sequences of *Leuctra hippopus* Kempny, 1899 and *Leuctra pseudorosinae* Aubert, 1954 were added to the data matrix as outgroups, as these have the most similar mitochondrial haplotypes according to Gattolliat et al. (2016).

The final data matrix included 25 COI sequences of 587–658 bp (no gaps or missing data). Analyses were conducted in MEGA7 (Kumar et al. 2016). We used uncorrected p distances to calculate genetic distances between haplotypes, and within and between major haploclades (Srivathsan and Meier 2012).

Tree topology was reconstructed using the Maximum Likelihood method based on the Tamura-Nei model (Tamura and Nei 1993). The tree with the highest log likelihood is shown. The percentage of trees in which the associated taxa clustered together is shown next to the branches (bootstrap, 1000 replicates).

Morphology: Ethanol-preserved specimens of *L. nigra* and potential *L. biellensis* from the collections of the Museum of Zoology in Lausanne (MZL), Delmastro (Del), Murányi (Mur), Ravizza (Rav) and Vinçon (Vin) were examined. Since 2016, all of Ravizza's collection is housed in the MZL. Neotype, as well as five male and five female imagoes are deposited at the Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italy. The full list of examined specimens is given in the results section.

Results

Molecular study

The mitochondrial phylogeny clearly recovers *L. nigra* and *L. biellensis* as distinct monophyletic clades (bootstrap of 100%), with intraspecific distances below 1% (Table 2). Distances between haplotypes of *L. biellensis* and haplotypes of *L. nigra* range from 8.8 to 9.1%, while distances between these species and *L. pseudorosinae* and *L. hippopus*, are between 13 and 15% (Table 2). Distances between populations within *L. nigra* are always under 1% even in the case of geographically distant sites such as Finnmark in Norway and Bavaria in Germany (Table 2).

Morphological re-examination and redescription

Leuctra nigra (Olivier, 1811)

Figs 1, 2a–g

Nemoura nigra Olivier 1811: 186

Leuctra acuminata Bengtsson, 1933 (syn. fide Brinck 1949).

Leuctra nigra Oliv., Mosely 1932: 27, figs 39–40, pl. V/26; Kühtreiber 1934: 76, fig. 55; Despax 1951: 140, fig. 61c-d; Illies 1955: 68, fig. 61; Aubert 1959: 65, figs 159–160; Mendl 1968: 70; Kis 1974: 87, 88, figs 37a–e; Ravizza and Vinçon 1998: 303, fig. 6a–f; Teslenko and Zhiltzova 2009, 223, figs 1235–1239; Lubini et al. 2012: 180, fig. 433, 196, fig. 477.

Locus typicus: France, Versailles.

Material examined. FRANCE: BRITANY: Finistère: Rosnoen, Toulencoat, 22.03.2001, 6♂ (Manach leg). **VOSGES MASSIF: Vosges:** SW Colmar, > Wasserbourg, Krebsbach, Fecht trib., Ill trib., 700 m, 17.05.1995, 10♂, 13♀; Ballon d'Alsace, Saut-de-la-Truite, 23.08.1996, 1♂, 8♀ (Vin). **MASSIF-CENTRAL: Saône-et-Loire:** Morvan Massif, Haut-Folon, 800 m, 14.07.1994, 5♂, 7♀ (Vin); **Puy-de-Dôme**: Forez Mountains, > Vertolaye, > Chansert Pass, Jasserie de la Croix Fossat, 1500 m, 17.07.1994, 3♂, 7♀; St Pierre-la-Bourlhonne, cross road to the Chansert Pass, Dore trib., 17.07.1994, 1♀; W. Clermont-Ferrand, between Pontaumur and La-Forêt, b., 21.04.2009, 1♂, 5♀ (Vin). **Loire:** Mont Pilat, Graix, 900 m, 17.07.1994, 1♀; Mont Pilat, Crêt de la Perdrix, Gier b., 1400 m, 17.07.1997, 3♀ (Vin). **Ardèche**: Mont Gerbier-de-Jonc, Loire spring, 16.06.2001, 2♀; Lachamp-Rafael, Bois de Cuze, peat bog, 1350 m, 15.06.2001, 4♂, 6♀ (Vin). **Cantal**: Plomb-du-Cantal Massif, > Super Lioran, 1300 m, 30.07.2004, 3♀ (Vin). **Tarn**: NW slope of Pic de Nord, Arnette trib., Thoré trib., 850 m, 1.05.1991, 4♂, 2♀ (Vin). **Aude**: > Citou, spring, trib. of Argent-double, 900 m, 1.07.1989, 1♀, 1.05.1991, 20♂, 3♀ (Vin). **JURA MASSIF: Ain:** La Vattay Ski Station, Faucille Pass, 1300 m, 30.05.1991, 1♂, 27.06.1995, 1♀, 13.07.1996, 1♀ (Vin); Valserine, Combe de Mijoux, Le Planet, 1200 m, 19.07.1991, 3♀; Valserine, Joux Verte, 19.07.1991, 2♀ (MZL); **Doubs**: Jougne, Swiss Border, Les Tavins, La Tavine, Orbe trib., 900 m, 28.06.1995, 1♀ (Vin). **ALPS: Haute-Savoie:** Montet Pass, > Vallorcine, Eau-Noire trib., 1450 m, 21.06.1991, 2♂, 15♀ (Vin); **Savoie**: Allevard, Val Pelouse, 1400 m, 7.06.1987, 10♂, 1♀; Saisie

Table 1. Specimens used for the phylogenetic analysis of the mitochondrial gene CO1.

Species	Sample ID	Collectors	Date	Country	Province	Exact Site	Lat	Lon	Elev	Accession number
Leuctra biellensis	LN_TI_15	P. Baumann	5/30/2007	Switzerland	Graubunden	Cavagliasch, Cavaglia	46°21’45”	10°02’43”	1690	GBIFCH00238522
Leuctra biellensis	LN_TI_16	P. Baumann	5/30/2007	Switzerland	Graubunden	Cavagliasch, Cavaglia	46°21’45”	10°02’43”	1690	GBIFCH00238523
Leuctra biellensis	LN_TI_17	H. Vicentini	6/2/2006	Switzerland	Ticino	Quelle Vignino, Montagnola	45°58’06”	8°55’03”	460	GBIFCH00238524
Leuctra biellensis	LN_TI_18	H. Vicentini	6/2/2007	Switzerland	Ticino	Quelle Vignino, Montagnola	45°58’06”	8°55’03”	460	GBIFCH00238525
Leuctra biellensis	LN_TI_19	H. Vicentini	6/19/2010	Switzerland	Ticino	Quelle Pian Sagno Acquacalda	46°32’04”	8°50’41”	1665	GBIFCH00238526
Leuctra biellensis	EPT-344	R. Tester Ryf	6/1/2009	Switzerland	Ticino	Ticono, Mte. Ceneri	46°08’11”	8°54’04”	680	GBIFCH00277633
Leuctra hippopus	EPT-321	S. Knispel	4/7/2010	Switzerland	Fribourg	Ruisseau, Villargiroud	46°41’22”	6°59’39”	795	GBIFCH00280313
Leuctra hippopus	EPT-322	P. Stucki	4/16/2010	Switzerland	Vaud	Veyron, La Chaux	46°37’07”	6°28’33”	540	GBIFCH00280288
Leuctra hippopus	EPT-323	V. Lubini	4/1/2009	Switzerland	Zürich	Wehrenbach, Zürich	47°21’10”	8°35’02”	500	GBIFCH00280295
Leuctra nigra	NHMO-EPT_89	B. Koese & L. Boumans	3/18/2010	Belgium	Limburg	Rekem, Ziepbeek	50°55’28”	5°39’15”	50 ca	KY250738
Leuctra nigra	NHMO-EPT_80	B. Koese & L. Boumans	3/18/2010	Belgium	Limburg	Rekem, Ziepbeek	50°55’28”	5°39’15”	50 ca	KY250735
Leuctra nigra	NHMO-EPT_55	L. Boumans	5/12/2010	Norway	Hedmark	Galten, bekk til Galthaen	61°53’54”	11°46’27”	655	KY250740
Leuctra nigra	NHMO-EPT_1553	T. Ekrem	7/20/2010	Norway	Finnmark	Sør-Varanger, Sameti, Sametijohka	69°24’04”	29°43’09”	45	KY250739
Leuctra nigra	NHMO-EPT_982	L. Boumans, T. Ekrem	7/28/2010	Norway	Finnmark	Lebesby, Kunes, Austerelva	70°20’37”	26°31’09”	10	KY250741
Leuctra nigra	M200612	G. Vincon	6/20/2010	Switzerland	Jura	Jura Massif, Tramelan, Gruere lake tributaries	47°14’17”	7°03’01”	1000 ca	KY250737
Leuctra nigra	NHMO-EPT_462	L. Boumans	5/26/2010	Norway	Oppland	O Heimdalsvatn, stream to outflow	61°53’54”	8°53’51”	1095	KY250736
Leuctra nigra	EPT-342	S. Knispel	5/18/2010	Switzerland	Vaud	Affl. Bressonne, Les Censières	46°34’24”	6°42’50”	865	GBIFCH00277517
Leuctra nigra	EPT-343	V. Lubini	5/21/2009	Switzerland	St-Gallen	Tüfenbach, Tüfi	47°19’21”	9°12’44”	800	GBIFCH00277566
Leuctra nigra	BC_ZSM_ AQU_00196	M. Hess, U. Heckes & M. Franzen	7/3/2009	Germany	Bavaria	Vorderer Bayerischer Wald	48.909	13.011	900	HM421988
Leuctra nigra	BC_ZSM_ AQU_00747	M. Hess & U. Heckes	7/16/2009	Germany	Bavaria	Mangfallgebirge	47.687	12.056	990	HQ563171
Leuctra nigra	BC_ZSM_ AQU_001124	M. Hess & U. Heckes	4/10/2011	Germany	Bavaria	Hinterer Bayerischer Wald	48.94	13.41	770	KY261279
Leuctra nigra	BIOUG03760-E10	G. Sellmayer	6/8/2012	Germany	Bavaria	Bayerischer National Park	48.9509	13.422	840	KY261521
Leuctra pseudorosinae	EPT-532	J.-P. Reding	5/26/2014	Switzerland	Vaud	Ste Croix, Affluent Dénériaz, la Merla	46°50’55”	6°31’33”	1200	GBIFCH00280264
Leuctra pseudorosinae	EPT-533	J.-P. Reding	5/26/2014	Switzerland	Vaud	Ste Croix, Affluent Dénériaz, la Merla	46°50’55”	6°31’33”	1200	GBIFCH00280174
Leuctra pseudorosinae	EPT-534	J.-P. Reding	5/26/2014	Switzerland	Vaud	Ste Croix, Affluent Dénériaz, la Merla	46°50’55”	6°31’33”	1200	GBIFCH00279996

Table 2. Estimates of evolutionary divergence between geographical clusters of *Leuctra nigra* and *Leuctra biellensis* using uncorrected p distances. Minimum and maximum distances are indicated in brackets.

	L. nigra **Germany & CH**	***L. nigra*** **Norway**	***L. nigra*** **Belgium**	***L. biellensis***	***L. hippopus***	***L. pseudorosinae***
L. nigra **Germany & CH**	0.000					
	(0.000–0.001)					
L. nigra **Norway**	0.007	0.001				
	(0.002–0.010)	(0.000–0.009)				
L. nigra **Belgium**	0.004	0.004	0.000			
	(0.000–0.007)	(0.002–0.009)	(0.000)			
L. biellensis	0.091	0.088	0.091	0.001		
	(0.090–0.094)	(0.085–0.090)	(0.090–0.092)	(0.000–0.002)		
L. hippopus	0.141	0.139	0.141	0.135	0.000	
	(0.140–0.143)	(0.138–0.140)	(0.141)	(0.135)	(0.000)	
L. pseudorosinae	0.154	0.152	0.155	0.128	0.133	0.001
	(0.153–0.157)	(0.152–0.153)	(0.155)	(0.124–0.131)	(0.131–0.136)	(0.000–0.007)

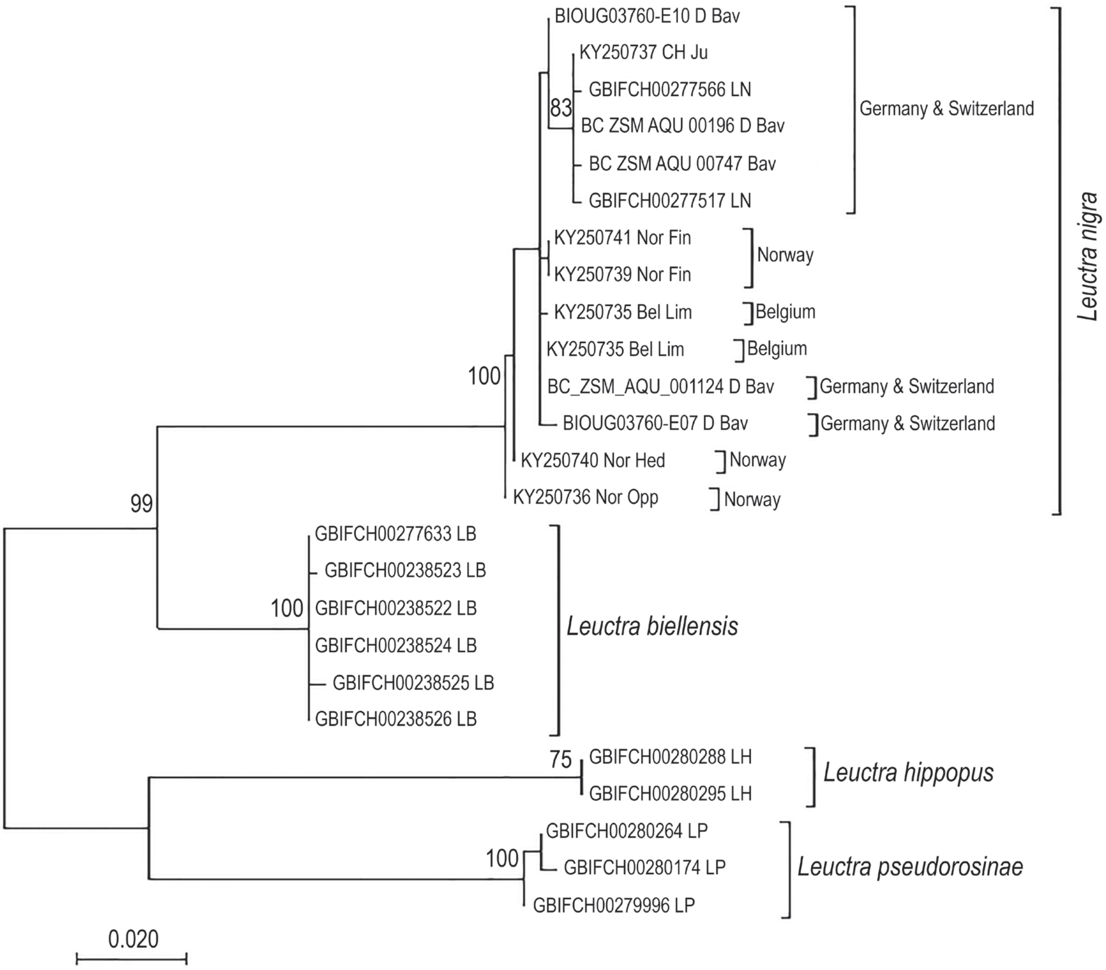

Figure 1. Maximum Likelihood (ML) consensus tree reconstructed for 25 specimens of *Leuctra* spp. Tree drawn to scale, branch lengths measured in number of substitutions per site, deeper nodes labelled above branches with Maximum Likelihood bootstrap support.

Pass, Nant Rouge trib., 1600 m, 22.05.1991, 1♂, 1♀ (Vin). **Isère**: Chartreuse Massif, < Charmette Pass, Tenaison b., Vence trib., 1200 m, 28.05.1988, 1♂ (Vin); Belledonne Massif, below Oursière Cascade, Doménon trib., brook, 1500 m, 4.06.1995, 1♂, 1♀; < Chamrousse, Fénérieux b., Prémol trib, between Prémol Forest House and Luitel Lake, 1200 m, 10.06.1985, 1♂, 3♀; < Chamrousse, Premol Forest House, Sonnant trib., 1100 m, 10.06.1985, 1♀,

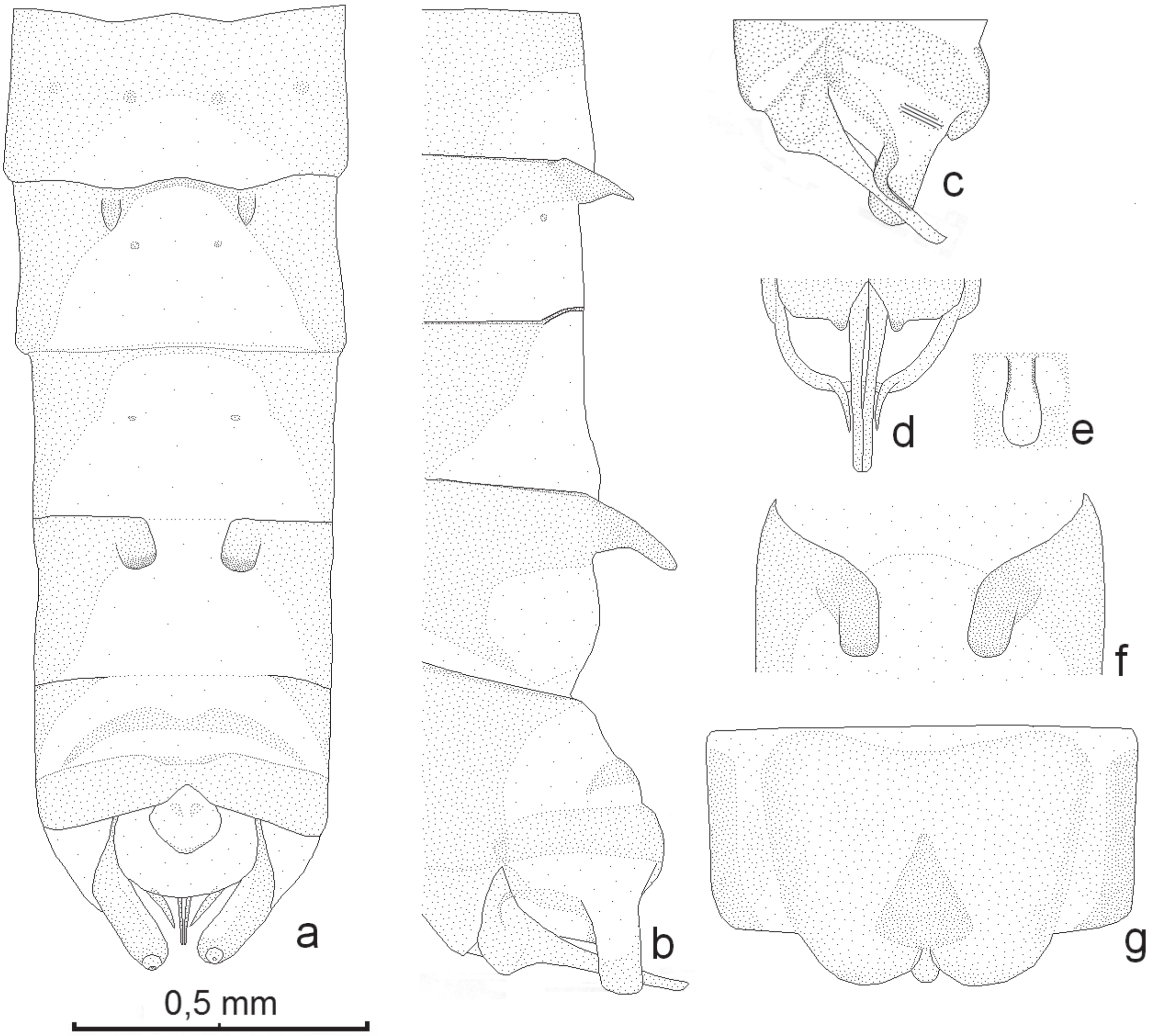

Figure 2. *Leuctra nigra*, from France, Allevard, Val Pelouse. Male: **a** = abdomen tip, dorsal view, **b** = lateral view; **c** = paraprocts lateral view, **d** = ventral view; **e** = ventral vesicle; **f** = tergite VIII top view. Female: **g** = subgenital plate, ventral view.

24.05.1998, 1♀, 19.05.2013, 7♂, 5♀, 2.06.2013, 2♂, 1♀ (Vin). **SWITZERLAND, JURA MASSIF**: NW Tramelan, Gruère Lake, b. right side of the lake, 20.06.2012, 5♂, 11♀ (Vin). **GERMANY**: Fulda, 1981, 2♂, 1♀ (Zwick leg), **SLOVAKIA**: Vysoké Mountains, Tatry, Podspady, Javorinka r., 11.07.1967, 5♂, 5♀ (Steinmann & Mur).

Complementary description. Based on French specimens: Savoie, Allevard, Val Pelouse, 1400 m, 7.06.1987. **Male** (Fig. 2a–f): Tergite VI with two small triangular appendices pointing upwards and backwards in side view (Fig. 2b). Tergite VII with non-interrupted anterior margin and wide median bell-shaped membranous area. Tergite VIII with two strong teeth pointing upwards and backwards in side view (Fig. 2a, b, f); teeth sub-rectangular in dorsal view (Fig. 2f). Tergite IX with anterior margin interrupted on nearly half segment width, lateral edges triangular ending in sharp angles near anterior margin. Lateral lobes of paraprocts with a sclerotized hook-shaped expansion turning backwards and extending along distal part of specilla (Fig. 2c–d). Specilla straight in ventral and side views (Fig. 2c–d), slightly curved at their tip (Fig. 2c). Sternite IX: ventral vesicle racket-shaped (Fig. 2e). **Female** (Fig. 2g): subgenital plate with two rounded lobes separated by a small rounded lamella; a triangular sclerite placed between the 2 lobes is visible beneath transparent cuticle.

Leuctra biellensis Festa, 1942

Figs 1, 3a–g, 4

Leuctra biellensis, Consiglio 1962

Leuctra nigra Oliv., Fochetti and Tierno de Figueroa 2008: 259, fig. 160a–f.

Locus typicus: Alpe Finestre, Val Chiobbia, Piemonte (altitude 1700 m).

Material examined. Neotype (GBIFCH00235761): Italy, Pennine Alps : Biellese mountains, Oropa, torrents and brooks, 1200–1900 m, 06.1978–07.1978, Coll. C.

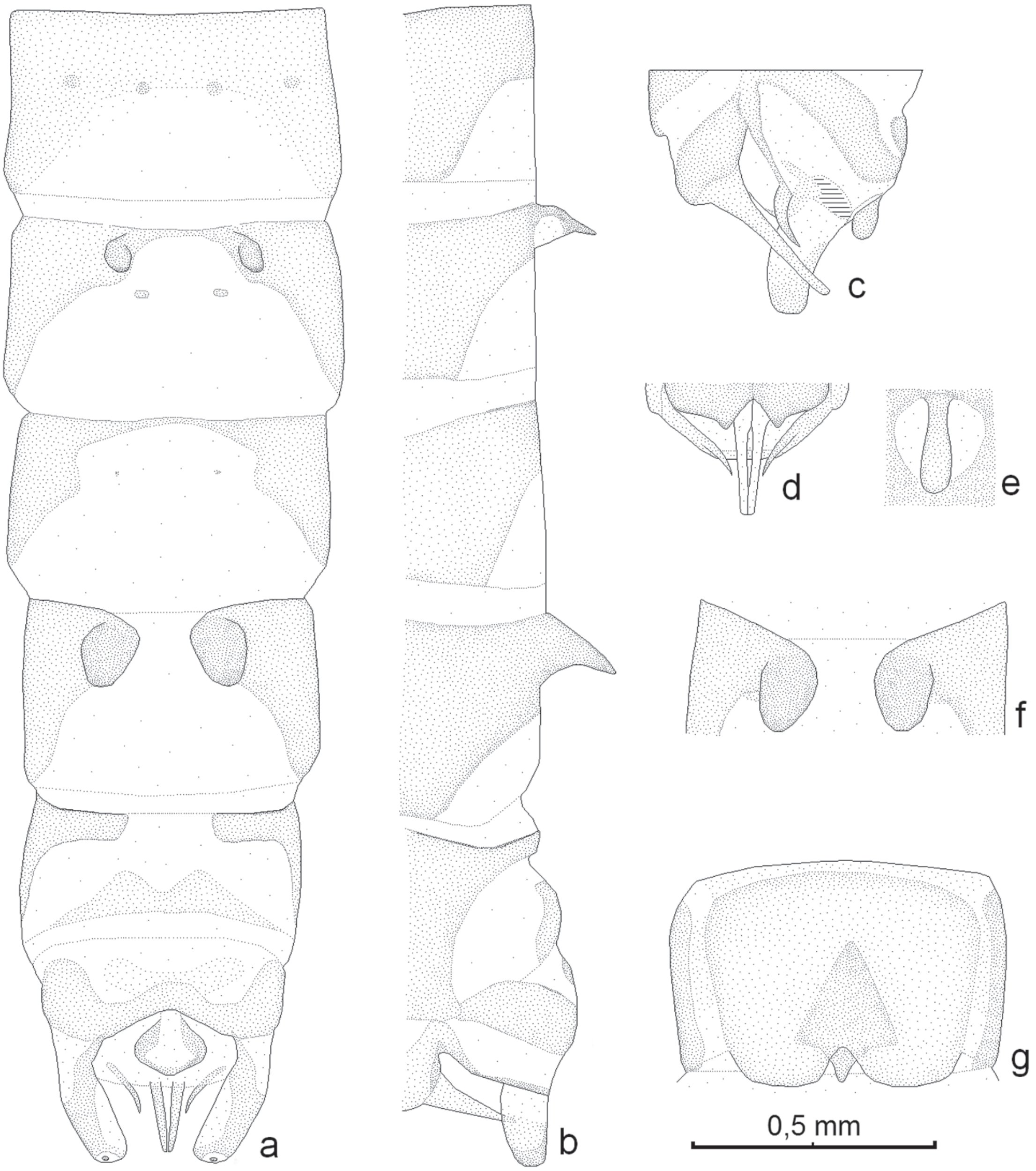

Figure 3. *Leuctra biellensis* from Swiss, Ceneri Mount, Isone. Male: a = abdomen tip, dorsal view, b = lateral view; c = paraprocts lateral view, **d** = ventral view; **e** = ventral vesicle; **f** = tergite VIII top view. Female: **g** = subgenital plate, ventral view.

Ravizza, 1♂ (Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italy).

Topotypes (GBIFCH00235762): same data as neotype: 175♂, 153♀.

ITALY: Pennine Alps: Civiasco, (NO), 700 m, 25.04.1992, 16♂, 2♀; Valsesia, Morce brook, 500 m, 25.04.1975, 5♂, 1♀ (Rav); Biellese mountains, brooks, Elvo trib., 1100 m, 18.05.1981, 7♂, 1♀(Rav); Biellese mountains, Donato, Vione tor., 950 m, 21.05.1979, 16 larves (1 male nymph) (Rav); Andrate, Graglia, slow brook, Mombarone mount, 5.06.1978, ♂, ♀ (Rav). Aosta Valley, Dora Baltea trib., > Trovinasse, Colla della Lace, 1900 m, 11.07.2003, 1♂; > Trovinasse, Colla della Lace, 1700 m, 24.05.2003, 4♂, 6♀; Dora Baltea trib., Pont-St-Martin, > Carema, 500 m, 1.06.1991, 2♂, 4♀; Dora Baltea trib., > Nomaglio, road from Andrate to Biella, 600 m, 1.06.1991, 13♂, 9♀; 31.03.2000, 1♂, 1♀; E. Varallo, Civiasco, Sesia trib., b., 850 m, 2.06.1991, 2♂, 1♀; N. Varallo, > Cervarolo, 1500 m, 2.06.1991, 4♂, 1♀; < Cervarolo, > Piane del Alpe, b., 1200 m, 2.06.1991, 9♂, 6♀; W. Grevellona, Val Strona, > Campello Monti, 1500 m, 13.08.2005, 1♀; Val Strona, > Massiola, < Rosarolo, b., 750 m, 26.04.1999, 12♂, 3♀; Val Strona, > Omegna, b., 500 m, 24.05.2003, 2♂, 1♀; SW. Domodossola, Valle Anzasca, Macugnaga, Staffa, b., 1300 m, 2.06.1991, 16♂, 16♀; Valle Anzasca, Macugnaga, Prequartera, 800 m, 1.06.1991, 3♂, 3♀ (Vin). **Cottian Alps:** Ceres, Almesio, 750 m, 11.06.2001, 4♂, 3♀; Lemie, Val d'Ovarda, A. Milone, 1650 m, 20.06.2001, 1♂, 4♀; Locana,

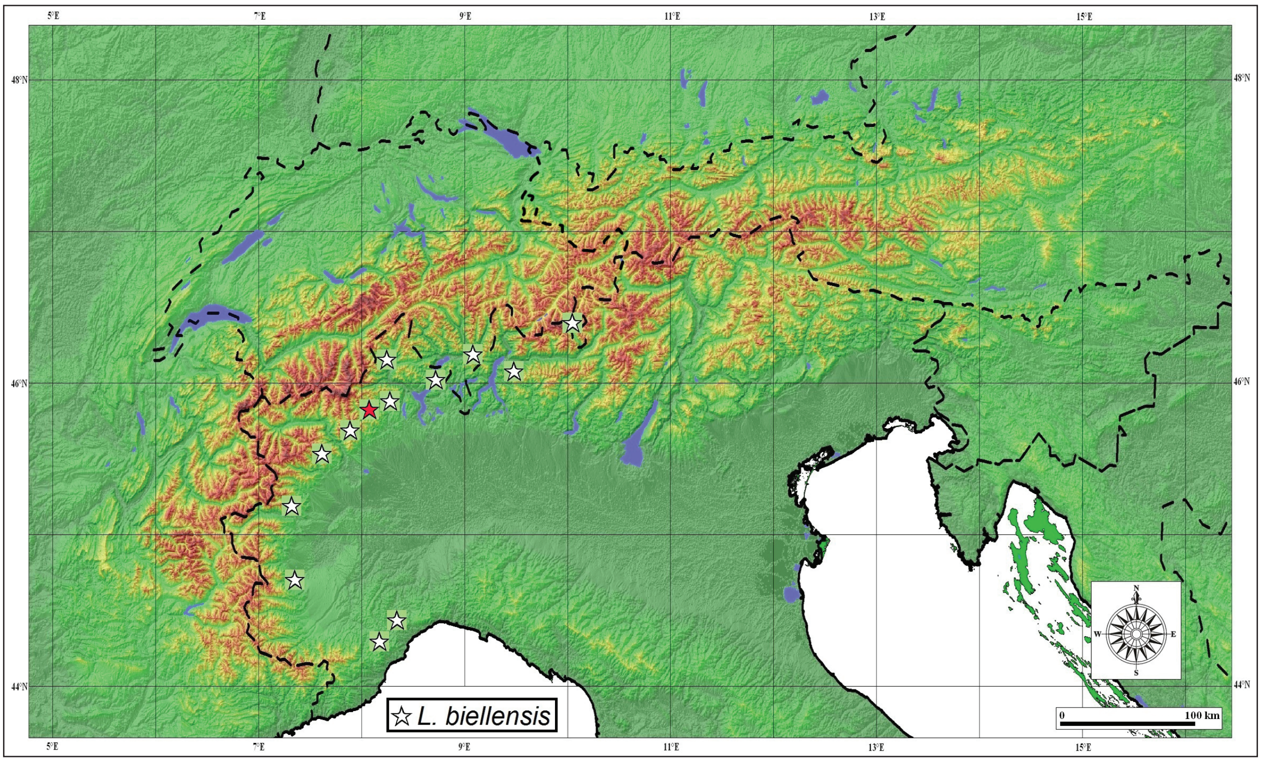

Figure 4. Distribution area of *Leuctra biellensis*. Red star = Type locality. White star = other localities with *L. biellensis*.

val Piantonetto, S. Giacomo, 1130 m, 26.06.2001, 1♀; Villafranca Piemonte, TO, Cappella della Missione, 260 m, 24.03.2002, 2♂; (Del); **Graian Alps**: Frassinato brook, Soana trib., 1000 m, 18.06.1992, 1♀ (Rav); Val Soana, 700 - 850 m, 11♂, 6♀ (Rav); Lis Pass, > Girardi, Stura di Lanza trib., b., 1100 m, 7.05.2000, 5♂, 2♀; 27.08.2005, 2♀; Val di Viu, Stura di Lanza trib., > Viu, Piazette, b., 1200 m, 1.04.2000, 3♂; Val di Viu, Stura di Lanza trib., < Viu, brook, 600 m, 22.04.2008, 3♂, 6♀; NE. Lanzo Torinese, > Corio, Pian d'Audi, Rio Malone trib., 865 m, 23.10.2000, 1♀; Aosta Valley, > Quincinetto, > Scalaro, 1500 m, 1.05.2009, 1♀; > Quincinetto, Rio della Folla, 1250 m, 11.07.2012, 1♀; > Quincinetto, road to Lecchia sup. and road to Scalaro (iron bridge), 1100 m, 1.05.2009, 1♂; Aosta Valley, > Champorcher, Valle della Legne, Ayasse trib., 1200 m, 6.05.2000, 1♂ (Vin). **Rhaetian Alps**: Po Valley, Rocchellaif, Po, 550 m, 1.05.1982, 4♂, 1♀ (Rav). **Liguria**: Calizzano brook, 900 m, 28.04.1976, 3♂ (Rav); (SV) Calizzano, Melogno Pass, Frassino trib. 800-1000 m, 27♂, 4♀ (Rav); Montenotte, Erro spring, 700-950 m, 4.05.1974, 48♂, 40♀ + 65♂, 58♀ (Rav); Mont San Giorgio, brook, 750 m, 16.04.1974, 10♂, 3♀ (Rav). **Lombardia**, Casargo, (CO), Varonne tor., 2.06.1973, 21♂, 16♀, Bucuarelli leg (Rav); PreAlps, San Michele (VA), Olocrene spring, 800 m, 8.07.1986, 2♂, 3♀(Rav).

SWITZERLAND: Ticino, Lepontine Alps: Ceneri Mount, > Isone, before the military base, 1.04.2015, 10♂, 5♀ (Vin); Valle Lucoresagguo, Piace Seguo, 1650 m, 23.05.1988, 28♂, 16♀ (Rav). **Rhaetian Alps: Graubünden,** Cavagliasch, Cavaglia, 1690 m, 30.05.2007, 2♂ (P. Baumann).

Complementary description. Male (Fig. 3a–f): Tergite VI with two small triangular appendices pointing upwards and backwards in side view (Fig. 3b). Tergite VII with non-interrupted anterior margin and wide median bell-shaped membranous area. Tergite VIII with two strong teeth pointing upwards and backwards (Fig. 3a, b) and nearly triangular in dorsal view (Fig. 3f). Tergite IX with anterior margin interrupted on nearly one third of segment width, lateral edges sub-triangular forming a wide strip along anterior margin (Fig. 3a). Lateral lobes of paraprocts with a sclerotized sickle-shaped expansion slightly bent towards distal part of specilla (Fig. 3c–d). Specilla straight in ventral and side views (Fig. 3c–d). Sternite IX: ventral vesicle racket-shaped (Fig. 3e). **Female** (Fig. 3g): subgenital plate with two rounded lobes separated by a small triangular lamella; a triangular sclerite placed between the 2 lobes is visible by transparency under the cuticle.

Ecological preferences and distribution area. *Leuctra biellensis* is a crenophilic species occurring in springs and brooklets at various altitudes (260–1900 m). The flight period is mainly in spring and early summer (III–VII) but few adults also occur in autumn (VIII–X). Its distribution area widely covers the western part of the Italian Alps from the Rhaetian Alps to the Maritime Alps and also extends in Liguria (Fig. 4). Its occurrence in Switzerland is restricted to the southern slope of the Alps.

Discussion

Aubert (1954) was the first who challenged the validity of *Leuctra biellensis*, suggesting that it could be a junior synonym of *Leuctra nigra*, but without formally establishing the synonymy. In the same way, Illies (1966) also considered the species as doubtful but did not change its status. Consiglio (1962, 1967) likewise adopted an ambivalent attitude. He first considered *L. biellensis* to be a valid species (Consiglio 1962), then changed his mind and established the synonymy with *L. nigra* (Consiglio 1967, p. 18). This synonymy was then confirmed by Zwick (1973). However, neither Aubert nor Consiglio adduced the required morphological details that would have justified this synonymy.

Male and female imagos of these two species can be morphologically distinguished by the following characters. In the male, the two teeth of tergite VIII are sub-triangular in dorsal view in *L. biellensis* (Fig. 3f), instead of sub-rectangular in *L. nigra* (Fig. 2f); the lateral edges of tergite IX form a wide sclerotized strip on nearly half part of the anterior margin in *L. biellensis* (Fig. 3a), while they end in acute angles in *L. nigra* (Fig. 2a); the distal expansions of the paraprocts are sickle-shaped and not lying along the specilla in *L. biellensis* (Fig. 3d), while they are hook-shaped with their tip lying along the specilla in *L. nigra* (Fig. 2d). In the female, the lamella between the two lobes of the subgenital plate is triangular in *L. biellensis* (Fig. 3g) and rounded in *L. nigra* (Fig. 2g).

Leuctra biellensis is an alpine micro-endemic species only occurring in the western and internal part of the Alps like other cryptic species of Plecoptera (Ravizza and Vinçon 1998) or Trichoptera (Graf et al. 2015). The species is strongly crenophilic, with long flight period (III–X). Conversely, *L. nigra* is a central north-European species, mainly occurring in lentic biotopes and with shorter flight period (V–VIII) (Ravizza and Vinçon 1998). Both species were never collected together in the same locations and therefore *L. biellensis* can be considered as a sister species of *L. nigra*, inhabiting the internal slope of the Alps where it was probably isolated from *L. nigra*. The same applies to many other alpine species such as *L. muranyii* Vinçon and Graf, 2011 and *L. juliettae* Vinçon and Graf, 2011, two sister species of *L. braueri* Kempnyi, 1898, isolated in a restricted part of the eastern Alps (Vinçon and Graf 2011). Molecular tools associated with morphological characters are very promising to separate species in groups with recent diversification (Vitecek et al. 2017).

We found around 9% of distance between COI haplotypes of *L. nigra* and *L. biellensis*. While a 3.5% COI sequence distance has been proposed in the DNA barcoding literature as a likely maximal value for intraspecific divergence (Hebert et al. 2003; Zhou et al. 2010), higher intraspecific K2P and p values are not uncommon (e.g., Meier et al. 2006), and have also been reported for Plecoptera (Mynott et al. 2011; Boumans and Baumann 2012; Gill et al. 2015). Nonetheless, 9% distance is an unlikely intraspecific value. We are aware that species cannot be identified or described based on mitochondrial sequences alone. A major reason for this is that strongly divergent haploclades in some populations may result from hybridisation and subsequent mitochondrial introgression (Boumans and Tierno de Figueroa 2016). For this reason, we emphasise that the mitochondrial and morphological data converge to identify *L. biellensis* as a valid species distinct from *L. nigra*. Since our molecular study also contains Scandinavian samples, our results confirm the presence of *L. nigra* in this area and tend to confirm the synonymy made by Brinck (1949) of *Leuctra acuminata* Bengtsson, 1933 with *L. nigra,* especially as *L. acuminata* was established for specimens from Sweden originally identified as *L. nigra*.

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PENSOFT.

Alpine Entomology

Remarkable discovery of the Atlanto-Mediterranean moth *Scythris ventosella* Chrétien, 1907 at high altitude in the Alps of Valais, Switzerland – a possible relict of the late-glacial steppe-belt fauna? (Lepidoptera, Scythrididae)

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Abstract

The unexpected discovery of *Scythris ventosella* Chrétien, 1907 in the Alps of Valais, Switzerland is reported. Early stages, life cycle and habitat characteristics are described. The unusual present-day distribution of this species is discussed and it is suggested that the population in the Valais Alps may represent a relict from the late-glacial steppe-belt fauna.

Zusammenfassung

Die bemerkenswerte Entdeckung der atlanto-mediterranen Kleinschmetterlingsart *Scythris ventosella* Chrétien, 1907 in den Walliser Hochalpen wird mitgeteilt. Angaben zur Biologie und zum Biotop werden aufgeführt. Mögliche Erklärungen zum ungewöhnlichen Verbreitungsmuster werden diskutiert, wobei das Vorkommen als spätglaziales Steppenrelikt gedeutet werden könnte.

Introduction

The Scythrididae are a family of small to medium-sized moths, distributed worldwide and occurring in a variety of different habitats from lowlands to high-mountain sites.

The most recent comprehensive treatment of the European and North African representatives of this family dates from 1997 and lists 237 species (Bengtsson 1997).

While some species occurring in the lowlands may be widely distributed, other taxa seem to be restricted to very small areas, especially in mountain regions thus representing local endemism (Huemer 2000). For Switzerland, 34 scythridid species are listed (SwissLepTeam 2010), eight of which however are considered doubtful records.

Alpine scythridids are usually brown, dark fuscous or greenish bronze, sometimes with some whitish marks on their forewings. They are notoriously difficult to identify based on their wing-pattern alone. Fortunately however, their male genitalia are not only rather elaborate but also very distinctive and differ considerably from species to species.

Material and methods

In July 2015, a single, unidentifiable small scythridid moth had been observed in the Zermatt mountains, Canton of Valais, Switzerland, at an altitude of 3000 m feeding on a flowering cushion of *Silene acaulis*. Unfortunately, the site was inaccessible, bordering on an abyss.

In the following year, in the same biotope at 3040 m, a male specimen of the same species could be caught. Routine genital dissection was performed.

Results

The male genitals surprisingly revealed characters assigning this specimen unambiguously to *Scythris ventosella* Chrétien, 1907 (Fig. 1).

The biotope in which *S. ventosella* was found is located at a sunny and dry south/southwest facing rocky mountain slope on calcarious ground. The sparse vegetation is characterized as association *Herniarietum alpinae* Zollitsch, 1968 (Steiner 2002) (Fig. 2). As mentioned above, one specimen of *S. ventosella* had been observed feeding on a cushion of *Silene acaulis*.

In the following year, four males and three females were sampled at the site on July 14.-15., the species was then reared from egg and the biology could be identified:

Larval foodplant is *Herniaria alpina* (Caryophyllaceae) (Fig. 3). The egg is white, oval with a sculptured surface. The young caterpillar lives in a silken tube in the plant cushion. It is of light yellowish-brown colour with irregular darker lines and marks, the pattern of which corresponds well with the caterpillars of other Scythridid species. Head and thoracic shield are dark brown. The latter is divided by a central yellowish streak that continues dorsally on the adjacent two body segments; anal shield brown (Fig.4). In autumn, the caterpillar produces a dense cocoon in which it hibernates. Most likely, the life cycle from egg to moth takes usually two years at this altitude, which means that the caterpillar will overwinter twice. Pupation takes place in a rather dense, spindle-shaped silken cocoon in the plant cushion or underneath a stone in early summer. The adult moth has a wingspan of 8–10 mm. Freshly emerged specimens are more or less densely covered with white scales, most of which apparently are lost in the course of lifetime (Figs 5 to 7). The moth does not fly extensively but rather jumps and crawls nervously among the vegetation; it is active during the day.

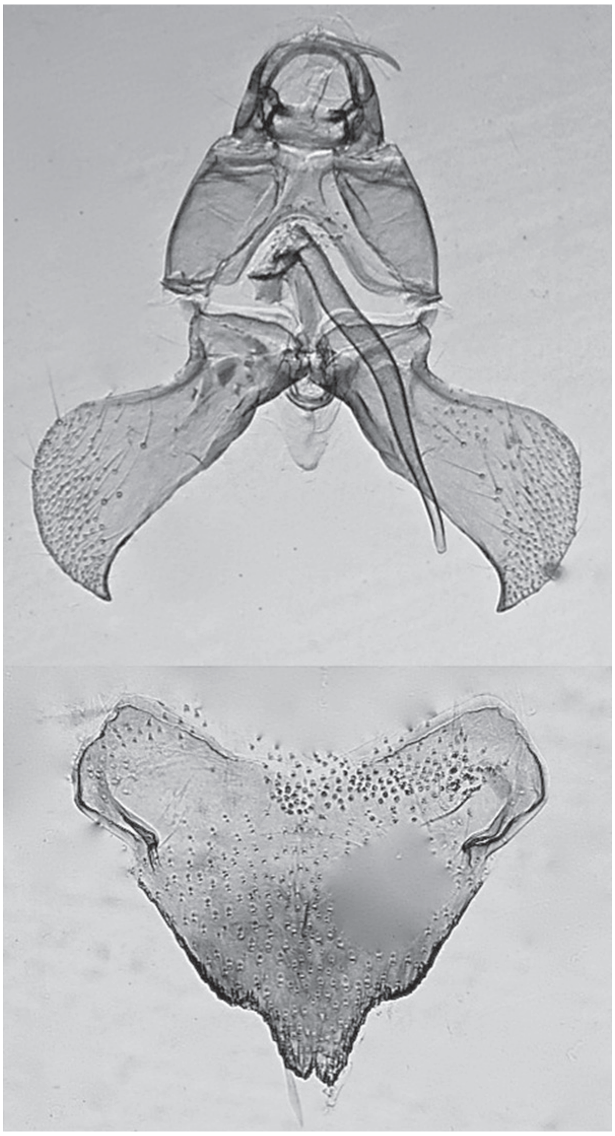

Figure 1. Male genitals (above) and sternum 8 (below) of *S. ventosella*. Site: Switzerland, Canton of Valais, Zermatt, Unterrothorn 3040 m, 6. VIII. 2016, leg., gen. prep. and coll. Jürg Schmid.

Mitochondrial barcode

Legs of a male specimen were used to obtain DNA barcode sequences from the mitochondrial cytochrome oxidase-1 gene The laboratory work was executed at the Canadian Centre for DNA barcoding (CCDB Biodiversity Institute of Ontario, University of Guelph, Canada, Process-ID:LEASS470-17), using the protocol described in De Waard et al. 2008. The results were compared to the data in the Barcode of Life Data System (BOLD) (Ratnasingham and Hebert 2007). The results yielded a 100 % match with the barcode of a specimen originating from the French Central Pyrenees (Gavarnie, 1450 m) (Process-ID:PHLAD268-11).

Discussion

S. ventosella was described in 1907 by Chrétien from material he collected in the south of France, locus typicus being Canet (Languedoc). Only a year later, De Joannis found what he considered a new Scythridid at Plouharnel in southern Bretagne, which he named *Scythris herniariae*. In 1936, Zerny found a Scythridid moth in Morocco, high Atlas mountains, which he described as *Scythris jugicolella*.

In his revision of the Scythrididae family, Passerin d'Entrèves (1976) examined original museum material of the above mentioned taxa and came to the conclusion, that *S. herniariae* and *S. jugicolella* both were synonyms of *S. ventosella*. Finally, Vives Moreno (1984), synonymized *Scythris canetella* Caradja from Portugal and Spain with *S. ventosella*.

Thus, the currently known distribution of *S. ventosella* would place this species into the group of Atlanto-Mediterranean organisms sensu De Lattin (1967), inhabiting a geographical area in the western Mediterraneum, from southern France, French Pyrenees, Spain, Portugal to Morocco with a northern outpost in southern Bretagne (Fig. 8).

Figure 2–7. 2) Biotope, 3040m a.s.l.; **3)** Herniaria alpina; **4)** Adult caterpillar; **5)** Freshly emerged moth; **6)** Reared moth. Scale bar unit: mm; **7)** Wild moth. Scale bar unit: mm.

The published data are:

Spain: Granada Pampaneira, 1140 m (Bengtsson 1997)
Portugal: Serra de Estréla, Torre, 1600–1950 m (Bengtsson 1997)
France: Canet, Languedoc (Chrétien 1907)
France: *S. herniariae*: Plouharnel, Bretagne; sand dunes, hostplant: *Herniaria glabra* (De Joannis, 1908)
France: Midi-Pyrenées, Gavarnie, 1450 m; 1.VIII.2002, leg. J. Nel (www.boldsystems.org)
Morocco: *S. jugicolella* Zerny 1936: Marokko, Grosser Atlas

Unfortunately, in the above-mentioned publications, very little information is given as to the climatic or botanical circumstances of the respective sites. The paucity of known sites may indicate, however, that *S. ventosella* is restricted to biotopes with narrowly defined climatic and/or botanical parameters. Bengtsson (1997) mentions *Paronychia argentea* as hostplant, a herb on very dry, calcareous soil (Aeschimann et al. 2004). De Joannis (1908) gives a detailed description of the caterpillar and identifies its hostplant as *Herniaria glabra*. This plant species prefers sandy or gravel soil in open, sunny and rather dry biotopes in low to subalpine altitudes. Its distribution in Switzerland is rather patchy but it is more common in the Valais main valley.

In contrast, *Herniaria alpina* grows in the subalpine and alpine zone predominantly in the western Alps. Its distribution in Switzerland is very limited; it has been found in the

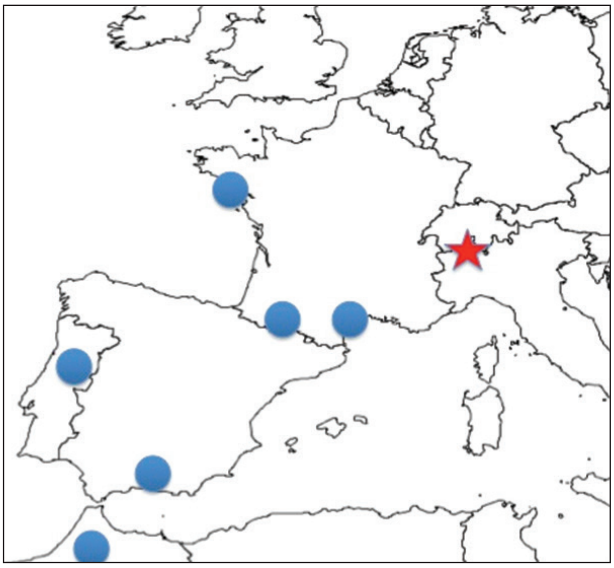

Figure 8. Currently known distribution of *S. ventosella* in the Alps (red asterisk) and in the Western Mediterraneum (blue dots).

southern chain of the Valais Alps, in northern Ticino and some old records exist from a few spots in central Grisons (Lauber and Wagner 1996, www.infoflora.ch).

The Zermatt region is famous for both its remarkable botanical and lepidopterological diversity, which again is derived from peculiar historical, climatic and geological conditions. A surrounding mountain chain with peaks beyond 4000 m shields the valley from precipitations. Genetic data have demonstrated (Bettin et al. 2007) that at least some slopes must have remained ice free during the last glaciation (nunataks) where typical steppe plants such as *Astragalus exscapus*, *Silene vallesia*, *Stipa joannis*, *Alyssum alpestre* survived to the present day (Delarze 1987, Steiner 2002). The specific biotope of *S. ventosella* is botanically characterized as *Herniarietum alpinae*, which includes *Draba aizoides*, *Oxytropis helvetica* and *Artemisia glacialis*, all plant species characteristic for very dry, soft limestone bedrock.

The exceptional altitude and the south/southwest facing exposition result in local climatic extremes: High noon ground temperatures, enhanced ultraviolet radiation, pronounced nocturnal and seasonal temperature drop in combination with very dry soil and unusual low precipitations form a microclimate somewhat comparable to a desert situation. Thus, similarities with steppes or desert-like localities in the western Mediterraneum, where *S. ventosella* locally occurs, appear not unlikely.

Organisms having survived at isolated refugia within the alpine mountain system during the entire Quaternary glaciation period, however, are expected to display considerable genetic differences when compared to their siblings having survived in peripheral refugia (Schönswetter et al. 2005). The fact that the mitochondrial barcode regions of *S. ventosella* from Zermatt and from the French Pyrenees are identical can be taken as indication that the geographic separation of these populations is recent, i.e. postglacial.

During the last glaciation, the region between the Pyrenees and the Alps was covered by tundra and cold steppe where cold-adapted organisms were able to survive. Some of these species are now restricted to high mountain areas (Habel et al. 2010). For the butterfly *Erebia epiphron*, a common genetic lineage between the populations of the Northern Pyrenees and the Western Alps has been documented (Schmitt 2010) thus demonstrating a once continuous area of occurrence where today only strictly separated populations thrive.

Likewise, it may be hypothesized that *S. ventosella* at a high alpine location in the Swiss Alps could be a surviving relict of the late-glacial steppe-belt which expanded from the Iberian Peninsula to the base of the ice-covered south-western Alps but must also have been in communication with selected ice-free nunataks within the alpine range. Later, in consequence of a progressively warmer and more humid postglacial climate, *S. ventosella* would have been forced to retreat to few favourable sites with dry, sunny cold microclimate such as mountain areas (Sierras) or coastal dunes, where it is found in isolated colonies to the present day. This scenario would also explain why this moth species does not accompany *Herniaria glabra*, the hostplant in coastal Bretagne, in the Valais main valley, where the mean annual temperatures for this insect may be much too high today.

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PENSOFT.

Alpine Entomology

An Alpine Malaise trap

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Abstract

The Southernmost region of Australia, the island of Tasmania, is also the most mountainous, with large areas of rugged alpine environments. This entomological frontier offers a distinct suite of insects for study including many endemic taxa. However, harsh weather, remote locations and rough terrain represent an environment too extreme for many existing insect trap designs. We report here on the design and efficacy of a new Alpine Malaise Trap (AMT), which can be readily hybridised with several other common insect trapping techniques. Advantages of the design include its light weight and portability, low cost, robustness, rapid deployment and long autonomous sampling period. The AMT was field tested in the Tasmanian highlands (AUST) in 2017. A total of 16 orders were collected. As expected, samples are dominated by Diptera. However, the trap also collected a range of flightless taxa including endemic and apterous species, *Apteropanorpa tasmanica* – closest relative of the boreal, snow scorpionflies (*Boreidae*). Combined and compared with other trap types the Alpine Malaise Traps captured less specimens but of a greater diversity than passive sticky traps, while drop traps captured less specimens but a greater diversity than AMT. The statistical potential of the catch is discussed.

Key Words

Long term
flight intercept
sampling
invertebrate
Tasmania
Apteropanorpa

Introduction

Most work on insect biodiversity ultimately relies on sampling populations in nature. The nature of the Tasmanian alpine environments is harsh. The Southernmost region of Australia, the island of Tasmania, is also the most mountainous with large areas of rugged alpine environments (Fig. 1). Low, wind pruned vegetation densely covers rocky, saturated soils. The winter season may see intermittent snow cover for several months, exposing plants to intense UV-B radiation in winter as well as summer. Among the multitude of different insect-trapping methods, few are well suited to the Tasmanian alpine environment.

A century ago René Malaise (1937) observed how efficiently his tent walls intercepted insects and funnelled them to the high points of the roof. His pioneering eponymous design for ‘a new insect trap’ was based on this observation. Malaise traps are still widely employed today. Malaise (1937) initially suggested the long-term, unmonitored operation of his trap tailored it for difficult to reach sites, like “high mountains”. The trap does boast the advantages of continuous autonomous operation; averaging out changing daily conditions and requiring no operator effort. However, early traps were large, gauzy constructions (Malaise 1937, Townes 1962); the adaptation published by Marston (1965) has more than 11 m of collecting face. As a result, classic malaise traps are actually ill suited to alpine sampling.

With such large collection faces, the collection chambers fill quickly. Rather than long term autonomous deployment, traps usually have to be emptied daily (Malaise 1937, Gressitt and Gressitt 1962, van Achterberg 2009, Russo et al. 2011, Diserud et al. 2013) though weekly, fortnightly (Clapperton 1999), and monthly (Doran 2003) are also reported. The fragile nature of the gauzy panes also makes them mismatched to the rough vegetation and wind exposure of Antarctic (Farrow and Greenslade 2013) and Tasmanian-highland sites (Hansen 1988, Doran 2003) although see Solem and Mendl (1989) and Finn and Poff (2008) for successful highland sampling elsewhere. In the advent of smaller traps based on the Malaise model, such as the SLAM and composite insect trap (Russo et al. 2011), we see devices which may be robust enough for alpine deployment. However other limitations persist.

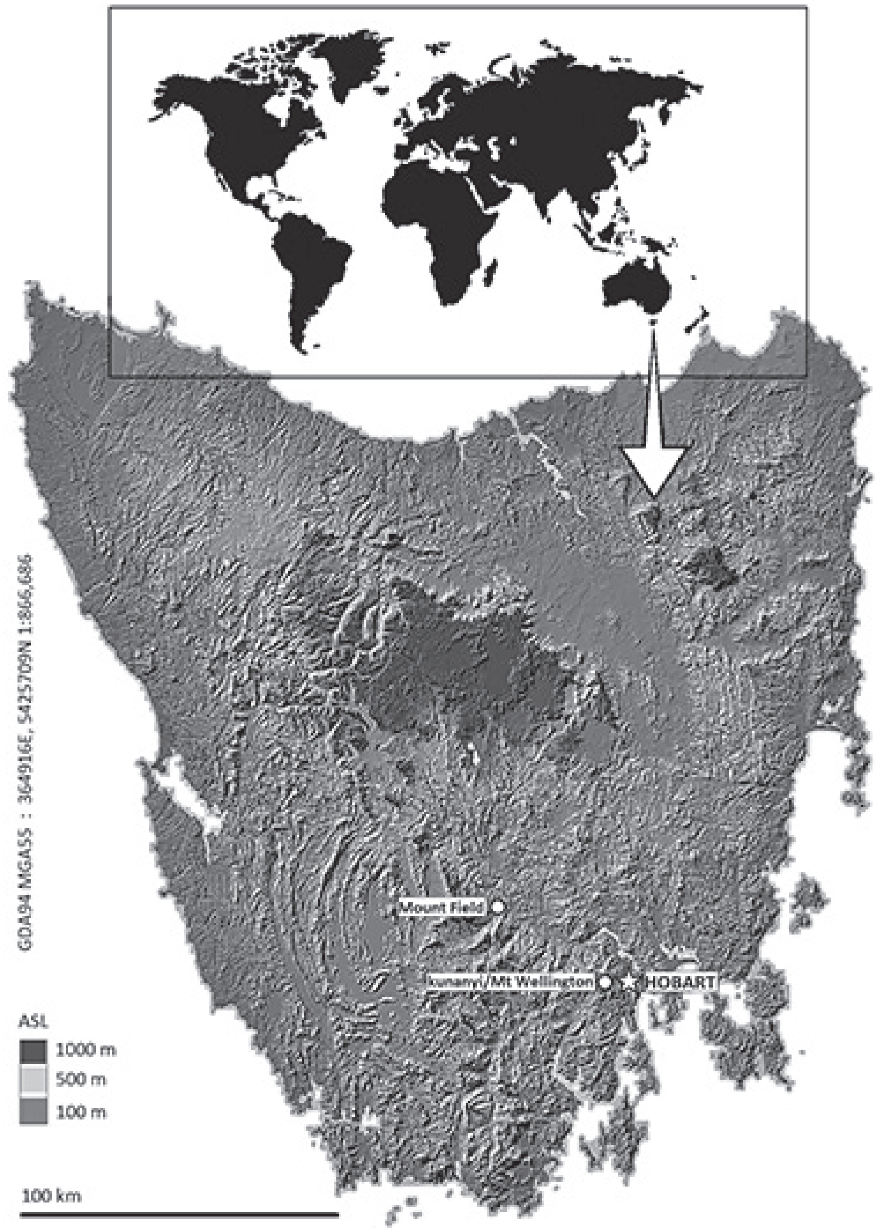

Figure 1. Tasmania, Australia. Elevation Above Sea Level by https://maps.thelist.tas.gov.au/

Ethanol is a widely available and relatively harmless preservative now favoured for Malaise traps. However, evaporation puts a limitation on deployment time and any liquid component adds up to an intolerable weight when replication of samples is desired from a remote location (Russo et al. 2011). Dry killing agents, including cyanide-infused plaster, were used in the earliest traps (Malaise 1937), however, dry traps also require daily emptying to prevent dead and brittle specimens from being damaged by live ones (van Achterberg 2009). Propanol is substituted in remote traps for its slower evaporation rate (Farrow 2013), however, it does not address the issue of weight.

Combining trapping methods expands sampling parameters and improves catch (Moir et al. 2005). A single apparatus which combines sampling techniques takes less time to deploy and operate than multiple individual traps (Russo et al. 2011). These are desirable traits when sampling time is constricted by access time. However, the additional liquid preservative needed to operate pan traps or drop traps adds intolerable weight to sampling systems which must be carried any distance (Hansen 1988). A persistent conflict exists between accessibility and service requirements for traps in remote locations (Farrow 2013, Price and Baker 2016).

Intercept devices for sampling airborne insects in alpine habitats need to be: light weight, for on foot transportation to remote sites; robust against extremes of weather, especially high winds, ice and strong UV-B radiation; have long term capture capacity, while maintaining specimen quality at ‘identification’ standard; and collect effectively enough to generate at least semiquantitative data useful for comparative purposes across a range of invertebrate orders. In the present paper, we assess the effectiveness in the alpine environment of a novel intercept trap that has these attributes, the Alpine Malaise Trap (AMT). We compare the catch of the AMT to those of both sticky traps and drop traps.

Methods

Trap design

The Alpine Malaise Trap design (Fig. 2) replaces gauze or polyester panels in traditional malaise traps with two interlocking Perspex panes set at right angles, forming a cross with four intercepting faces, after Hines and Heikkenen (1977) and Wilkening (1981). This cross is topped with a rigid, clear plastic cone. The cone has a 10 cm diameter opening at the upper end and is attached to a threaded collar (the screw top of a round plastic container with the top cut away, leaving the thread). The thread allows a 10 cm plastic jar to be screwed on and off, forming the top collection chamber and allowing for easy removal of samples. Elastic string, threaded through holes in the panes and cone at each arm of the cross, secure the trap to the ground with a metal peg. Airborne insects are intercepted by the panes and are funnelled upwards by the cone; they collect on a removable sticky insert that lines the collecting chamber. The insert comprises a thin flexible sheet of acetate which conforms to the diameter of the container and holds itself in place with kinetic tension. The sheet is painted with Tanglefoot insect trap coating on the innermost side. With a hole in the top of the collection chamber, a (bamboo) stake can be used to help secure the trap. Staked traps proved to be more robust to wind than unstaked traps and requiring only two opposing elastic tethers (not four). Additional devices, such as colours, baits and lights could also be attached to the stake.

Hybridisation

A hinged, rubber plastic Compact Disk (CD) case, with one inner face coated with Tanglefoot (after Bar-Ness 2012), mounted on the bamboo stake of the AMT acts as a passive flight intercept trap (Fig. 3). The CD case was folded back on itself to clamp the stake and secured in place with an elastic string (rubber bands degraded too quickly); this can be easily removed and reused when recharging the trap. Additionally, the sticky sample sheet used in the Malaise collecting chamber can be engineered to fit precisely into the other half of the CD case, doubling sampling power without doubling resources. Sample units can be collected and stored together in the same case and recharges can be pre-prepared in the lab and carried to site in the same way. We transcribed collection details for both directly onto the exterior of the CD case in the field.

A second catchment array can be utilised as a drop trap (DT, Fig. 4). Benefits include use of existing resources. Additionally, the hole through which the stake passes allows drainage and prevents overflowing, increasing possible sampling period compared with pitfall or pan traps.

Figure 2. Basic Alpine Malaise Trap deployed on kunanyi/Mount Wellington, Hobart (Fig 1.), Tasmania, 2017.

Operation

Alpine Malaise Traps with sticky CD traps (n=35) were trialled from March–December 2017 on Tarn Shelf in Mount Field National Park, Tasmania, 42.6692°S 146.5603°E (1225 m a.s.l.). Alpine Malaise Traps with drop traps (n=4) were trialled from May–December 2017 on the summit of kunanyi/Mount Wellington (Cabinent 2013), Tasmania, 42.8967°S 147.2348°E (1255m a.s.l.). Samples were collected and traps refreshed six weekly.

Sample processing and analysis

At the end of the trial, sampled specimens were left in situ on sticky surfaces, identified to the lowest taxonomic resolution possible and counted by trap. Insect orders were classified by size, for example: Hemiptera, psyllids and thrips – small, Lygaeidae and cicadas – large; Coleoptera, Cantharidae and Mordellidae – small, Chrysomelidae Paropsis and Scarabaeidae Melolonthinae – large; Diptera, Simuliidae – small, Tachinidae – large.

t-Test (two sample assuming equal variances) were performed in Microsoft Excel to compare the total catch

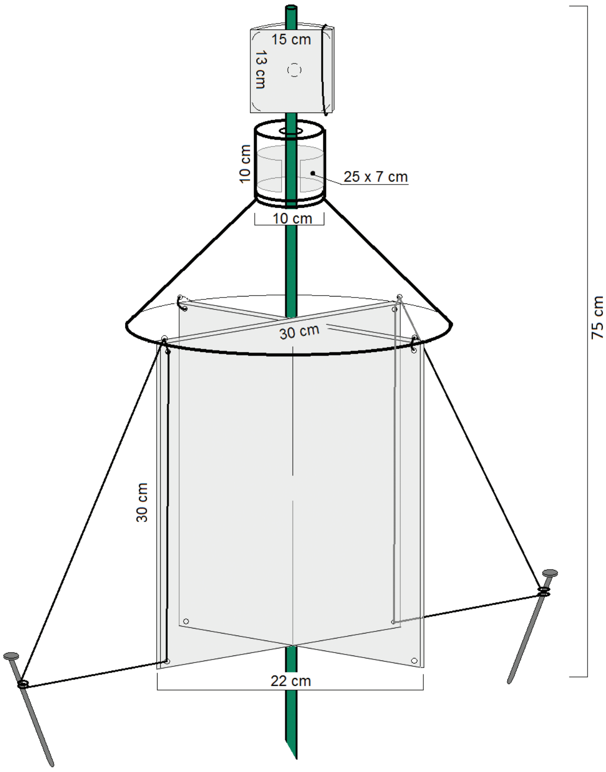

Figure 3. Alpine Malaise Trap including additional stake for securing the trap and passive sticky CD trap.

of each trap type. Mann-Whitney U tests were performed in R (R Core Team 2013) to test whether trap types differed in their capture of individuals in each order.

Results

Field deployment

Our traps were demonstrably robust to the weather conditions prevailing in the Tasmanian highlands. Wind speeds on kunanyi/Mount Wellington (no wind data for Mount Field) during the sampling period could exceed 100 kph and minimum temperatures were below 0 °C for extended periods (Bureau of Meteorology 2017). On Mount Field, snowy winter conditions persisted for 2.5 months leaving some traps buried under snow at the spring data collection. After summer, autumn and winter in the field only 17.6% (6 of 34) were damaged; requiring replacement of one or two Perspex panes and in one case the upper catchment cup. Bamboo poles were replaced in spring as most had degraded due to waterlogging though had not yet broken.

Smaller collecting faces meant that the traps filled up slowly. After 6 weeks deployment in summer there remained space on the sample sheets and freshly caught insects were observed at the time of collection, indicating that the traps were still active and had not reached capacity. Despite undergoing long exposure, sometimes including repeated freeze-thaw cycles, the specimens were predominantly in identifiable condition (Fig. 5).

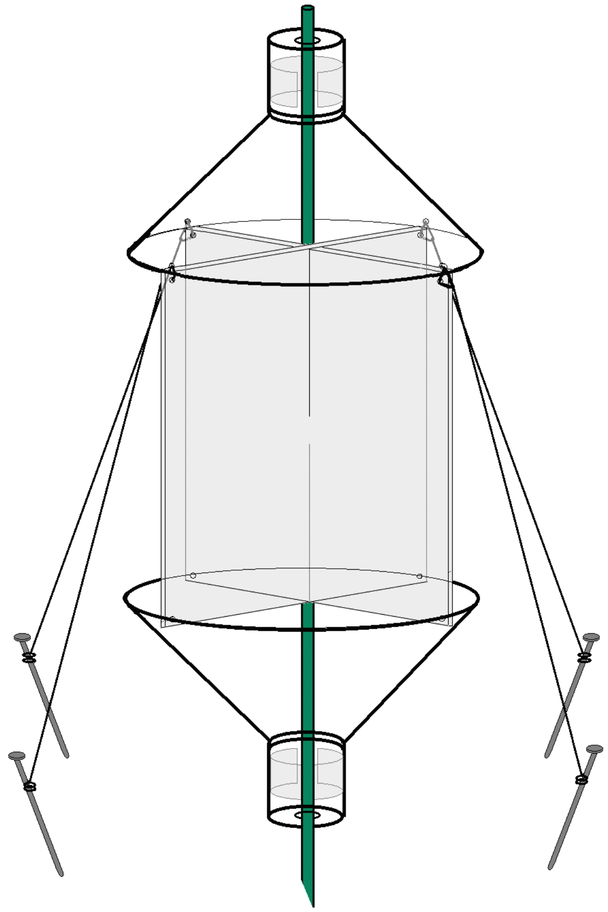

Figure 4. AMT with second collection array arranged as a drop trap (DT).

Profile of the invertebrate catch

At Mt Field 16 orders of invertebrates were sampled, 15 by AMT and 16 by CD (Table 1). Orders per trap ranged from 3–10 on CD, to 3–12 on AMT. Each hybrid AMT+CD captured 417 specimens on average; 239 on sticky CD and 179 specimens in the malaise trap. Alpine Malaise Traps did not catch any Ephemeroptera, however did capture an extra order on average per trap (mean ± sd for CD-traps 7.166 ± 1.555; AMT 8.187 ± 2.023, $t_{2,60}$=2.166, p=0.031). Sticky CD traps captured nearly 2,000 more Diptera and therefore significantly more specimens than AMT (*p*=0.008). However in all other orders the two traps were either equal or AMT captured significantly more specimens (Table 1). Diptera dominated the catch profile of both trap types (AMT 79.5%, CD 88.2%), followed by Hymenoptera (AMT 6.8%, CD 6.2%), however the overall catch profile of AMT is balanced across more orders than the sticky CD samples.

At kunanyi/Mount Wellington 11 orders of invertebrates were sampled. Orders per trap ranged from 8–9 in AMT and 8–11 in DT (Table 2). An average of 890 specimens were captured per hybrid AMT+DT; 567 specimen per AMT and 323 per DT. Flies (Diptera) dominated the catch profile of both trap types (AMT 79.7%, DT 66.7%), followed by Hemiptera (AMT 14,2%, DT 20.6%). Alpine

Table 1. Catch statistics, Mean (Total), of hybrid Alpine Malaise and Sticky CD Traps, n=35, deployed for 6 weeks, March-April, on Tarn Shelf, Mount Field National Park, Tasmania.

	CD		AMT		*p*
Orders	**7.16**	**(16)**	**8.18**	**(15)**	**0.03**
Specimens	**239**	**(7155)**	**179**	**(5716)**	**0.008****
Araneae	0.56	(17)	0.59	(19)	0.95
Blattodea	0.7	(21)	1.18	(38)	0.13
Coleoptera	2.76	(83)	2.09	(67)	0.09
Collembola	0.33	(10)	0.84	(27)	0.02*
Diptera	212	(6380)	138	(4444)	0.002**
Ephemeroptera	0.1	(3)	0	(0)	0.14
Hemiptera	1.2	(36)	1.9	(61)	0.03*
Hymenoptera	14.9	(449)	12.4	(398)	0.44
Lepidoptera	2	(60)	7.7	(247)	<0.001***
Mecoptera	0.23	(7)	1.09	(35)	0.008**
Neuroptera	0.03	(1)	0.03	(1)	1
Orthoptera	0.36	(11)	2.59	(83)	<0.001***
Plecoptera	0.03	(1)	0.12	(4)	0.23
Psocoptera	0.16	(5)	0.06	(2)	0.29
Thysanoptera	2.1	(63)	8.8	(282)	0.04*
Trichoptera	0.26	(8)	0.25	(8)	0.82

* indicate significant *p* values, <0.05, of t-Test and Wilcoxon rank-sum test.

Table 2. Catch statistics, Mean (Total), of hybrid Alpine Malaise and Drop Traps (n=4) deployed for 6 weeks (Oct-Dec) on kunanyi/Mount Wellington, Tasmania. * indicate significant *p* values, <0.05, of t-Test and Wilcoxon rank-sum test. Right hand columns indicate the percent of total catch in the large body size category.

ORDER	AMT		DT		*p*	%Large	
						AMT	DT
Orders	8.5	(9)	9	(11)	0.53		
Specimens	567	(2268)	323	(1999)	0.05*	8.08	91.9
Araneae	5	(20)	3.5	(14)	0.58	0	7.1
Blattodea	0.25	(1)	0.5	(2)	1	0	0
Coleoptera	9	(36)	10.25	(41)	0.58	8.3	51.2
Collembola	0.5	(2)	1.5	(6)	0.02*	0	0
Diptera	452	(1809)	215	(862)	0.12	0.1	4
Formicidae	0.25	(1)	2.25	(9)	0.18	0	0
Hemiptera	81	(324)	66	(267)	0.62	0	2.6
Hymenoptera	4.5	(18)	5.75	(23)	0.62	0	34.7
Lepidoptera	5	(23)	3.5	(14)	0.26	8.7	50
Myriapoda	0	(0)	0.25	(1)	1	0	100
Orthoptera	2	(8)	8	(32)	0.25	0	34.3
Psocoptera	6.5	(26)	5.25	(21)	0.87	0	0

Malaise Traps captured significantly more specimens than DT ($p=0.0599$), due to the capture of nearly 1,000 more Diptera. However in all other orders the two traps were statistically equal (Table 2). Excluding Diptera, Alpine Malaise Trap samples were heavily dominated by Hemiptera, with other categories contributing minimally to the overall composition. Drop trap samples were more balanced between Hemiptera, Coleoptera, Orthoptera and Arachnida. Only 2% (n=99) of total specimens were large bodied, however DT captured 91.9% of these (8.08% AMT). Fifty percent of Coleoptera and Lepidoptera and 34% of Orthoptera and Hymenoptera captured by the drop trap were large bodied, compared with 8% and 0% respectively for the AMT (Table 2).

Unexpected capture of apterous taxa

Apart from the usual profile of expected alate species, various flightless taxa were present in the samples including spiders, immature psocids, ants, immature grasshoppers, apterous microhymenoptera, brachypterous moths and flightless scorpionflies, Apteropanorpidae (Carpenter 1940). In late summer, the AMT captured five times more *Apteropanorpa tasmanica* than sticky CD traps (Table 1); in samples from Autumn (March-October), that number rises to 17 times ($p>0.001$. 317 AMT:18 CD). Trial traps on Mount Wellington at this time captured 131 specimens of *A. tasmanica* in two AMT.

Discussion

The AMT offers a number of advantages over existing designs, especially in relation to sampling in extreme habitats. Its lightness, inexpensiveness and the lack of a need to clear the trap on a daily or weekly basis, make it particularly suited to remote sampling sites (Table 3). The employment of a sticky plastic film in place of a liquid preservative considerably reduced the weight per trap, increasing portability, and eliminated the limitation of evaporation on operating time. Its small size meant a slower capture rate. The traps can be operated in an alpine environment for six weeks of summer without reaching capacity. They were also robust to several meters and months of snow and winds exceeding 100 kph (Bureau of Meteorology 2017). In spite of these extremes, the AMT preserved specimens representing a comprehensive cross section of the airborne alpine insect fauna including some unexpected apterous and brachypterous taxa. A compromise of this method is the quality of specimens recovered. In situ, the sticky gel can obscure and distort characters necessary for species level identification. In this project, specimens were easily assigned to family without further treatment; genus or species in the case of remarkable specimens. Tanglefoot can be dissolved and the specimens recovered into ethanol for taxonomic resolution where necessary. Miller et al. (1993) describe a citrus-oil solvent preferable to the traditional petrochemicals, though dry trapping methods are still recommended if specimen quality is critical.

Flies and wasps are attracted to white or yellow colours (classical Malaise traps are usually white). The transparency of our trap should partly eliminate this bias making for more representative samples. The use of transparent surfaces also allows our trap, when fitted with a drop capture array, to function like a classic window trap, capturing fliers strong enough to become unconscious upon impact with the panes (Hines and Heikkenen 1977, Wilkening 1981). The bias in catches towards flies was expected, as Diptera are often dominant

Figure 5. Sticky acetate sample sheet from AMT deployed for 6 weeks in Mount Field National Park. The sheet is cut to fit a CD case for storage and transport.

Table 3. Comparison of Alpine Malaise Trap with comparable products ^as priced by Australian Entomological Supplies.com or ^^Russo et al. (2011). diy: 'do it yourself' construction costs.

Type	Size (m)	Mass (kg)	$ AUS	Sample window	Visibility	Preservative
AMT – Alpine Malaise Trap	1 x 0.22 x 0.22	1 kg	$50 diy	6 weeks	Low	adhesive
Malaise Trap^	1.5 x 1.8	3 kg	$480–540	1–14 days	V High	ethanol
Composite Insect Trap^^	1.5 x 0.9	4.5 kg	$100 diy	1 day	High	ethanol
Sea Land Air Malaise Trap^	1 m ^{3}	3 kg	$400-600	1–14 days	High	ethanol

elements of the fauna in highland areas (Levesque and Burger 1982, Shaw and Taylor 1986, Konno 2006).

Our catch is largely congruent with that of Doran (2003) who extracted 85% Diptera and 6% Hymenoptera with classic malaise traps from the Warra LTER research site in alpine Tasmania. However, the inclusion of Mecoptera and Orthoptera in our AMT samples diverges from the Warra malaise samples and is more similar to the Warra pitfall samples (Bashford et al. 2001, Doran 2003). The apterous element in the AMT samples suggests that wind is augmenting the trap's flight intercept catch with otherwise sedentary or ambulatory taxa, resulting in samples that fall in-between classic malaise and pitfall traps. If this means that the AMT samples are more location specific, the trap may be more sensitive to differences in environment and treatment. Large mobile insects have already proven a poor indicator of environmental differences at Tasmanian (Driessen and Kirkpatrick 2017) and other sites (Polchaninova et al. 2016, Lazarina et al. 2017).

The most notable captures of flightless taxa were the apterous alpine scorpionfly, genus *Apteropanorpa*, an endemic family of four species similar in appearance to Northern Hemisphere snow scorpionflies (Boreidae). It was first identified by Carpenter in 1940 and formerly presumed rare. Recent reviews identified the new species *A. evansi*, *A. warra* and *A. hartzi;* highlighting the potential for more discoveries (Byers and Yeates 1999, Palmer et al. 2007). Our survey on Mount Field in late summer captured only 39 specimens, however a review of the unprocessed autumn-winter samples reveal 335 more, predominantly

(17:1) captured by the AMT. Trial traps on kunanyi/Mount Wellington captured almost exclusively *A. tasmanica.* Thousands of Apteropanorpidae were captured in pitfall traps at the Warra Long-Term Ecological Research site (Doran 2003). Pitfall traps were decided against for our study due to dense vegetation on thin, rocky, saturated soil. As the AMT is sampling a cross section of flying and pit-fall taxa it may be a useful alternative to pitfalls at other difficult sites.

Despite being considerably shorter than classic malaise traps, 30 cm high intercept faces fit precisely within the 'boundary layer – allowing independent insect flight' as hypothesised and tested by Taylor (1974). While this height was established over grass, and the true boundary layer at our site may be impacted by the height of vegetation, the addition of passive sticky traps projecting above 30 cm, into the 'free air' (Taylor 1974) helps address this potential short fall. Conversely, the extreme wind conditions at our site will have increased turbulence and decreased the boundary layer at times. The same conditions that dictated the small size of the traps compensates for the potential loss of invertebrate catch. Indeed, while flightless species may climb into the traps from contact points with the ground, their even positioning on the sticky sample surface (Fig. 5) suggests a passive carriage to the traps on strong winds. In the case of *A. tasmanica*, such transport constitutes a significant contribution to sampling.

Combining trapping methods is a proven way to counter the limitations of particular trap types and improve sample yield (e.g. Querner and Bruckner 2010). Adding compatible devices to create a single trapping station has been found to reduce the cost and time of using multiple individual traps (Campos et al. 2000, Russo et al. 2011). Similar trap designs to ours include the Composite insect trap (Russo et al. 2011), and the Sea Land and Air Malaise (SLAM) trap.

As the sticky CD traps alone would constitute a robust, cheaper and lighter alpine sampling technique, we were interested to compare the sampling strengths of each. While CD traps captured significantly more specimens overall this is obviously tied to the capture of nearly 2,000 more Diptera. Otherwise the traps are either comparably effective or the AMT captured significantly more specimens of a given order. The AMT did not catch as many taxa or specimen as CD traps, however it does deliver a more taxonomically balanced sample. The CD trap catches were dominated by Diptera and Hymenoptera. While still the top two orders sampled by AMT, dominance of Diptera and Hymenoptera was balanced by higher counts of other taxa. Similarly, samples from the small drop trap trial were both dominated by Diptera followed by Hemiptera. While drop traps captured significantly less specimens overall, a greater diversity of orders contributed to the total catch. As predicted by the literature, the drop capture array significantly increased the capture of beetles (Russo et al. 2011) as well as other apterous or cursorial species like spiders and flightless Tasmanian alpine grasshoppers (*Russalpia* spp.), particularly larger bodied specimens.

Conclusions

The success of the Alpine Malaise Trap is illustrated by our ability to deploy 34 replicates in rough terrain, 1.5 hours hike from vehicle access, with three people in 9 hours. The traps were able to operate continuously and autonomously for 6 weeks in summer, collecting 8,029 readily identifiable invertebrates (Basic AMT) and a further 7,155 from the hybrid CD attachment and 1,229 from hybrid drop capture array. Further, the traps were robust to extremes of wind, rain, snow and UVB. The invertebrate profile of samples is an intermediate of classic malaise and pitfall traps. The environmental sensitivity this conveys over standard malaise traps is being investigated further.

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Supplementary material 1

Figure S1

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Supplementary material 2

Figure S2

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PENSOFT

Alpine Entomology

Zu Verbreitung und Morphologie einiger *Onthophagus*-Arten der Schweiz (Coleoptera, Scarabaeidae)

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Abstract

On distribution and morphology of some *Onthophagus* species in Switzerland (Coleoptera: Scarabaeidae). – On the basis of 1097 specimens from 12 collections, the distribution of ten dung beetle species of the genus *Onthophagus* (Scarabaeidae) in Switzerland is compiled and shown in distribution maps: *O. taurus*-group: *O. illyricus*, *O. taurus*; *O. fracticornis*-group: *O. fracticornis*, *O. opacicollis*, *O. similis*; *O. ovatus*-group: *O. baraudi*, *O. grossepunctatus*, *O. joannae*, *O. ovatus*, *O. ruficapillus*. New characters of the female genitalia allow species identification of *O. fracticornis*, *O. similis*, and *O. ruficapillus*. Reduced male characters of a small *O. gibbulus* are described.

Key Words

Onthophagini
Central Europe
Alps
faunistics
morphology
dung beetles

Einleitung

In Ökosystemen, die Wirbeltiere beherbergen, fallen regelmässig und oft in grossen Mengen Kot und Kadaver an, bei deren Abbau Dungkäfer eine wichtige Rolle spielen. Die Verbreitung der Blatthornkäfer der Schweiz, zu denen die Dungkäfer zählen, wurde von Victor Allenspach (1970) in einem Katalog der *Fauna Helvetica* zusammenfassend bearbeitet. Seit der Fertigstellung dieses faunistischen Kataloges im Jahre 1968 wurden in ergänzenden Arbeiten einige zusätzliche *Onthophagus*-Arten für das Schweizer Gebiet gemeldet (Ieniştea 1979; Vit und Hozman 1980). Im Rahmen der Überarbeitung des Lamellicornia-Teils von Machatschke (1969) im Bestimmungswerk *Die Käfer Mitteleuropas* (Krell und Fery 1992; Krell 1998) wurde begonnen, Schweizer Funde der Gattung *Onthophagus* zu revidieren, mit besonderer Berücksichtigung der schwierig zu bestimmenden Artengruppen. Seitdem wurde umfangreiches, zusätzliches Material dieser Artengruppen aus den meisten größeren Schweizer Museen untersucht und hier zusammengestellt. In der vorliegenden Arbeit werden einige bisher oft verkannte oder leicht verwechselbare Schweizer Dungkäfer-Arten eingehender besprochen, verifizierte Nachweise präsentiert, und neue Bestimmungsmerkmale vorgestellt. Die verifizierten Nachweise dienten zum Teil als Grundlage für die entsprechenden Art-Bearbeitungen von Cosandey et al. (2017) in deren neulich in dieser Zeitschrift veröffentlichten Katalog der Scarabaeoidea der Schweiz.

Material und Methoden

1097 Exemplare (Abb. 1), gesammelt zwischen 1853 und 1998, aus folgenden Sammlungen wurden untersucht:

DMNS	Denver Museum of Nature & Science, 2001 Colorado Boulevard, Denver, Colorado 80205-5798, U.S.A.

ETH	ETH Zürich, Institut für Pflanzenwissenschaften, ETH Zentrum, Clausiusstr. 21, CH-8092 Zürich.
FMNH	Field Museum of Natural History, 1400 S. Lake Shore Drive, Chicago, IL 60605-2496, U.S.A.
JBNC	Privatsammlung Joachim Böhme, formerly Neuhofen, nun im Staatlichen Museum für Naturkunde Stuttgart, Deutschland (Niehuis 2012).
MHNG	Muséum d'Histoire naturelle, Route de Malagnou, Case postale 434, CH-1211 Genève 6.
MNSL	Museo cantonale di storia naturale, viale Carlo Catteneo 4, CH-6906 Lugano.
MZL	Musée Cantonal de Zoologie, Place Riponne 6, CH-1005 Lausanne.
NMB	Naturhistorisches Museum Basel, Entomologische Abteilung, Augustinergasse 2, CH-4001 Basel.
NMBE	Naturhistorisches Museum, Bernastraße 15, CH-3005 Bern.
NMLU	Naturmuseum Luzern, Kasernenplatz 6, CH-6003 Luzern.
NMSO	Naturmuseum Solothurn, Klosterplatz 2, CH-4500 Solothurn.
ZMHB	Museum für Naturkunde der Humboldt-Universität zu Berlin, Zoologisches Museum, Invalidenstraße 43, D-10115 Berlin, Deutschland.

Alle Individuen von *Onthophagus ovatus*, *O. joannae* und *O. baraudi* wurden genitalpräpariert, ebenso alle kleineren Individuen der *O. fracticornis*-Gruppe. Die Genitalien wurden nicht chemisch behandelt, weder mazeriert noch gebleicht. Die Zeichnungen wurden mit Hilfe eines Zeichenapparates am Zeiss SV5 angefertigt. Binokulare mit Auflichtbeleuchtung sind zur Untersuchung der weiblichen Kopulationsorgane für die Determination ausreichend.

Nur selbst verifiziertes Material wurde in die Zusammenstellung aufgenommen, da die behandelten Arten leicht fehlbestimmt werden können. Ausnahmsweise wurden die Literatur-Nachweise von *O. joannae* in Binaghi et al. (1969), von *O. fracticornis* in Uhlig und Uhlig (2006) und Falahee und Angus (2010) und ein Nachweis von *O. baraudi* in Cosandey et al. (2017) berücksichtigt, da sie von zuverlässigen Experten (Binaghi et al., R. Angus, J. Schulze, E. Rössner) determiniert wurden, die mit den spezifischen taxonomischen Problemen vertraut sind.

Monnerat et al. (2015) weisen auf die Unzuverlässigkeit verschiedener alter Etikettierungen hin, insbesondere der Etiketten der Sammlungsstücke von Charles Maerky (im MHNG). Diese Nachweise werden entgegen der Empfehlung von Monnerat et al. (2015) berücksichtigt, da man nicht ausschliessen kann, dass deren Etikettierung korrekt ist. Jedoch sind Maerky-Exemplare in den Materiallisten in eckigen Klammern aufgeführt und in den Verbreitungskarten als graue Punkte markiert, um deren potentielle Unzuverlässigkeit klar darzustellen. Die grauen Punkte zeigen ein mögliches Vorkommen, jedoch kein gesichertes Vorkommen an.

Die Verbreitungskarten wurden mit Hilfe des Online-Programmes SIMPLEMAPPR (Shorthouse 2010) erstellt. Es wurde nicht versucht, die Ungenauigkeit der Fundortangaben zu visualisieren. Alle Fundpunkte in den Karten sind gleich groß und bezeichnen das Zentrum des in Frage kommenden Fundgebietes, auf eine Minute genau. SimpleMappr verwendet die vom World Wildlife Fund erarbeiteten *Terrestrial Ecoregions of the World* (http://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world; Olson et al. 2001), die die Schweiz in drei Naturräume einteilen: *Western European broadleaf forests* im Norden und Nordwesten (in der Karte hell), *Alps conifer and mixed forest* im Süden und Osten (in der Karte dunkel) und *Po Basin mixed forests* im südlichsten Zipfel des Tessins (in der Karte ebenfalls dunkel). In dieser Einteilung wird der Jura nicht vom Mittelland getrennt, die Oberrheinische Tiefebene bei Basel bleibt unberücksichtigt, und auch Alpennordflanke, Westliche und Östliche Zentralalpen und Alpensüdflanke bilden eine einzige Region. In der Diskussion der Verbreitung der einzelnen Arten wird jedoch auf die biogeographische Einteilung der Schweiz von Gonseth et al. (2001) in sechs Regionen bezug genommen.

Die Schweiz ist relativ gut besammelt. Nur in der Zentralschweiz im Grenzgebiet zwischen Mittelland und Alpennordflanke, in der westlichen Alpennordflanke und im westlichen Bereich der Östlichen Zentralalpen sind grössere Lücken in der Sammelaktivität festzustellen (Fig. 1), die bei der Interpretation der Verbreitungsbilder gegenwärtig noch berücksichtigt werden müssen, aber durch neue Aufsammlungen und Kartierungsprojekte zunehmend geschlossen werden (cf. Cosandey et al. 2017).

Die *Onthophagus taurus*-Gruppe

Nach Rahola Fabra (1987: 25) zeigen *Onthophagus taurus* und *O. illyricus* in Südfrankreich unterschiedliche ökologische Potenz. Während *O. taurus* Ubiquist sei, bevorzuge *O. illyricus* tiefgründig feuchte Böden und meide Gebiete mit ausgeprägter sommerlicher Trockenheit. Allerdings führt dies nach seinen Verbreitungskarten (pp. 73f) nicht dazu, dass *O. taurus* ebenfalls die Areale von *O. illyricus* besiedelt. Großflächige Sympatrie konnte er nicht feststellen. Jedoch ist Sympatrie beider Arten in anderen Gebieten ausreichende documentiert (Allenspach 1970: 35; Palestrini et al. 1994; Pizzo et al. 2006a; diese Arbeit, Abb. 2 und 3), so dass wir diese Gruppe als Arten-Gruppe (sensu Haffer 1986: 175f) ansehen können. Es wurde jedoch bisher kein *character displacement* beobachtet, sondern sogar „Übergangsformen", mutmaßliche Hybriden (Allenspach l.c.), die allerdings genetisch zu *O. illyricus* gehören (Pizzo et al. 2006b). Wenn auch Wilson und Angus (2005) keine karyotypischen Unterschiede zwischen beiden Formen feststellen konnten, wiesen Pizzo et al. (2006b) die genetische Selbständigkeit beider Arten nach. Unterschiede in der Genitalmorphologie sowie der Kopfgröße wurden von

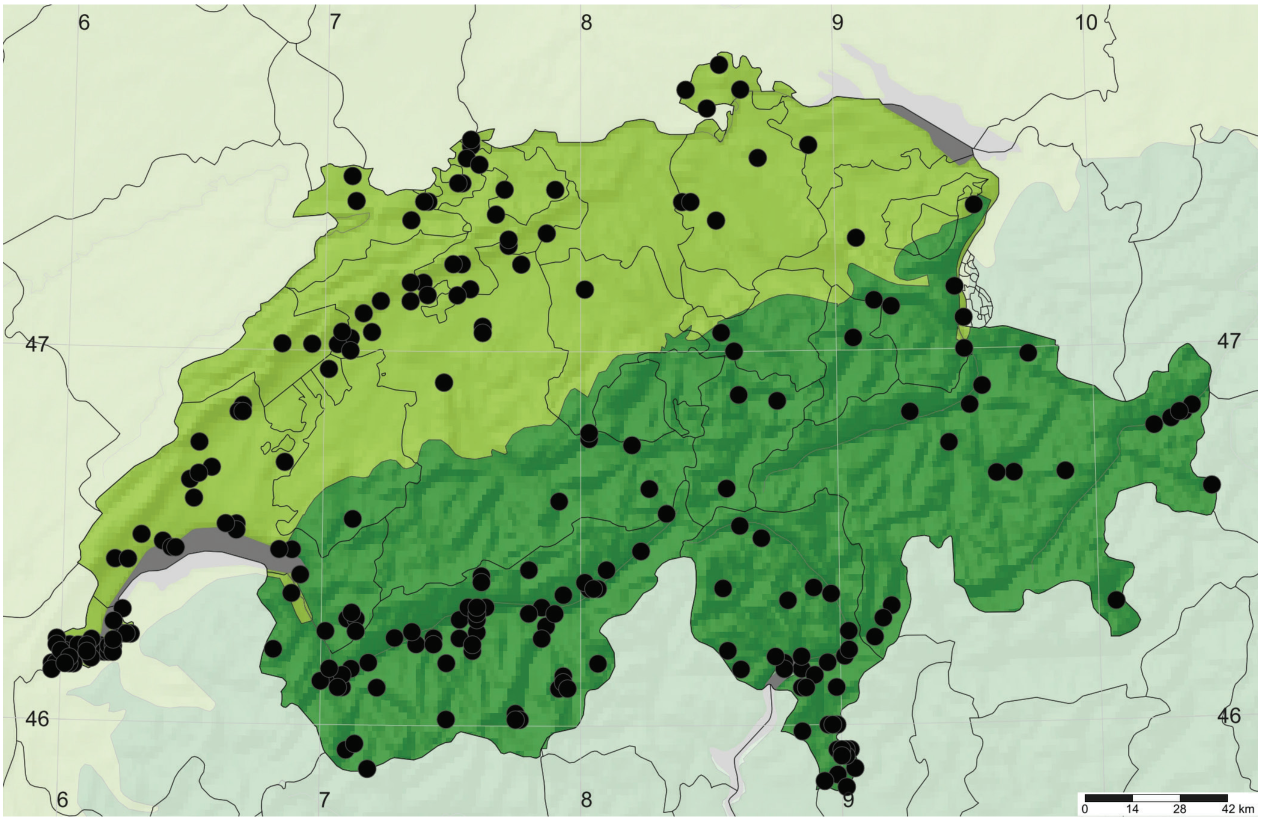

Abb. 1. Fundpunkte aller untersuchten *Onthophagus*.

Pizzo et al. (2006a) in geometrisch-morphometrischen Analysen gefunden.

Die Determination der beiden Arten beruht auf den von Krell und Fery (1992: 206) aufgeführten differentialdiagnostischen Merkmalen, vor allem dem Behaarungsmuster der Elytren und deren Punktur; bei kleinen Individuen von *O. taurus* kann die Punktur der nur schwach ausgeprägten Halsschild-Absturzfläche kräftiger sein als bei größeren Individuen und sich so der Ausprägung bei *O. illyricus* annähern, ein Phänomen, das wir bei kleinen Individuen einer Art öfters vorfinden (cf. Krell 1993: 259).

Nachweise von *Onthophagus taurus* (Schreber, 1759) in der Schweiz (Abb. 2)

Untersuchtes Material. 63 Exemplare, gesammelt zwischen 1872 und 1988).

BL: Wenzlingen, Berner Jura; 1 ♀ 17.ix.1944, leg. J.-P. Wolf; ETH. **BE:** Erlach; 1 ♀ viii.1937; NMLU. Gampelen; 1 ♀ v.1937; ETH. **SG:** Amden-Betlis; 2 ♀♀ 24.vi.1965, 1278, det. V. Allenspach, D20/47; MHNG (cf. Allenspach 1970: 34). Betlis; 5 ♂♂, 1 ♀ 24.vi.1965, 1224, det. V. Allenspach; MHNG (cf. Allenspach 1970: 34). Quinten; 1 ♂, 3 ♀♀ 7.vii.1965, 1257; MHNG (cf. Allenspach 1970: 34). **SO:** Grenchen; 2 ♂♂ 9.v.1948, coll. H. Steiner, EK. 11489/1998, det. A. Linder; NMSO. Staad; 1 ♂, 1 ♀ 13.vii.1947, coll. H. Steiner, EK. 11489/1998, det. A. Linder; NMSO. **TI:** Bellinzona; 2 ♂♂, 2 ♀♀ 23.vii.1950, Menschenkot, leg. C. Besuchet; MZL. Biasca; 2 ♂♂ 31.vii.1948; 1 ♀ 13.vii.1951, alle: leg. J.-P. Wolf; ETH; 1 ♀ 17.ix.1950, Rinderkot, leg. C. Besuchet; MZL. Lugano; 1 ♂ ix.1912; ZMHB. Magadino; 1 ♀ 15.x.1966, leg. A. Linder, „1454" (det. A. Linder: *O. illyricus*); MHNG; 1 ♂ vi.1938; ETH (von Allenspach (1970: 35) als *O. illyricus* gemeldet). Monte Brè; 2 ♂♂, 1 ♀ 30.ix.1943, coll. H. Steiner, EK. 11489/1998, det. A. Linder; NMSO. Tenero-Gordola; 1 ♂ 13.vi.1937, leg. J. Pochon; NMLU. Tremona; 1 ♂, 3 ♀♀ ix.1967 (eingeordnet unter *O. illyricus*); ETH (von Allenspach (1970: 35) als *O. illyricus* gemeldet). **VD:** Bussigny; 1 ♂ 23.v.1951, leg. C. Besuchet; MZL. Cossonay; 1 ♂, coll. E. Bugnion; MZL. Lausanne; 1 ♀ vi.1872, 1 ♂ ohne Datum, coll. E. Bugnion; MZL. **VS:** Buitonaz; 1 ♀ 13.viii.1987, Eselskot, leg. S. Jungclaus; MZL. Follatères; 5 ♀♀ 02.viii.1949 [„Les Follaterres"], 3 spm. Rinderkot, 2 spm. Pferdekot, leg. C. Besuchet; 1 ♂, 2 ♀♀ 13.vi.1951, Rinderkot, leg. C. Besuchet; 1 ♀ 6.v.1957, Rinderkot, leg. C. Besuchet; 3 ♂♂ 13.vi.1987, Rind, leg. R. Delarze; 1 ♀ 3.vi.1988, „vignes (porc)", leg. et det. R. Delarze; MZL. Laquintal; 1 ♂ 10.vi.1939, leg. J. Pochon; NMLU. Martigny; 1 ♂ vi.1939; ETH. Mt. Rosel; 3 ♂♂ 13.vi.1987, Sand (2x), "porc" (1x), leg. R. Delarze; 1 ♂ 12.viii.1987, 1000 m, leg. R. Delarze; MZL. Sierre; 1 ♀ viii.1917, det. H. d'Orbigny, coll. E. Bugnion; MZL.

Onthophagus taurus wurde von Besuchet et al. (2012: 128) für den Kanton Genf gemeldet nach Material aus dem MHNG, das ich nicht untersucht habe.

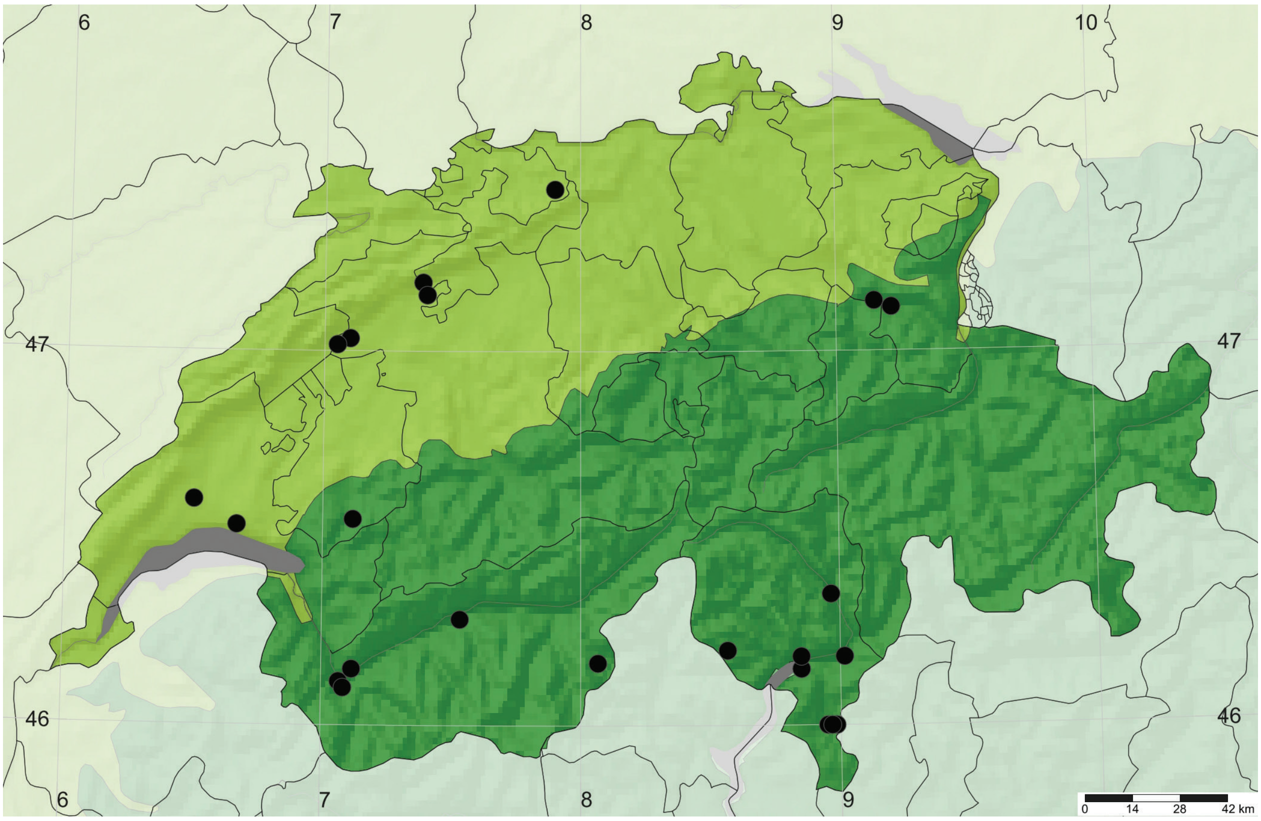

Abb. 2. Bestätigte Verbreitung von *Onthophagus taurus* (Schreber) in der Schweiz. Für neuere Funde vergleiche die Karte von Info Fauna https://lepus.unine.ch/carto/index.php?nuesp=22637&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de

Nachweise von *Onthophagus illyricus* (Scopoli, 1763) in der Schweiz (Abb. 3)

Diese von Machatschke (1969: 287) noch als Subspecies von *O. taurus* behandelte Art wurde erstmals von Allenspach (1970: 35) für das Gebiet der Schweiz nachgewiesen.

Untersuchtes Material. 35 Exemplare, gesammelt zwischen 1887 und 1966.

BL: Hölle, Berner Jura; 1 ♂ 11.v.1947, leg. J.-P. Wolf; ETH. Kleinblauen, Berner Jura; 1 ♀ 27.v.1945, leg. J.-P. Wolf; ETH. Ziefen, Basler Jura; 1 ♂ 30.vi.1946, leg. J.-P. Wolf; ETH (cf. Allenspach 1970: 35). **BE:** Meienried; 1 ♀ 25.ix.1948, coll. H. Steiner, EK. 11489/1998 (det. A. Linder als *O. taurus*); NMSO. **GE:** Hermance; 1 ♂ 15.vi.1965 ("Rind 1533"), det. V. Allenspach; MHNG (cf. Allenspach 1970: 35). **GR:** Lostallo; 1 ♂, 1 ♀ 26.vii.1965, „1242", Doublette ex coll. A. Spälti, (det. V. Allenspach [♂]); MHNG (cf. Allenspach 1970: 36). **JU:** Höllenweide, Berner Jura; 1 ♀ 15.ix.1946, leg. J.-P. Wolf; ETH. **SO:** Grenchen; 1 ♀ 9.v.1948, coll. H. Steiner, EK. 11489/1998, det. A. Linder (as *O. taurus*); NMSO. Born (Wangen bei Olten); 1 ♂ v.1934, coll. H. Steiner, EK. 11489/1998 (det. A. Linder als *O. taurus*); NMSO. Staad; 2 ♂♂, 1 ♀ 13.vii.1947, coll. H. Steiner, EK. 11489/1998 (det. A. Linder als *O. taurus*); NMSO. **TI:** Agno; 1 ♂ ix.1960; NMLU (cf. Allenspach 1970: 35). Arbedo; 1 ♂ 3.ix.1950, leg. C. Besuchet; MZL. Bellinzona; 1 ♀ 23.vii.1950, Menschenkot, leg. C. Besuchet, det. V. Allenspach (cf. Allenspach 1970: 36). Biasca; 2 ♀♀ 17.ix.1950, Rinderkot, leg. C. Besuchet (1 ♀ an Nadel mit *O. taurus*; 1 ♀ det. V. Allenspach; cf. Allenspach 1970: 36); MZL. Gudo; 1 ♂ 15.x.1966, „1454", leg. et det. A. Linder; MHNG. Locarno; 1 ♀ 27.vi.1951, Menschenkot, leg. C. Besuchet, det. V. Allenspach; MZL. Magadino; 1 ♂ vi.1938; ETH (cf. Allenspach 1970: 36); 1 ♀ 4.ix.1950, Rinderkot, leg. C. Besuchet, det. V. Allenspach, det. R. Pittino; 2 ♀♀ 11.ix.1950, leg. C. Besuchet, det. V. Allenspach; MZL (cf. Allenspach 1970: 36). **VD:** Aubonne; 1 ♀ coll. E. Bugnion; MZL. Bussigny; 1 ♂ 23.v.1951, leg. C. Besuchet; MZL. **VS:** Follatères; 1 ♀ 13.v.1920, Rinderkot, coll. W. Morton; MZL. Martigny; 1 ♂, 1 ♀ 7.vi.1887, leg. A. Gaud, det. V. Allenspach; MZL; 1 ♂ vi.1939; ETH. Saas; 1 ♂ viii.1939, leg. J. Lautner; ETH (coll. J.-P. Wolf) (cf. Allenspach 1970: 35). Saillon; 1 ♀ vi.1921, coll. E. Bugnion; MZL. Salgesch; 1 ♀ 13.viii.1951, leg. J.-P. Wolf; ETH. **ZH:** Wollishofer Allmend; 2 ♂♂ 3.viii.1929, leg. V. Allenspach, coll. A. Nägeli (det. A. Linder als *O. taurus*); NMSO.

Diskussion—die Verbreitung der *O. taurus*-Gruppe in der Schweiz

Die Verbreitungsbilder von *Onthophagus taurus* (Abb. 2) und *O. illyricus* (Abb. 3) zeigen keine augenfälligen Unterschiede. Die Zentralschweiz (südliches Mittelland und Alpennordflanke) scheint von beiden Arten gemieden zu werden. Die beiden aktuellen Verbreitungskarten von Info Fauna (https://lepus.unine.ch/carto/index.

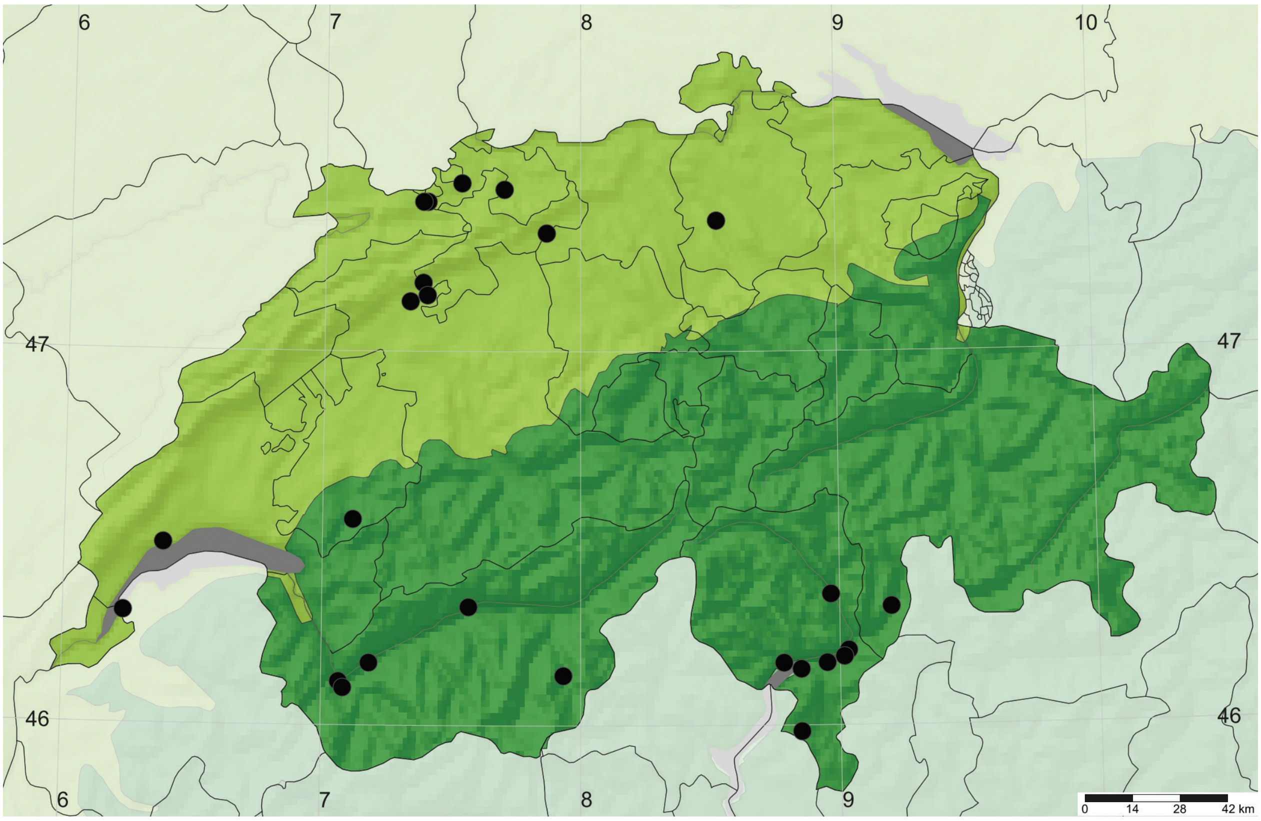

Abb. 3. Bestätigte Verbreitung von *Onthophagus illyricus* (Scopoli) in der Schweiz. Für neuere Funde vergleiche die Karte von Info Fauna https://lepus.unine.ch/carto/index.php?nuesp=22629&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de

php?nuesp=22629&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de, https://lepus.unine.ch/carto/index.php?nuesp=22637&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de, eingesehen am 30.12.2017) enthalten eine Menge neuerer Funde, die im Rahmen dieser Studie nicht berücksichtigt werden konnten. Nach diesen Karten sind beide Arten sehr viel ausgedehnter im nördlichen Mittelland und im Jura vom Genfer See bis zum Bodensee verbreitet, fehlen jedoch auch weitgehend im südlichen Mittelland und der Alpennordflanke und zeigen keine ausgeprägten artspezifischen Unterschiede in ihrer Verbreitung.

Die *Onthophagus fracticornis*-Gruppe

Onthophagus fracticornis (Preyssler) und *O. similis* (Scriba)

Im Jahre 1956 erkannten Delabie (1956) und unabhängig davon Lohse (1957), dass mit dem Namen *Onthophagus fracticornis* Preyssler bis dato zwei distinkte Species benannt worden waren. Eine Zusammenschau der diesbezüglichen Literatur präsentiert Palestrini (1981). Die Unterscheidung der Arten *O. fracticornis* und *O. similis* kann manchmal schwierig sein. Die Körperlänge kann in vielen Fällen nicht als artdiagnostisches Merkmal dienen, da ein Überlappungsbereich existiert: Die Körperlänge von *O. fracticornis* Pr. beträgt 5,9–10 mm, *O. similis* Scr. misst 4–8 mm, wobei jedoch festzustellen ist, dass Individuen von *O* *fracticornis* von unter 7 mm bzw. Individuen von *O. similis* von über 7 mm Länge selten sind. Ljungberg (2002) gibt die Länge von *O. fracticornis* mit 5,5–9,5 mm an. Ich selbst habe keine Individuen dieser Art unter 5,9 mm gesehen.

So sind Weibchen und schwach ausgeprägte Männchen von 5,9 mm bis 8 mm Körpergröße zumeist schwierig anhand externer Merkmale allein zu bestimmen. Morphologische Merkmale der Körperoberfläche wie Kopfsuturen, Punktierung zwischen Stirn- und Scheitelleiste, oder das Verhältnis der Länge der Glieder der Maxillartaster konnten vom Autor nicht als konstant differierend erkannt werden. Da die Ausprägung der Punktierung bei den Scarabaeidae sehr oft variiert und durch die grabende Lebensweise der Tiere abgenutzt sein kann, sollte man zur Absicherung der Determination die Genitalien untersuchen. Für die Männchen ist der Aedoeagus ein traditionelles und klares Bestimmungsmerkmal (Machatschke 1969, Ljungberg 2002). Fuer die Weibchen sollte man ein Merkmal heranziehen, das sich bereits bei der Unterscheidung anderer Geschwisterarten bei *Onthophagus* bewährt hat: den spangenartigen Sklerit der weiblichen äußeren Genitalien (Abb. 4, 5), der wohl, auf Grund seiner Lage, homolog zu den Vaginalpalpen anderer Taxa der Lamellicornia ist.

Palestrini (1981: 17) bildet erstmalig die weiblichen Kopulationsorgane der beiden Arten ab. Die von ihr angewandte Präparationsmethode der Zunino-Schule durch Einbettung in ein Einschlussmittel bedingt eine Aufhellung der Sklerite, die damit weniger deutlich zu erkennen

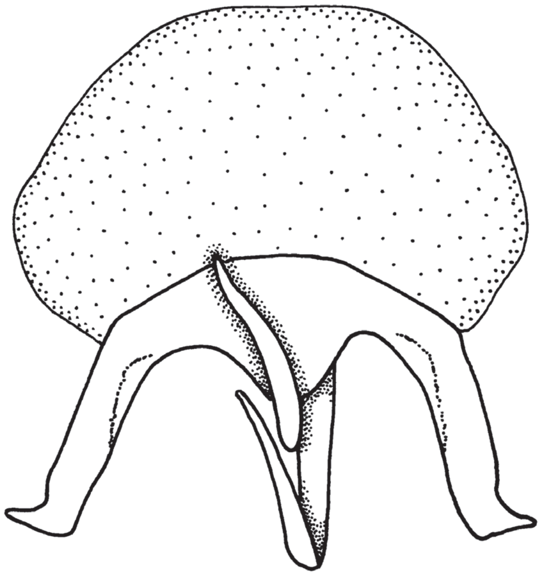

Abb. 4. Weiblicher Kopulationsapparat von *Onthophagus fracticornis* (Pr.); Schweiz, Sankt Gallen, Quinten, MHNG.

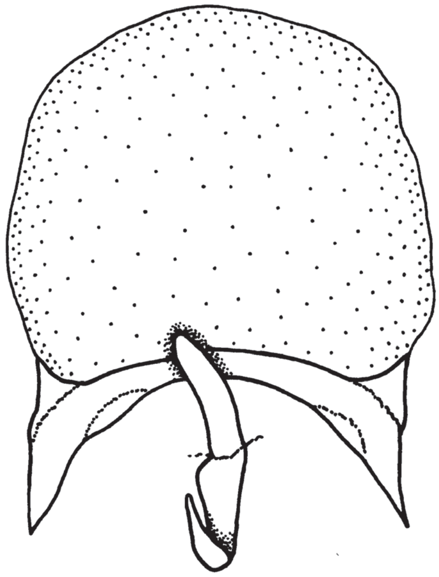

Abb. 5. Weiblicher Kopulationsapparat von *Onthophagus similis* (Scr.); Deutschland, Baden-Württemberg, Gernsbach-Lautenbach, leg. Krell 7.vii.1984, DMNS.

sind, verglichen mit der direkten Betrachtung des Organs im frischen oder gequollenen Zustand. Daher sind Palestrini's Abbildungen zur Differenzierung der Arten nicht geeignet. Der spangenartige Sklerit bietet durch seine bei maturen Individuen kräftige Sklerotisierung deutliche Unterscheidungsmerkmale, die in den Abb. 4 und 5 dargestellt sind. Die Präparate wurden nach aufgekochten Trockenpräparaten (Museumsmaterial) gezeichnet. Jedwede Aufhellung, auch durch Einbettung in ein Einschlussmittel, wurde vermieden, da sich die oft schwache Sklerotisierung dann nicht mehr deutlich von den membranösen Teilen abhebt. Bei *O. fracticornis* (Abb. 4) ist der spangenartige Sklerit im Allgemeinen stärker sklerotisiert und die Seitenäste fast parallelseitig und in einem kleinen Haken endend. Bei *O. similis* (Abb. 5) laufen die kürzeren Seitenäste spitz zu.

Die Parameren eines kleinen Männchens aus Bella Vista, Monte Generoso (Abb. 6) sowie eines weiteren vom Gemmipass, zeigen ähnliche Ausprägung wie bei *Onthophagus massai* Baraud (Baraud 1975), einer kleinen, auf Sizilien endemischen Species, die dort *O. fracticornis* ersetzt. Diese Form der Parameren wurde bereits von Palestrini (1981) bei kleinen *O. fracticornis* aus Kalabrien, Griechenland und Anatolien festgestellt. In einer neueren Studie zum taxonomischen Status von *O. massai* konstatieren Pizzo et al. (2011), dass es sich bei der sizilianischen Form um eine Zwergform von *O. fracticornis* handelt, d.h. dass die Tiere aus Sizilien im Durchschnitt kleiner sind, aber nicht notwendigerweise einer unterschiedlichen Art angehören. Dies steht jedoch im Widerspruch zu Resultaten von Chromosomenuntersuchungen von Falahee und Angus (2011). Unsere Tiere aus Bella Vista und vom Gemmipass zeigen, dass kleine Tiere mit ähnlich ausgeprägten Aedoeagus in mitteleuropäischen Populationen von *O. fracticornis* vorkommen können.

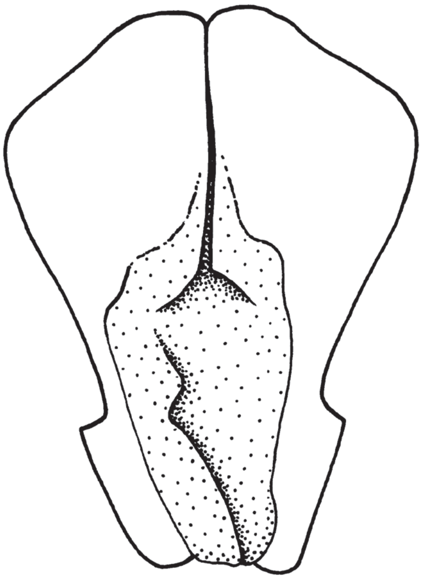

Abb. 6. Aedoeagus eines kleinen *Onthophagus fracticornis* (Pr.) vom Monte Generoso, Bella Vista, MHNG. Paramerenform sehr an diejenige von *O. massai* angenähert).

Nachweise von *Onthophagus fracticornis* (Preyssler, 1790) in der Schweiz (Abb. 7)

Untersuchtes Material. 328 Exemplare, gesammelt zwischen 1868 und 1996.

Vollständige Materialliste als elektronisches Supplement (Suppl. materials 1, 2).

Onthophagus similis (Scriba, 1790) und *Onthophagus opacicollis* Reitter, 1893

Onthophagus opacicollis unterscheidet sich von *O. similis* und *O. fracticornis* äußerlich durch die auch im medi-

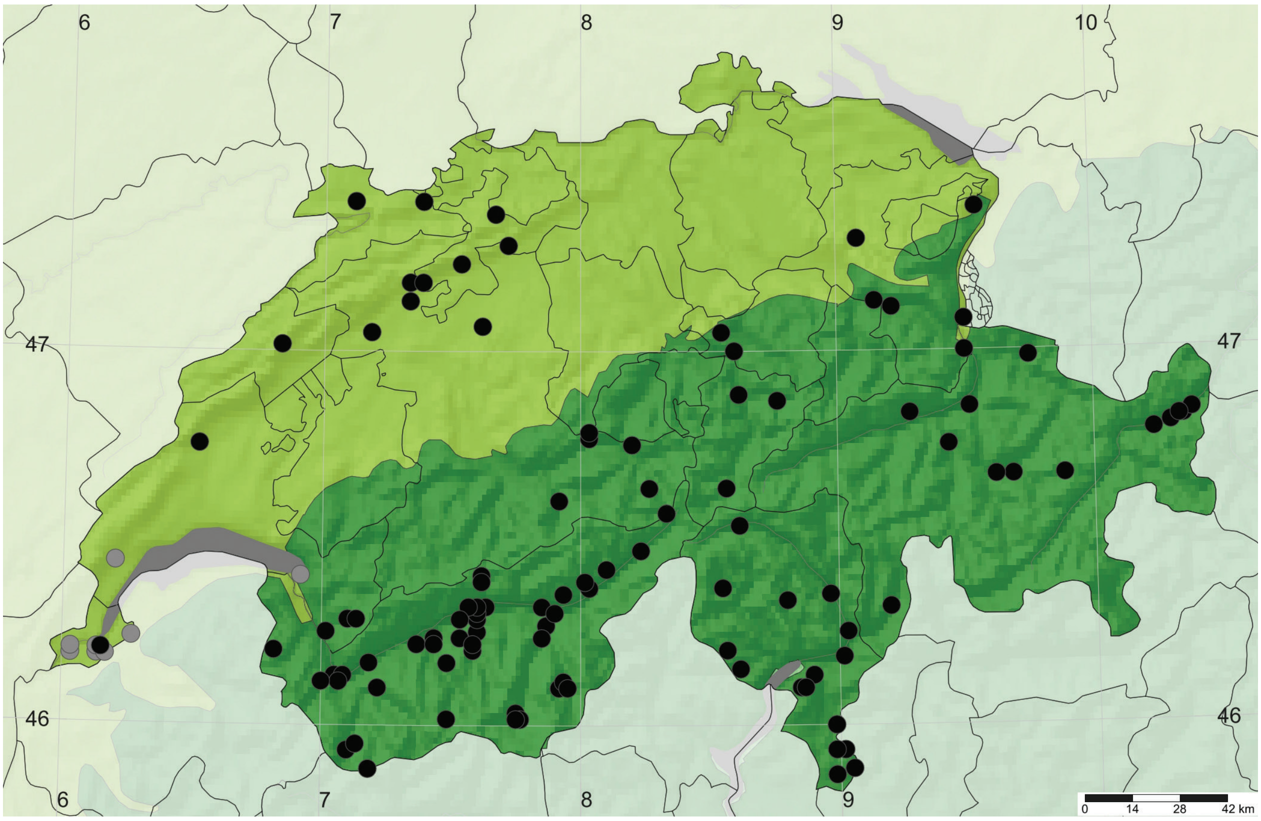

Abb. 7. Bestätigte Verbreitung von *Onthophagus fracticornis* (Preyssler) in der Schweiz. Graue Kreise: Unsichere Maerky-Nachweise. Für neuere Funde vergleiche die Karte von Info Fauna https://lepus.unine.ch/carto/index.php?nuesp=22625&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de

anen Basalbereich des Pronotum raspelige Punktur sowie durch die laterale Ausrandung des Kopfschildes (Krell und Fery 1992: 209). Bei den letztgenannten Arten befinden sich in medianen Basalbereich des Pronotum einige normale, nicht raspelige Punkte, und der Kopfschild ist lateral konvex bogenförmig gerundet, nicht ausgerandet.

Die artdiagnostischen Merkmale sind jedoch nicht immer deutlich ausgeprägt. Zwischen *O. similis* (Scr.) und *O. opacicollis* Reitt. existieren morphologische Übergangsformen, or „Individuals with Uncertain Taxonomic Status“ (Pizzo et al. 2013). Die Schwierigkeit der Zuordnung einzelner Individuen führte zu einer jahrzehntelangen Diskussion über den taxonomischen Status dieser beiden Taxa, die erst in den letzten Jahren einer Lösung nähergekommen ist.

Palestrini (1981) stellte aufgrund dieser morphologischen Übergänge bzw. Annäherungen *O. opacicollis* Rtt. synonym zu *O. similis* (Scr.). Martín Piera (1984: 150f) schloss sich dieser Auffassung an, betrachtete den Fall jedoch differenzierter. Seiner Auffassung nach stellten *O. similis* s.str. und *O. opacicollis* unterschiedliche Phänotypen innerhalb einer Species dar, deren statistische Verteilung mit der geographischen Breite und der Höhenlage schwanke: Im Allgemeinen bevorzuge *O. opacicollis* Rtt. mediterrane Klimate, wohingegen *O. similis* (Scr.) gemäßigte Klimate bewohne und in der Mediterraneis in höheren Lagen aufzufinden sei. Avila und Pascual (1988: 31) folgten ebenfalls der Aufassung Palestrinis (1981) und berichteten, dass „en Sierra Nevada se encuentran todos los fenotipos intermedios entre estas dos antiguas especies“, ohne jedoch durch eine biometrische Untersuchung zu klären, ob wirklich ein kontinuierlicher Übergang oder aber doch ein Dimorphismus vorliegt. Baraud (1985) wiederum hielt die diagnostischen Merkmale für hinreichend konstant, um zwei Arten zu begründen. Rahola Fabra ([1986]) versuchte, die Artverschiedenheit beider Species durch phänologische und chorologische Differenzen zu beweisen, doch ist seine Beweisführung nicht reproduzierbar, da z.B. die Anzahl der untersuchten Individuen nicht angegeben wird.

Sympatrisch wurden beide Formen von Lumaret (1978: 110), Galante (1979: 147, 149), Avila und Pascual (1981: 96), Martín Piera und Boto (1999), Angus (2008) und Pizzo et al. (2013) aufgefunden. Lumaret (1978: fig. 32) fand Unterschiede in der Höhenpräferenz zwischen den beiden Formen: Wohingegen *O. opacicollis* vornehmlich im Flachland, seltener, an Wärmestellen, bis 850 m vorkommt (Lumaret 1990: 102), ist *O. similis* zwischen 300 m und 1200 m häufig.

Ergebnisse molekularbiologischer und morphometrischer Untersuchungen zur *O. fracticornis*-Gruppe zeigen, dass *O. opacicollis* näher mit *O. similis* als mit *O. fracticornis* verwandt ist und dass außerdem alle drei Taxa als distinkte Arten anzusehen sind (Boto und Martín-Piera 1994; Macagno et al. 2011). Martín-Piera und Boto (1999) teilen jedoch mit, dass *O. opacicollis* und *O. similis* in manchen Gebieten nicht vollständig reproduktiv isoliert zu sein scheinen, was von Pizzo et al. (2013) bestätigt wird. Wilson und Angus (2005) und Angus (2008) konnten jedoch deutliche Unterschiede im Karyotyp beider Arten nachweisen. Nach dem gegenwärtigen Kenntnisstand erscheint es angebracht, die Artverschiedenheit von *O. similis* und *O. opacicollis* beizubehalten.

Die rezente nördliche Verbreitungsgrenze von *O. opacicollis* liegt in Luxemburg (Miessen 2005), der Schweiz und der Slowakei (Král und Souček 1987). Coope (1974: 335; 1977: 63; 1979: 253) behauptete, dass das Arealsystem von *O. opacicollis* sich im letzten Interglacial (42.000 yr BP) bis England erstreckte, teilte jedoch brieflich mit (3. Feb. 1994), dass er diese sehr häufigen fossilen Fragmente nunmehr als den heute sizilianischen Endemiten *Onthophagus massai* interpretiere, wie er es dann auch publizierte (Coope 1990, 2000, 2010).

Nachweise von *Onthophagus similis* (Scriba, 1790) in der Schweiz (Abb. 8)

Untersuchtes Material. 5 Exemplare, davon nur eines datiert (1921).

GE: [Sierne; 1 ♂ 24.v.; MHNG (coll. C. Maerky) (see Ieniştea 1979)]. [Vessy; 2 ♀♀ 2.iv., 1 ♀ ohne Datum; MHNG (coll. C. Maerky) (cf. Ieniştea 1979)]. **VS:** Saillon; 1 ♀ (7,3 mm) vi.1921; MZL (coll. W. Morton).

Nachweise von *Onthophagus opacicollis* Reitter, 1893, in der Schweiz (Abb. 9)

Folgende der von Ieniştea (1979: 123) publizierten Nachweise und zusätzliche, unpublizierte Exemplare konnen nach eidonomischer und genitalmorphologischer Überprüfung als *O. opacicollis* bestätigt werden. Sie weisen sowohl eine leichte laterale Ausrandung des Kopfschildes als auch die mediobasale Raspelung der Pronotum-Punktur auf, jedoch nicht in der starken Ausprägung, die wir bei südeuropäischen Individuen beobachten.

Untersuchtes Material. 14 Exemplare, gesammelt zwischen 1934 und 1972.

GE: [Lancy; 1 ♂; MHNG (coll. C. Maerky)]. [Peney; 1 ♂ 1.i. (od. 7.vii.); MHNG (coll. C. Maerky)]. **GR:** Piani di Verdabbio, Schafkot; 3 ♂♂ und 3 ♀♀ 14.iv.1970, 1 ♂ 13.iv.1972; NMB (coll. V. Allenspach). Ieniştea (l.c.) meldet 8 + 12 Exemplare, deren Verbleib unbekannt ist. **TI:** Ascona; 1 ♀ vii.1934, leg. G. Toumayeff; MHNG. Bellinzona, Menschenkot 2 ♂♂ (steckten unter *O. similis*, an der Nadel mit 1 ♂ *O. fracticornis*) 23.vii.1950, 1 ♀ 23.vii.1956, Menschenkot, leg. C. Besuchet; MZL. Mendrisio, Schafkot; 1 ♀; NMB (coll. V. Allenspach). Das ♀ weist eine nur schwache Ausrandung des Kopfschildes auf, kann aber noch als *O. opacicollis* angesprochen werden.

Cosandey et al. (2017) präsentieren zusätzliche Meldungen von Alto Malcantone, Biasca, Breggia, Chiasso, Locarno, Monteceneri und Monte Generoso (TI), die in der Verbreitungskarte (Abb. 9) als weisse Kreise dargestellt sind. Das von Ieniştea (1979) aus Graubünden, Motta Maluns, als *O. opacicollis* gemeldete ♂ (viii.1937, leg. G. Toumayeff; MHNG) gehört eindeutig zu *O. fracticornis*.

Diskussion—die Verbreitung der *O. fracticornis*-Gruppe in der Schweiz

Die bei weitem häufigste Art dieser Gruppe in der Schweiz mit fast flächendeckender Verbreitung (aber mit spärlichen Nachweisen im südlichen Mittelland) ist *Onthophagus fracticornis* (Abb. 7). Das Fehlen von Nachweisen in der Nordost-Schweiz ist wahrscheinlich ein Sammel-Artefakt, da die Art in Südwestdeutschland weit verbreitet ist (Frank und Konzelmann 2002). Diese Interpretation wird bestätigt durch die aktuelle Verbreitungskarte von Info Fauna (https://lepus.unine.ch/carto/index.php?nuesp=22625&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de, eingesehen am 30.12.2017), die eine Menge neuerer Funde enthält, die im Rahmen dieser Studie nicht berücksichtigt werden konnten. In Südfrankreich meidet *O. fracticornis* das Flachland unter 300 m ü.NN, wie auch *O. similis*, ist jedoch erheblich häufiger über 1000 m ü.NN (Lumaret 1978: fig. 32) und wurde in den französischen Alpen bis auf 2800 m ü.NN nachgewiesen (Lumaret 1990: 106). In der Schweiz sind Nachweise über 2300 m ü.NN nicht selten.

Die beiden anderen Schweizer Arten der Gruppe sind im Gebiet selten. Von *Onthophagus similis* sind mir nur fünf Schweizer Exemplare von drei Lokalitäten aus Genf und dem Wallis bekannt, von denen zudem vier von einem unzuverlässigen Sammler stammen. Cosandey et al. (2017: 82) erwähnen noch ein weiteres Exemplar von Basel, ebenfalls aus einer unzuverlässigen Sammlung (nicht in die Karte aufgenommen). In anderen Regionen, wie z.B. in Belgien (De Bast 1983), Grossbritannien (Johnson 1967) oder Spanien (hier exemplarisch in der Provinz Salamanca, Galante 1979), ist die Art erheblich häufiger und weiter verbreitet ist als *O. fracticornis*. *Onthophagus similis* kommt in den umliegenden Ländern der Schweiz (Frankreich, Deutschland, Österreich und Italien) vor (Ziani und Bezděk 2016), offenbar jedoch nicht in Liechtenstein (Brandstetter und Kapp 1998). Es ist möglich, dass *O. similis* weiter in der Schweiz verbreitet ist, jedoch durch seine extreme Seltenheit nicht häufiger gesammelt wurde.

Die dritte Art der Gruppe, *O. opacicollis*, ist eine südliche, wärmeliebende Art, und im Mittelmeergebiet eine der Arten mit der höchsten Biomasse und Bedeutung für die Abarbeitung von Rinderdung (Galante et al. 1995). Sie wurde in nur wenigen Exemplaren in den südlichsten Bereichen der Schweiz, in der Genfer Umgebung, dem Südwestzipfel Graubündens und dem südlichen Tessin, nachgewiesen (Abb. 9). Die Genfer Meldungen stammen aus der unzuverlässigen Sammlung Charles Maerky (Monnerat et al. 2015) und bedürfen einer Bestätigung durch neue Funde oder Examplare aus anderer Quelle.

Zur Ausprägung des Pronotum von *Onthophagus gibbulus* (Pallas, 1781)

Ein kleines ♂ aus Trimmis (GR; 1 ♂, 1 ♀ 14.x.1967 („117 1533“), det. A. Linder; MHNG) besitzt nur eine angedeutete, laschenförmige Erweiterung der Scheitelleiste. Der Hinterrand der Halsschild-Absturzfläche trägt

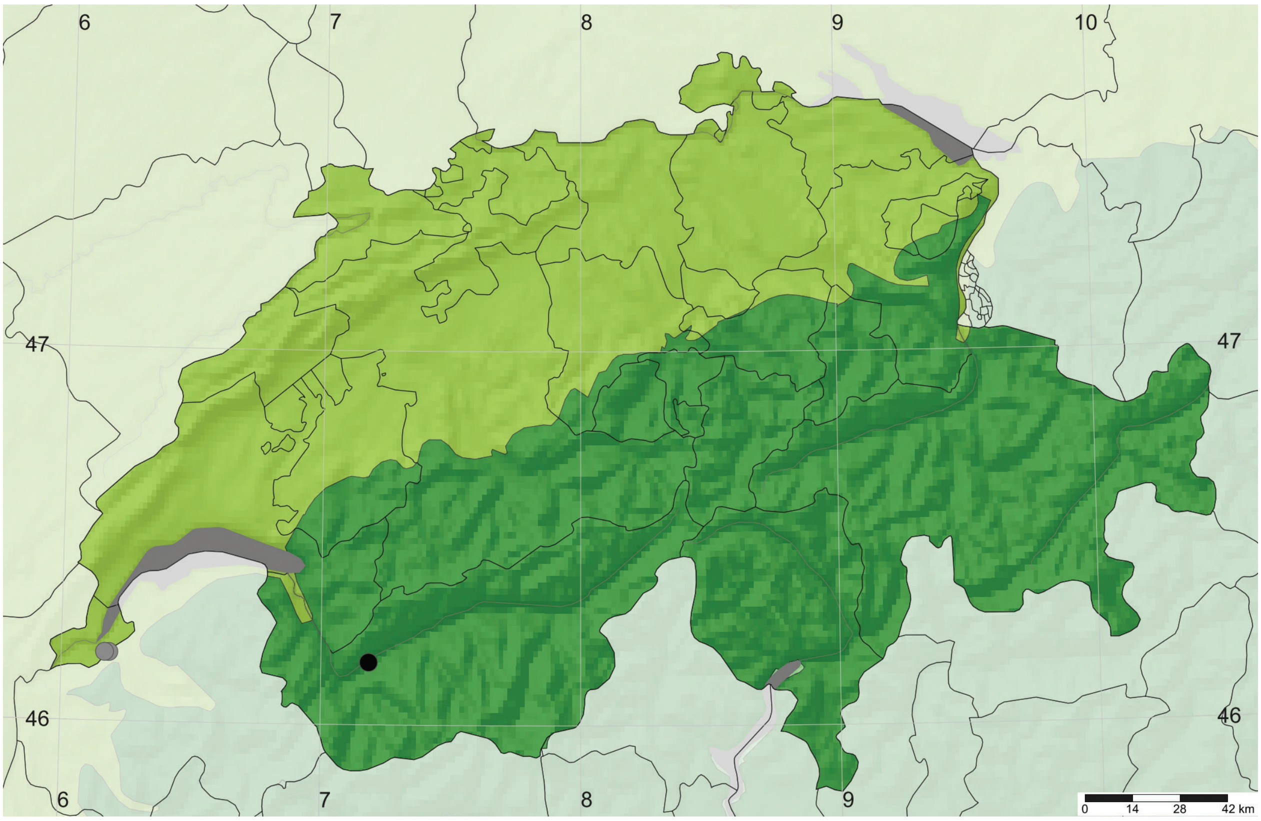

Abb. 8. Mögliche und bestätigte Verbreitung von *Onthophagus similis* (Scriba) in der Schweiz. Graue Kreise: Unsichere Maerky-Nachweise.

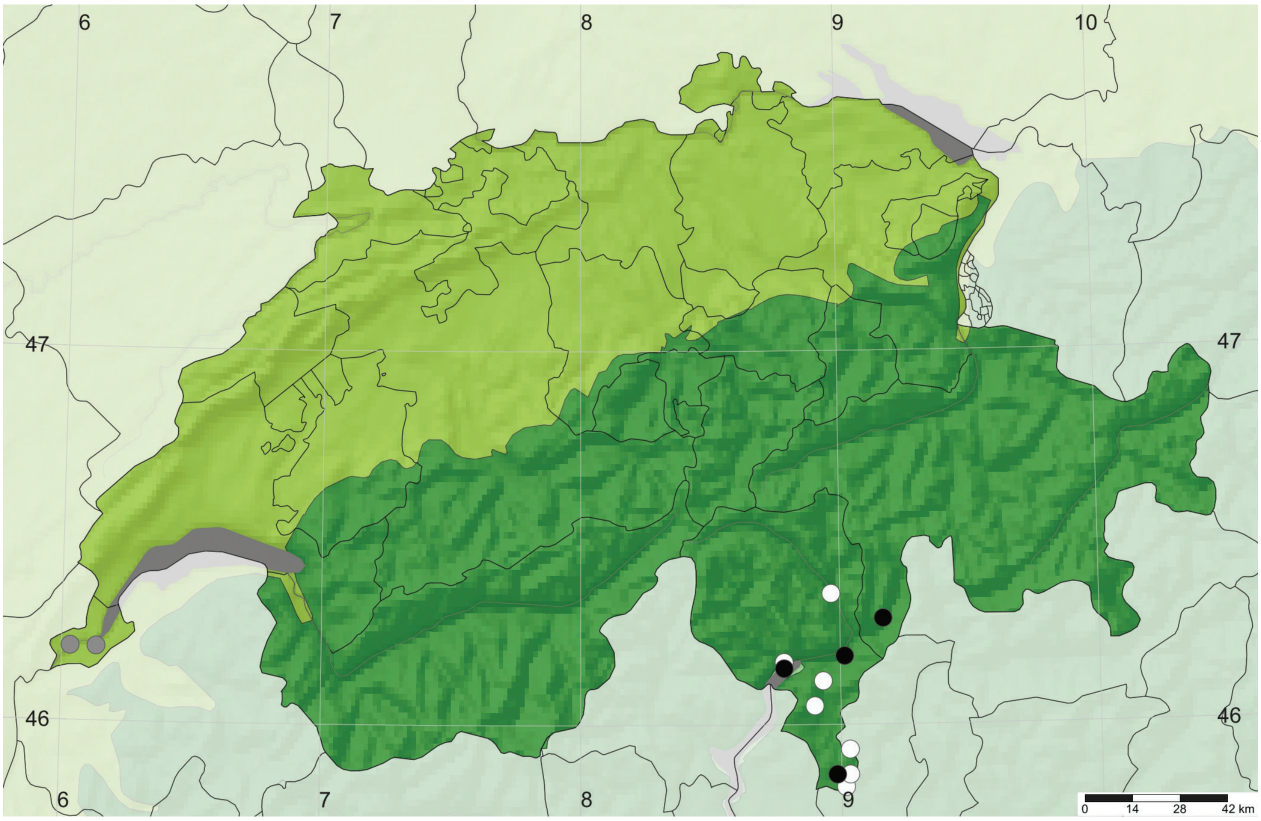

Abb. 9. Bestätigte Verbreitung von *Onthophagus opacicollis* Reitter in der Schweiz. Graue Kreise: Unsichere Maerky-Nachweise. Weisse Kreise: Zusätzliche Meldungen von Cosandey et al. (2017), nicht persönlich verifiziert.

median eine kräftige, paarige Beule anstelle der bei kräftigen Männchen vorhandenen Impression, so dass bei flüchtigem Blick ein Weibchen vorzuliegen scheint. Die beiden Teile der Beule sind jedoch deutlich getrennt, wohingegen sie beim ♀ immer cranial verschmolzen sind. Balthasar (1963: 369f) erwähnt in seiner Monographie diese Ausprägungsmöglichkeit nicht, und auch bei anderen Autoren findet sich kein diesbezüglicher Hinweis. Es ist zu vermuten, dass mit zunehmender Größe der ♂♂ die beiden Teile der Beule laterad auseinanderweichen und sich verflachen, um eine Reibung mit der caudodorsad erweiterten Scheitelleiste zu vermeiden. Die Verbreitung dieser Art wurde im Rahmen der vorliegenden Studie nicht untersucht.

Die *Onthophagus ovatus*-Gruppe

Auch die Arten dieser Gruppe kommen teilweise sympatrisch vor, so dass wir hier von einer Gruppe und nicht etwa von einer Superspecies reden müssen.

Die zuverlässige Bestimmung von *O. ovatus* und *O. joannae* anhand externer Merkmale ist schwierig, da beide Arten in vielen Merkmalen variabel sind (Ljungberg 2002). Rößner (2006) stellt die beschriebenen differenzialdiagnostischen Merkmale zusammen und beschreibt ein zusätzliches: Der Außenrand des Pronotum ist bei *O. ovatus* vorne verdickt. Bei frischen Exemplaren scheint dieses Merkmal recht zuverlässig zu sein. Dennoch wurden bei allen unten aufgelisteten Exemplaren die Genitalien untersucht, um eine sichere Bestimmung zu gewährleisten. Zur Determination geeignete Abbildungen der männlichen und weiblichen Genitalapparate von *O. ovatus* und *O. joannae* bringen Martín Piera (1981: 206) und Krell und Fery (1992: 208, reproduziert in Ljungberg 2002).

Nachweise von *Onthophagus baraudi* Nicolas, 1964, in der Schweiz (Abb. 10)

Onthophagus baraudi wurde von Ieniştea (1979) und Vit und Hozman (1980) aus der Schweiz, Kanton Graubünden, gemeldet, für lange Zeit die einzigen Schweizer Nachweise (Krell und Fery 1992: 207; Krell 1998). Diese Meldungen werden hier bestätigt und durch weitere Nachweise aus den Kantonen Bern, Waadt und Wallis ergänzt.

Untersuchtes Material. 24 Exemplare, gesammelt zwischen 1963 und 1978.

BE: Wengen; 1 ♂ ohne weitere Daten, 1 ♀ 22.viii.1863, Ziegenkot; MZL (coll. E. Bugnion). **GR:** Schuls; 1 ♀ viii[?].1938; von S. Vit 1975 und M.-A. Ieniştea 1977 bereits korrekt determiniert; MHNG (coll. G. Toumayeff). Es handelt sich um das von Ieniştea (1979: 123) und Vit und Hozman (1980: 293) publizierte Exemplar. Val da Cologna, Poschiavo, 1400 m ü.NN; 1 ♂, 3 ♀♀ 3.vii.1978, leg. S. Vit. Es handelt sich bei zwei von S. Vit im Jahre 1978 als *O. joannae* determinierten Weibchen um zwei aus der von Vit und Hozman (1980) genannten Serie. Das Datum wurde in der genannten Publikation fälschlich als „3.VIII.1978" angegeben (C. Besuchet in litt. 1991). 1 ♂ und 1 ♀ wurden von S. Vit 1978 korrekt determiniert. Aus der gleichen Fundserie liegen 1 ♂ *O. joannae* und 1 ♀ vor, das zu *O. joannae* oder *O. ovatus* gehören könnte. **VD:** Chaux Ronde/Gryon, 2050 m ü.NN; 1 ♀ 13.ix.1961, leg. C. Besuchet; MHNG. Fracherets/Gryon, 1600 m ü.NN; 2 ♂♂, 1 ♀ 23.v.1948, Fuchslosung, leg. C. Besuchet, „*O. baraudi* 8 exx."; MHNG. Fracherets, 1 ♂, 5 ♀♀ 23.v.1948, Rinderkot, leg. C. Besuchet (det. R. Pittino 1991; 1 zusätzliches Exemplar in coll. R. Pittino); MZL. La Varraz; 1 ♀ 28.vii.1949, Menschenkot, leg. C. Besuchet; MZL. **VS:** Gredetschtal, 1200 m ü.NN; 1 ♂ v.1982, leg. G. Toumayeff (det. R. Pittino [1990]); MHNG. Lötschental, in der Anan, 2250 m ü.NN; 1 ♂, 1 ♀ 28.vi.1944 (♂: det. Zunino [1977]); MHNG (coll. R. Julliard). Törbel; 1 ♂, 1 ♀ 5.vi.1949, leg. J.-P. Wolf (det. anon.: *O. ovatus*); ETH. Umgebung Zermatt, 1650 m ü.NN; 1 ♂ 24.vi.1959, Rinderkot, [leg. C. Besuchet]; MHNG. Trift-Zermatt, 26.vii.1997, leg. W. Hoffmann, det. E. Rössner (Cosandey et al. 2017: 72).

Cosandey et al. (2017) präsentieren zusätzliche Meldungen von Arvigo, Lü, Surses, Trupchun, Zernez (GR), Vetta (TI), Blatten und Simplon (VS), die in der Verbreitungskarte als weisse Kreise dargestellt sind. Das von Cosandey et al. (2017) aus dem Kanton Glarus gemeldete Exemplar von 1879 aus der ETH wurde hier als *O. ovatus* bestimmt und ist unter dieser Art berücksichtigt.

Die bei *O. baraudi* zumeist vorhandene caudomediane flache Grube des Pronotum findet sich selten auch bei *O. ovatus*, ist also allein kein sicheres Merkmal für die Determination. Die zur Halsschildbasis weitläufigere Punktierung ist jedoch immer deutlich von den anderen Arten der Gruppe zu unterscheiden.

Nachweise von *Onthophagus grossepunctatus* Reitter, 1905 in der Schweiz (Abb. 11)

Die Determination der von Ieniştea (1979) aufgeführten Individuen wird bestätigt. Deren Funddaten, zusammen mit neuen Nachweisen, sind im folgenden aufgeführt.

Untersuchtes Material. 67 Exemplare, gesammelt zwischen 1853 und 1987.

GR: Roveredo; 1 ♀ 16./22.vi.1947 (det. V. Allenspach: *furcatus*); NMB (coll. V. Allenspach). Wurde von Allenspach (1970: 37) als *O. furcatus* gemeldet. **TI:** Bellinzona; 3 ♂♂, 3 ♀♀ 23.vii.1950, Menschenkot, 2 ♂♂, 1 ♀ 23.vii.1960, leg. C. Besuchet; MZL. Biasca; 1 ♂ 17.viii.1931; 1 ♂ 22.viii.1931 (beide det. V. Allenspach: *O. furcatus*); NMB (coll. V. Allenspach). Von Allenspach (1970: 37) als *O. furcatus* gemeldet. **VS:** unter[halb] Betten, 820 m ü.NN, 645-135; 1 ♀ vi.1982; MHNG (coll. W. Marggi). Branson; 23 ♂♂, 14 ♀♀ 15.iv.1878 [Brançon]; MZL (coll. E. Bugnion); 1 Ex. 2.vi.1918; NMB (coll. E. Handschin) (see Ieniştea 1979). Folatères [Follatères]; 1 ♂ 30.iv.1918; 2 ♂♂, 2 ♀♀: 26.v.1918; 1 ♂ 30.vi.1918; 1 ♀ 31.vi.1918; NMB (coll. E. Handschin) (see Ieniştea 1979). Leuk; 1 ♂ 30.ix.1967; NMB (coll. V. Allenspach)

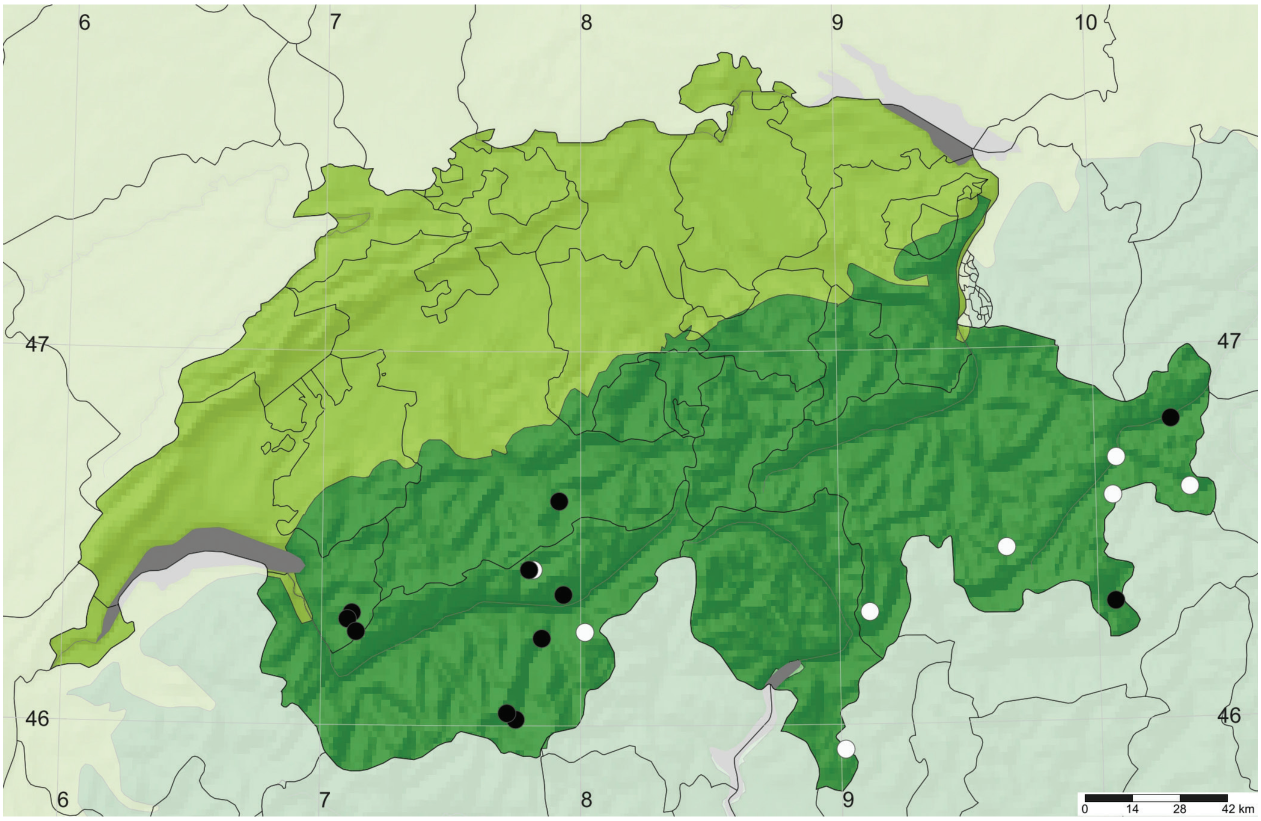

Abb. 10. Bestätigte Verbreitung von *Onthophagus baraudi* Nicolas in der Schweiz. Weisse Kreise: Zusätzliche Meldungen von Cosandey et al. (2017), nicht persönlich verifiziert.

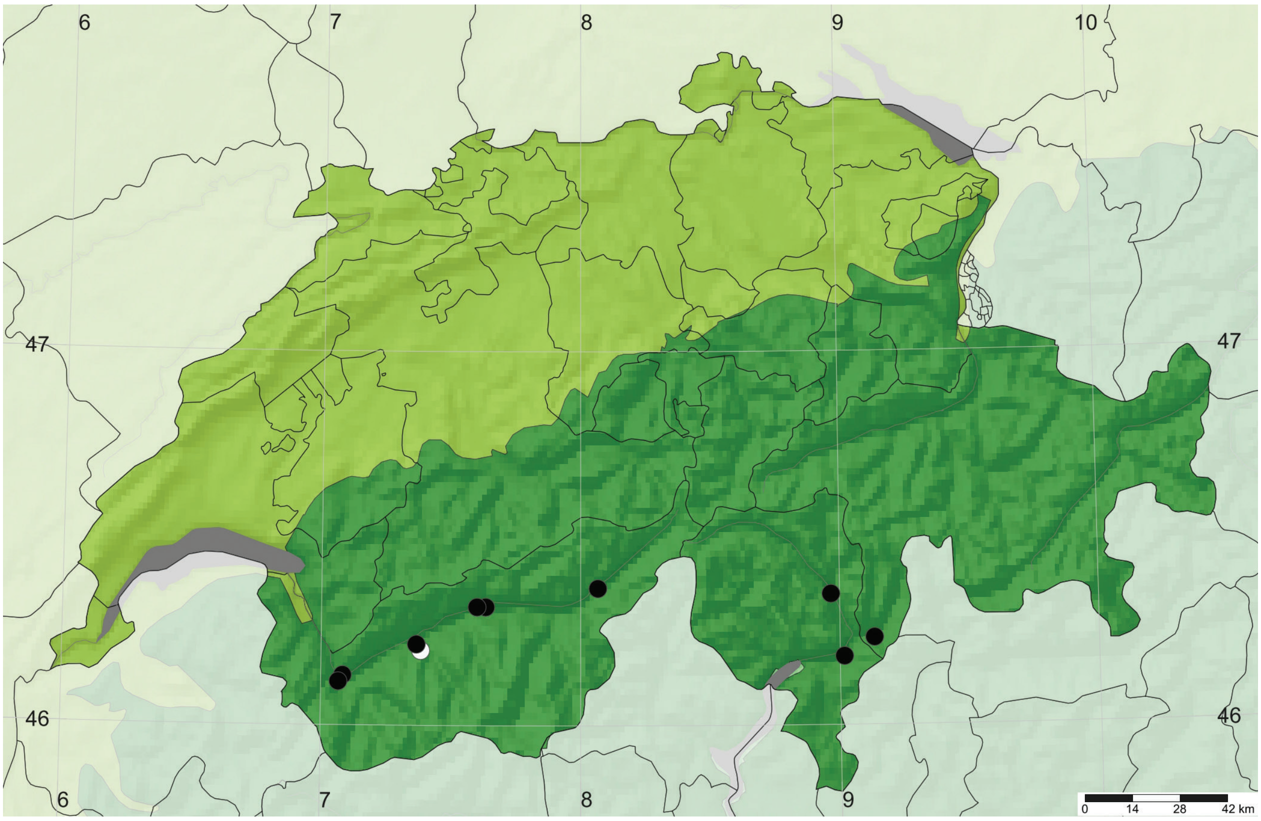

Abb. 11. Bestätigte Verbreitung von *Onthophagus grossepunctatus* Reitter in der Schweiz. Weisser Kreis: Zusätzliche Meldung von Cosandey et al. (2017), nicht persönlich verifiziert.

(see Ieniştea 1979). Sion; 1 ♀ 1853; MZL (coll. W. Morton); 1 ♂ iv., Kot; MZL (coll. E. Bugnion). Oberhalb Varen; 1 ♂, 6 ♀♀ 17.iv.1987, leg. C. Besuchet (1 ♂ det. Z. Stebnicka); MHNG.

Cosandey et al. (2017) führen neun Exemplare von Vex (VS) auf, die in der Verbreitungskarte als weisser Kreis dargestellt sind.

Nachweise von *Onthophagus joannae* Goljan, 1953, in der Schweiz (Abb. 12)

Untersuchtes Material. 213 Exemplare, gesammelt zwischen 1878 und 1995.

Vollständige Materialliste als elektronisches Supplement (Suppl. materials 1, 2).

Nachweise von *Onthophagus ovatus* (Linné, 1767) in der Schweiz (Abb. 13)

Untersuchtes Material. 342 Exemplare, gesammelt zwischen 1868 und 1998.

Vollständige Materialliste als elektronisches Supplement (Suppl. materials 1, 2).

Onthophagus ruficapillus Brullé, 1832 (Abb. 14)

Der einzige publizierte Schweizer Nachweis von *O. ruficapillus* stammt von Novak (1921), der die Art aus Biel (Kanton Bern) meldet. Allenspach (1970) übersah diese Art. In der Kartendarstellung der Nachweise in Martín Piera und Zunino (1986: 440) finden wir einen Fundpunkt auf Schweizer Gebiet markiert, der sich wahrscheinlich auf den Novakschen Fund bezieht. Brieflich teilte Martín Piera mit, er habe den Nachweis aus der Literatur übernommen, habe selbst jedoch kein Exemplar aus der Schweiz gesehen (F. Martín Piera in litt., 1993). Löbl et al. (2006) und Ziani und Bezděk (2016) geben die Schweiz als Verbreitungsgebiet an, was ebenfalls auf dem Novakschen Fund basiert (A. Bezdek in litt. 2018).

Die meisten der im Folgenden aufgelisteten Neunachweise sind jedoch bereits, wie oben erklärt, in Cosandey et al. (2017) aufgeführt.

Untersuchtes Material. 6 Exemplare, gesammelt zwischen 1930 und 1970.

BE: Aarwangen; 1 ♀ iv.1930, leg. A. Linder (war eingeordnet unter *O. ovatus*); ETH (coll. A. Linder). Burgdorf; 3 ♀♀ iv.1970, leg. S. Kiener (1 ♀ det. R. Pittino [1990]; 2 ♀♀ det. A. Linder [1971]: *O. ovatus*); MHNG (coll. S. Kiener). **NE:** Chaumont; 1 ♀ (war eingeordnet unter *O. ovatus*); ETH (coll. M. Bänninger). **VS:** Salgesch, Leuggh; 1 ♂ [mit handschriftlichem Etikett „*Onthophagus ovatus*“]; NMSO (coll. A. Nägeli).

Das Männchen aus Salgesch, zwei der drei Weibchen aus Burgdorf sowie die Weibchen aus Aarwangen und Chaumont weisen die diagnostische Ausrandung an den Seiten des Kopfschildes nur schwach auf. In derartigen Zweifelsfällen sollte der weibliche Kopulationsapparat untersucht werden (Abb. 15, 16): Bei *O. ruficapillus* sind die Seitenstücke spitz und deutlich dreieckig erweitert. Die Querverbindung dazwischen ist—in Aufsicht bei entfernter Bursa copulatrix—sehr breit (Abb. 5). Insgesamt ist die Genitalspange bei *O. ruficapillus* kräftiger sklerotisiert als bei *O. ovatus*, doch hängt der Sklerotisierungsgrad auch vom Alter der Imago ab. Frisch geschlüpfte Imagines besitzen in beiden Geschlechtern nur schwach sklerotisierte Kopulationsorgane.

Cosandey et al. (2017) führen ein Exemplar von Chiasso aus dem südlichsten Tessin auf, das nicht untersucht wurde und in der Verbreitungskarte (Abb. 14) als weisser Kreis dargestellt ist.

Diskussion—die Verbreitung der *O. ovatus*-Gruppe in der Schweiz

Die beiden häufigsten Arten dieser Gruppe in der Schweiz, *Onthophagus ovatus* und *O. joannae*, zeigen unterschiedliche Verbreitungsbilder: Wohingegen *O. ovatus* hautpsächlich im Naturraum *Western European broadleaf forests*, vor allem im Mittelland, aber auch an der Alpensüdflanke (südliches Tessin) vorkommt (Abb. 13), ist *O. joannae* im Naturraum *Alps conifer and mixed forest* konzentriert, hier vor allem in den westlichen und östlichen Zentralalpen und der Alpensüdflanke (Abb. 12). In den westlichen Zentralalpen scheint die Art vor allem in der Gegend des Rhonetals verbreitet zu sein, doch zeigt Abb. 1 eine starke Konzentration der Sammeltätigkeit in diesem Gebiet, so dass dies ein Sammelartefakt sein könnte. Neuere Funde, dargestellt in den Verbreitungskarten von Info Fauna, zeigen eine ausgedehntere Verbreitung von *O. ovatus* im Rhonetal an sowie vereinzelte Funde von *O. joannae* im Jura und dem nördlichen Mittelland, die oben beschriebenen Verbreitungsmuster bleiben jedoch im Grossen und Ganzen unverändert.

Lumaret (1978: fig. 30) stellte in Südfrankreich *O. ovatus* hauptsächlich in Höhenlagen unter 800 m fest, wohingegen *O. joannae* bis über 1200 m häufig vorkommt. Auch in Ostdeutschland geht *O. joannae* höher und auch nördlicher als *O. ovatus* (Rößner 2012). Alle Nachweise der *O. ovatus*-Gruppe aus Norwegen, diese Tendenz bestãtigend, beziehen sich auf *O. joannae* (Ødegaard 2001). Auch in der Schweiz kommt *O. joannae* tendenziell in höheren Regionen vor.

Die Schweizer Vorkommen von *Onthophagus baraudi* (Abb. 10) verbinden das Verbreitungsgebiet dieser auf die Alpen beschränkten Art in den Ostalpen (Tirol, Südtirol: Ballerio 1993; Steiermark: Krell 1996; Bayerische Alpen: Rössner 2008) mit dem in den französischen Westalpen (Hautes-Alpes, Alpes de Hautes-Provence; Lumaret 1990: 96f), wo die Art lokal häufig sein kann (Lumaret und Stiernet 1990). Die südliche Verbreitungsgrenze der Art befindet sich in Ligurien (Ziani 2009), das zur Ökoregion *Northern Alpine Chain Province* gehört (Blasi et al. 2010). Alle Schweizer Fundorte liegen in der südlichen Hälfte des Landes, im Naturraum *Alps conifer and mixed forest*.

Onthophagus grossepunctatus ist eine thermophile, mediterrane Art (Martín Piera und Zunino 1986: 449). Balthasar (1967) betrachtet Nové Mesto nad Váhom in

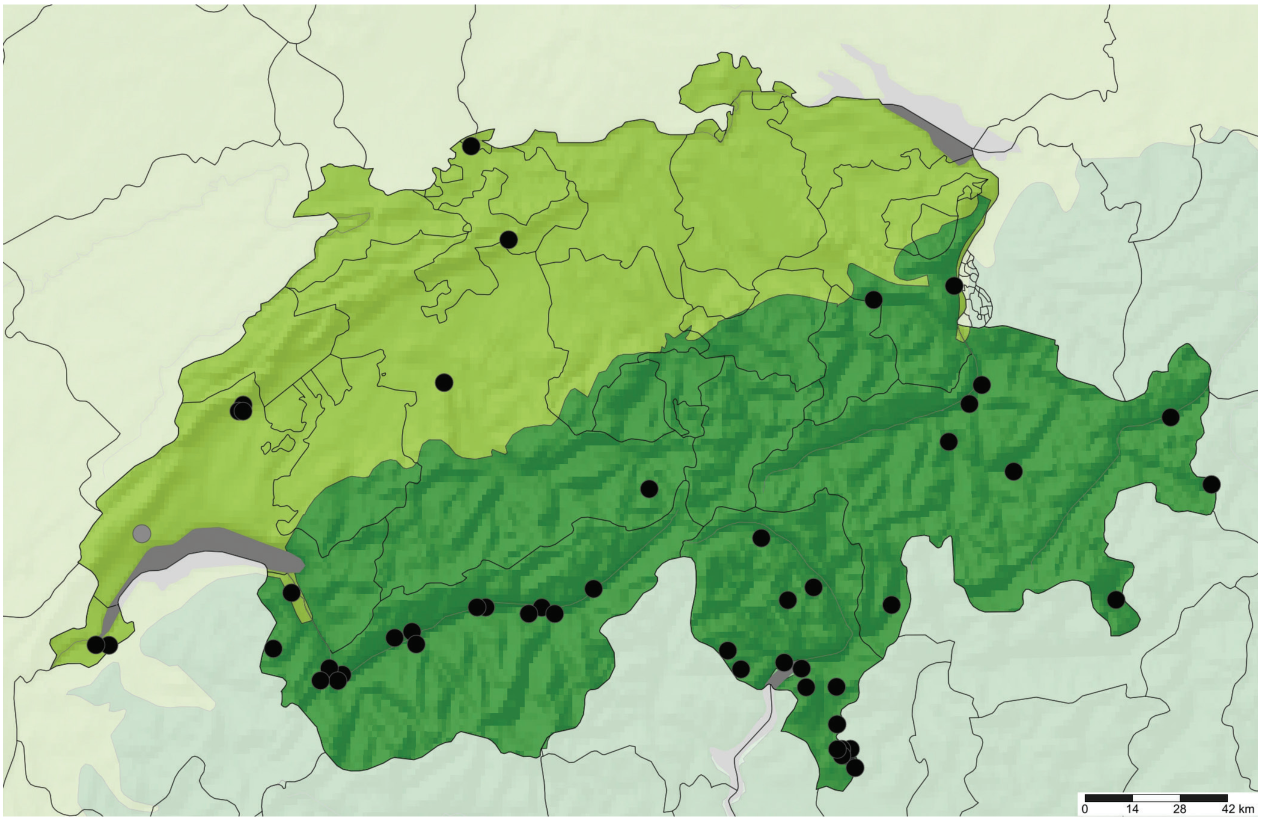

Abb. 12. Bestätigte Verbreitung von *Onthophagus joannae* Goljan in der Schweiz. Grauer Kreis: Unsicherer Maerky-Nachweis. Für neuere Funde vergleiche die Karte von Info Fauna https://lepus.unine.ch/carto/index.php?nuesp=22630&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de

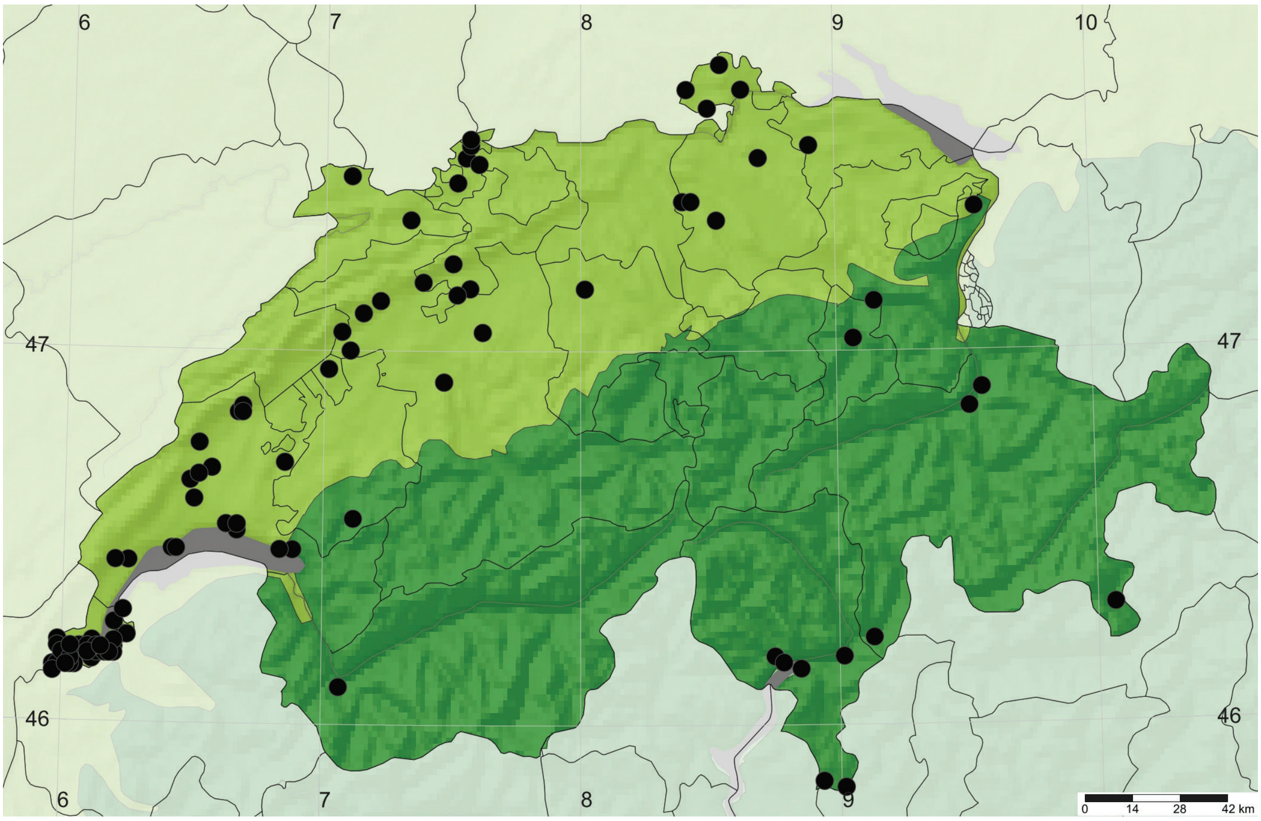

Abb. 13. Bestätigte Verbreitung von *Onthophagus ovatus* (L.) in der Schweiz. Für neuere Funde vergleiche die Karte von Info Fauna https://lepus.unine.ch/carto/index.php?nuesp=22634&rivieres=on&lacs=on&hillsh=on&data=on&year=2000&lang=de

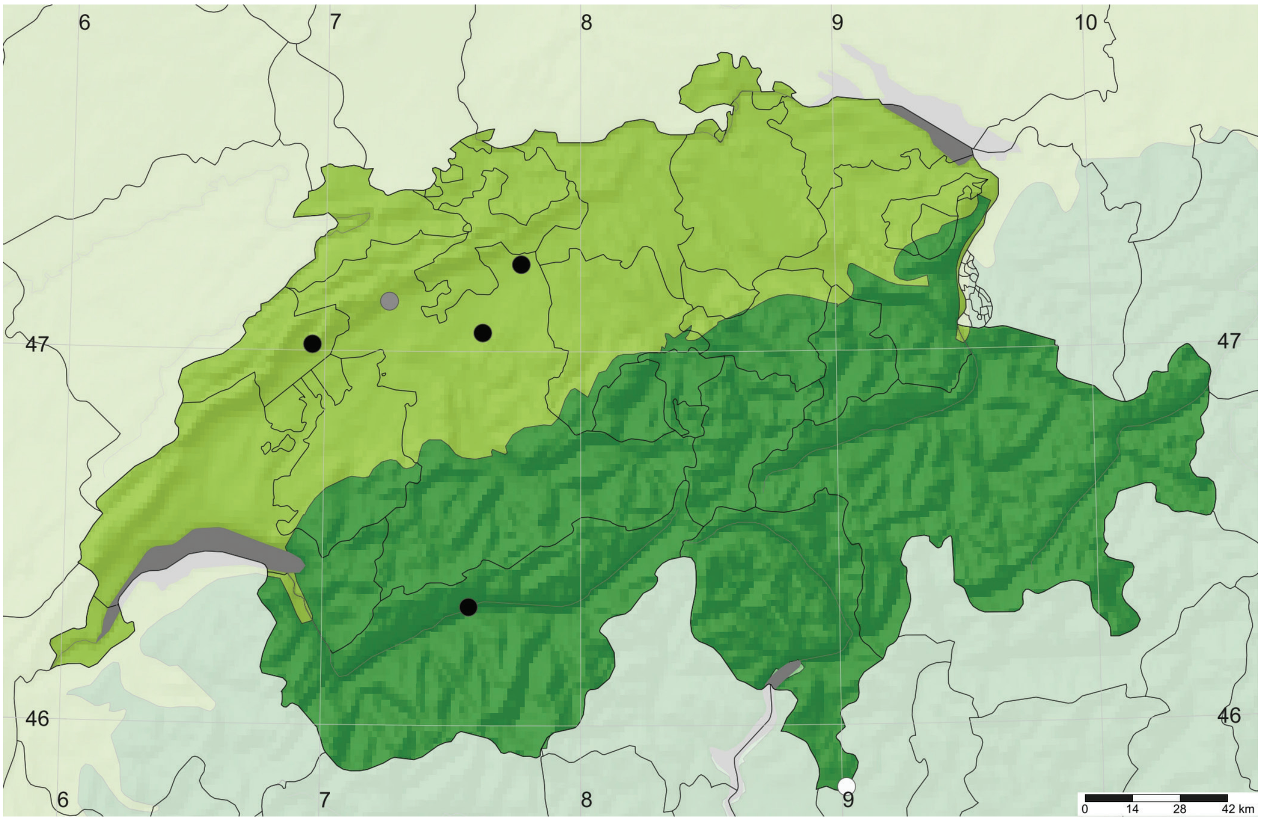

Abb. 14. Bestätigte Verbreitung von *Onthophagus ruficapillus* Brullé in der Schweiz. Grauer Kreis: Novaks (1921) Erstmeldung für die Schweiz, nicht persönlich verifiziert. Weisser Kreis: Zusätzliche Meldung von Cosandey et al. (2017), nicht persönlich verifiziert.

Abb. 15–16. Apikalbereich des weiblichen Kopulationsapparates von *Onthophagus ruficapillus* Br.; Schweiz, Bern, Burgdorf, leg. S. Kiener iv.1970, coll. S. Kiener, MHNG. Abb. 16 zeigt die Aufsicht auf den Sklerit von cranial. Bursa copulatrix und Ductus receptaculi sind teilweise, das Receptaculum seminis vollständig entfernt.

der Slowakei (48°45’N, 17°50’E) als nördliche Verbreitungsgrenze dieser Art. Alle Schweizer Fundorte (Abb. 11) liegen weit südlicher und sind beschränkt auf das Rhonetal und die Alpensüdflanke, wo das Klima für südliche Arten zuträglich ist (Beaumont 1968). Betten (VS) markiert mit 46°22“N die bisher nördlichste Verbreitungsgrenze in der Schweiz.

Onthophagus ruficapillus ist im mediterranen Gebiet abundant und weit verbreitet (Martín Piera und Zunino 1986). In Frankreich ist die Art häufig südlich von 45°N, jedoch sind einzelne Meldungen aus den Regionen Île-de-France und Centre bekannt (Gagnepain 2008). Mit dem Schwerpunkt seiner Verbreitung südlich des Schweizer Gebietes ist die Art erwartungsgemäss selten in der Schweiz gefunden worden, und nur in niederen Höhenlagen (Abb. 14).

Abschlussdiskussion

Durch ihre zentrale Lage in Europa, an der Grenze zwischen dem gemässigtem Klima Mitteleuropas und der Mediterraneis, mit einem aussergewöhnlichen Höhengradienten (193–4624 m ü.NN) auf relativ kleinem Gebiet, ist die Schweiz besonders interessant für das Studium der geographischen Verbreitung von Organismen. Die Schweiz bildet oft die nördliche Verbreitungsgrenze mediterraner Arten und, durch ausgedehnte alpine Regionen, eine natürliche südliche Ausbreitungsgrenze für temperate Arten. Wir finden verschiedene solcher Muster bei den Dungkäfern. *Onthophagus similis*, weit verbreitet in Europa, scheint in der Schweiz weitgehend zu fehlen. *Onthophagus ruficapillus* wird als wärmeliebende, südliche Art, nur sporadisch in der Schweiz gefunden, wohingegen andere thermophile

Arten, wie *O. grossepunctatus* und *O. opacicollis*, häufiger, aber nur in südlichen Bereichen der Schweiz vorkommen. Um potentielle Unterschiede in den Verbreitungsbildern häufigerer Arten zu finden, z.B. zwischen *Onthophagus taurus* und *O. illyricus*, sind weitere Datenaufnahmen und Aufsammlungen unbedingt notwendig. Laufende Kartierungsprojekte (Cosandey et al. 2017) helfen, diese Lücken zu füllen, Verbreitungsmuster zu ergänzen, zu korrigieren und präzisieren, wie es in den hier präsentierten Verbreitungskarten von *Onthophagus baraudi* und *O. opacicollis* eindrucksvoll demonstriert wird.

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Supplementary material 1

Material examined of *Onthophagus fracticornis*, *O. joannae*, and *O. ovatus*

Author: Frank-Thorsten Krell

Data type: Material examined, pdf

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/alpento.2.23345.suppl1

Supplementary material 2

All localities for the discussed *Onthophagus* species

Author: Frank-Thorsten Krell

Data type: Occurrence

Explanation note: Excel file of all localities for all species as visualized in the distribution maps.

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PENSOFT.

Alpine Entomology

Heuschrecken (Orthoptera) in Biodiversitätsförderflächen der voralpinen Kulturlandschaft Schönenbergs (Schweiz, Kanton Zürich) mit Trends seit 1990

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Switzerland

Zusammenfassung

Unsere Untersuchungen in der voralpinen Kulturlandschaft Schönenbergs (Schweiz, Kanton Zürich) haben ergeben, dass die Biodiversitätsförderflächen-Typen Streuefläche, Extensivweide und Extensivwiese im Vergleich zu konventionell bewirtschafteten Fettwiesen einen stark positiven Effekt auf die Diversität und Individuendichte von Heuschrecken ausüben. Innerhalb der Biodiversitätsförderflächen wiesen Heuschrecken in Streueflächen wiederum signifikant höhere Diversitätswerte und Individuendichten auf als in Extensivwiesen und Extensivweiden. Sie beherbergten zudem fast 95% aller beobachteten Individuen der Heuschrecken der Roten Liste. Innerhalb der Streueflächen war in Pfeifengraswiesen und Hochstaudenfluren eine signifikant höhere Heuschreckendiversität zu verzeichnen als in Kleinseggenrieden, Grossseggenrieden und verschilften Teilflächen. Die Individuendichten in Pfeifengraswiesen und Hochstaudenfluren erwiesen sich im Vergleich zu Grossseggenrieden als signifikant höher.

Im Vergleich zu früheren Erhebungen in Schönenberg ZH aus den Jahren 1990 und 2000 veränderte sich die Heuschreckendiversität in den Fettwiesen 2016 nicht signifikant, jedoch zeigten sich auf Artebene deutliche Verschiebungen der relativen Häufigkeiten. So kam die eher trockenheitsliebende Art *Chorthippus biguttulus* in den Fettwiesen 2016 bedeutend häufiger vor als 1990 und 2000, während die in der Region eher feuchtigkeitsliebende Art *Chorthippus dorsatus* einen gegenteiligen Trend aufwies. Die 1990 und 2000 noch nicht beobachtete Art *Chorthippus albomarginatus* fand sich 2016 in einigen Fettwiesen, welche zu den östlichsten Fundorten im Voralpenraum gehören.

In den Streueflächen wurde 2016 eine signifikant höhere Heuschreckendiversität als 1990 festgestellt. Die in der Schweiz gefährdete Art *Conocephalus fuscus* erlitt seit 1990 massive Einbussen, dafür nahmen andere Arten in ihrer relativen Häufigkeit markant zu, z.B. die potenziell gefährdeten Arten *Chrysochraon dispar* und *Decticus verrucivorus*. Zusätzliche Massnahmen zur Heuschreckenförderung werden erörtert, mit Schwerpunkt auf der asynchronen Nutzung, schonenden Mähtechniken sowie räumlich und zeitlich wechselnden Altgrasinseln.

Abstract

Grasshoppers (Orthoptera) in ecological compensation areas of a pre-alpine cultural landscape near Schönenberg (Switzerland, canton of Zürich) with trends since 1990. Our investigations in the pre-alpine cultural landscape of Schönenberg (Switzerland, canton of Zürich) have shown that ecological compensation areas (ECA) such as reeds and extensively managed semi-natural grassland have a highly positive effect on the species diversity and density of grasshoppers compared to conventionally managed cut meadows. ECA reeds showed significantly higher diversities and densities of grasshopper species than ECA meadows and ECA pastures. ECA reeds also contained almost 95% of all observed individuals of the grasshoppers on the Swiss Red List. Within the ECA reeds, significantly higher species diversity was recorded in moor grass meadows and tall forb communities compared to low sedge fens, tall sedge fens and subareas with high density of *Phragmites australis*. Grasshopper densities in moor grass meadows and tall forb communities proved to be significantly higher than those in tall sedge fens.

Compared to previous surveys in Schönenberg ZH from 1990 and 2000, the grasshopper diversity in the conventionally managed meadows did not significantly change, but there were considerable shifts in the relative abundance at species level. For example, the rather xerophilous species *Chorthippus biguttulus* was more frequent in conventionally managed meadows in 2016 than in 1990 and 2000, while the regionally more hygrophilous species *Chorthippus dorsatus* showed an opposite trend. *Chorthippus albomarginatus*, a species which had not been observed in 1990 and 2000, was found in 2016 within some conventionally managed meadows. These findings currently belong to the easternmost sites of the Swiss pre-alpine region.

In 2016, a significantly higher species diversity of grasshoppers was found within the ECA reeds compared to 1990. Although the endangered species *Conocephalus fuscus* suffered a massive decline since 1990, other species significantly increased in their relative abundance, e. g. the potentially endangered species *Chrysochraon dispar* and *Decticus verrucivorus*.

Measures to promote grasshoppers on ECA grassland are discussed, with a focus on the asynchronous management, the use of compatible mowing techniques and the maintenance of temporally and spatially varying subareas with uncut vegetation.

Einleitung

Die biologische Vielfalt wurde während der letzten Jahrhunderte durch traditionelle Nutzungsformen, welche eine vielfältige und artenreiche Kulturlandschaft hervorgebracht haben, entscheidend geprägt (Bosshard 2015, Duelli and Obrist 2003). So kommen etwa 80% der Schweizer Heuschreckenarten im landwirtschaftlich genutzten, offenen Kulturland vor (Lachat et al. 2010). Durch den teilweise dramatischen Rückgang von extensiv genutztem Grünland aufgrund von Nutzungsintensivierung, Nutzungsaufgabe oder Überbauung haben jedoch in den letzten Jahrzehnten viele Tier- und Pflanzenarten massive Bestandseinbussen erlitten oder sind ganz aus unserer Kulturlandschaft verschwunden (Fischer et al. 2015). Die Rote Liste der gefährdeten Heuschrecken der Schweiz zeigt, dass Arten des Grünlands mit fast einem Drittel bedrohter Arten von diesem Rückgang besonders stark betroffen sind (Monnerat et al. 2007).

Im Kanton Zürich gingen gemäss Naturschutz-Gesamtkonzept die Magerwiesen zwischen 1939 und 1990 von rund 60000 ha auf 1000 ha zurück (Baudirektion des Kantons Zürich 1995). Gesamtschweizerisch liegt der Flächenverlust bei trockenen Magerwiesen und -weiden seit 1900 bei ca. 95% (Lachat et al. 2010). Bei den Feuchtgebieten ist der Rückgang ähnlich drastisch: im Kanton Zürich reduzierte sich deren Gesamtfläche von knapp 14000 ha im Jahr 1850 auf noch rund 1200 ha im Jahr 2000 (Gimmi et al. 2011). Gesamtschweizerisch beträgt der Verlust bei den Mooren im Zeitraum 1900 bis 2010 mehr als 80% (Lachat et al. 2010). Die noch verbliebenen Magerwiesen, Magerweiden und Moore unterliegen, wie die gesamte Landschaft, selbst bei sachgemässer extensiver Nutzung einem flächigen Nährstoffeintrag aus der Luft, was zu einer schleichenden Verarmung der Artenvielfalt und Nivellierung des Artenspektrums führt (Kohli 2011). Flächenverluste und Lebensraumdegradation haben dazu geführt, dass in der Hügelzone nur noch 3.5 bis 4.5% und in der Bergzone I noch 3 bis 4.5% der landwirtschaftlichen Nutzfläche als ökologisch wertvoll bezeichnet werden kann (Walter et al. 2013).

Um den damit verbundenen Artenverlust in der Landwirtschaft entgegenzuwirken, erhalten Landwirte für ökologische Ausgleichsmassnahmen, welche zur Erhaltung und Förderung der Biodiversität beitragen, Direktzahlungen des Bundes. Den höchsten Flächenanteil weisen die Biodiversitätsförderflächen-Typen Extensivwiese mit knapp 82000 ha und Extensivweide/Waldweide mit etwas mehr als 45000 ha auf. Der Typ Streuefläche umfasst lediglich knapp 8000 ha (BLW 2017).

Einige Studien belegen positive Effekte von Biodiversitätsförderflächen auf Flora und Fauna, z.B. in Bezug auf die Artenvielfalt bei Gefässpflanzen, Heuschrecken und Wildbienen in extensiv genutzten Wiesen (Knop et al. 2006). Andere Untersuchungen wiederum vermitteln ein uneinheitliches Bild: so hatten Biodiversitätsförderflächen im Kanton Aargau einen signifikant positiven Einfluss auf die Artenvielfalt bei Gefässpflanzen und Schnecken, nicht jedoch bei Vögeln und Tagfaltern (Roth et al. 2008). Ein Forschungsprojekt von Kampmann et al. (2008) im Bergland ergab keinen signifikant positiven Einfluss von extensiv genutzten Wiesen auf Heuschrecken im Vergleich zu konventionell genutzten Wiesen, dafür jedoch einen signifikant positiven Einfluss von extensiv genutzten Weiden im Vergleich zu extensiv und konventionell bewirtschafteten Wiesen.

Die in unserer Untersuchung im Zentrum stehenden Heuschrecken werden in vergleichend-ökologischen Studien gerne verwendet, weil die Form der Bewirtschaftung einen bedeutenden Einfluss auf deren Vorkommen im Grünland ausübt (Sachteleben et al. 2007). Die schnelle Reaktion auf Veränderungen in der Umwelt und die kurzen Generationszeiten machen Heuschrecken zu nützlichen Indikatoren für die Beurteilung von Lebensräumen in der Agrarlandschaft (Chisté et al. 2016). Gemäss *Fauna Indicativa* sind 57 von 112 bewerteten Schweizer Heuschreckenarten fähig, extensive Wiesen und extensive Weiden in der collinen bis montanen Höhenstufe des Mittellands und der Alpennordflanke als Habitat zu nutzen (Klaiber et al. 2017), darunter 30 Arten der Roten Liste (Monnerat et al. 2007) und 23 für die Schweiz prioritäre Arten (BAFU 2011). In mässig feuchten bis feuchten Fettwiesen sind es, bei denselben Auswahlkriterien, maximal 20 Heuschreckenarten, wobei die meisten davon nur sporadisch bzw. in Randbereichen von Fettwiesen auftreten und nur eine Handvoll anspruchsloser, nicht gefährdeter Generalisten im Innern von intensiv genutztem Grünland dauerhaft überleben kann. In Flachmooren und Feuchtwiesen können in der collinen bis montanen Stufe des Schweizer Mittellands und der Alpennordflanke bis zu 25 Heuschreckenarten vorgefunden werden. Bei diesen Arten handelt es sich tendenziell um Lebensraumspezialisten, die vor allem intakte Feuchtgebiete besiedeln (Baur et al. 2006, Klaiber et al. 2017), darunter 12 Arten der Roten Liste (Monnerat et al. 2007) und 9 prioritäre Arten (BAFU 2011).

Als Untersuchungsgemeinde wählten wir Schönenberg ZH, weil von dort bereits Vergleichsdaten von Heuschrecken-Kartierungen aus den Jahren 1990 und 2000 vorliegen, die zur Beurteilung langfristiger Bestandestrends miteinbezogen werden können. Die Daten von 1990 stammen aus dem Heuschrecken-Inventar des Kantons Zürich (ALN 2018), diejenigen von 2000 aus einer Diplomarbeit, welche die Entwicklung der Heuschreckenfauna Schönenbergs ZH zwischen 1990 und 2000 thematisierte (Peter 2001).

Zusammenfassend verfolgten wir folgende Fragestellungen:

i) Unterscheiden sich die Heuschreckendiversität und -dichten der Biodiversitätsförderflächen-Typen Extensivweide, Extensivwiese und Streuefläche untereinander sowie im Vergleich zu konventionell bewirtschafteten Fettwiesen? In welchem Ausmass leisten die Grünland-Biodiversitätsförderflächen einen Beitrag zur lokalen Heuschreckenvielfalt und zum Vorkommen stenotoper Lebensraumspezialisten?
ii) Unterscheiden sich die Heuschreckenartenzahlen und -dichten der verschiedenen Biotoptypen innerhalb der Streueflächen?
iii) Wie haben sich die Diversität und Individuendichten der Heuschrecken in den Fettwiesen und Streueflächen im Vergleich zu den Erhebungsjahren 1990 und 2000 entwickelt?

Methoden

Untersuchungsgebiet

Die Untersuchungen fanden in der Gemeinde Schönenberg ZH statt (Abb. 1). Die Gemeinde liegt, basierend auf den Kriterien von Körner et al. (2017), am nördlichen Rand des Voralpengürtels (GMBA 2017). Sie befindet sich auf montaner Höhenstufe zwischen knapp 600 und rund 750 m ü. M. und umfasst eine Fläche von 1102 ha, wovon 76.5% landwirtschaftlich genutzt werden (Statistisches Amt Kanton Zürich, 2017). Von den Biodiversitätsförderflächen im Grünland entfielen 2015 46.8 ha auf Extensivwiesen, 34.8 ha auf Streueflächen und 6.0 ha auf Extensivweiden (ALN 2015).

Schönenberg ZH liegt in der „Glaziallandschaft zwischen Lorzentobel und Sihl mit Höhronenkette“, welche zu den Landschaften und Denkmälern von nationaler Bedeutung gehört (BLN Objekt Nr. 1307). Rund 280 ha der BLN-Fläche bilden Teil der Moorlandschaft von nationaler Bedeutung Hirzel (BAFU 2007).

Auswahl der Untersuchungsflächen

Die Heuschreckenfauna der Gemeinde Schönenberg ZH erfassten wir in 100 Untersuchungsflächen, unterteilt in 70 Biodiversitätsförderflächen (10 Extensivweiden, 30 Extensivwiesen und 30 Streueflächen) sowie in 30 konventionell genutzte Fettwiesen (Lage vgl. Abb. 10, Anhang 1). Die kleinere Stichprobenmenge der Extensivweiden ist auf die Seltenheit dieser Nutzungseinheit im Untersuchungsgebiet zurückzuführen. Als Grundlage diente ein interner Datenbankauszug aller Biodiversitätsförderflächen der Gemeinde Schönenberg ZH (ALN 2015).

Die Auswahl der Flächen erfolgte auf Basis eines nach SWISSGRID ausgerichteten Rasters (Rasterquadrat: 100 m × 100 m). Die Rasterkartierung gilt bei der Erfassung der Flora als internationaler Standard und lässt sich ohne weiteres auch auf einige Tiergruppen, wie z. B. Heuschrecken, übertragen (Kranebitter et al. 2007). Bei der Auswahl der Rasterquadrate wurde darauf geachtet, dass die Quadrate möglichst in der ganzen Gemeinde verteilt waren und die im Fokus stehende landwirtschaftliche Nutzungseinheit jeweils mindestens 20% des Rasterquadrats bedeckte. Die ungleiche Verteilung der Grünland-Biodiversitätsförderflächen in der Gemeinde erlaubte es nicht, unmittelbar benachbarte Rasterquadrate mit derselben Nutzungseinheit generell von der Untersuchung auszuschliessen, da ansonsten die Stichprobenzahl zu klein geworden wäre. Hingegen war es bei den Fettwiesen möglich, ausschliesslich nicht direkt aneinander grenzende Rasterquadrate zu berücksichtigen und damit die räumliche Unabhängigkeit der Stichproben zu gewährleisten.

Abb. 1. Landschaftsausschnitt Schönenberg ZH mit Streuefläche im Vordergrund (Foto: S. Schnetzler, 17.8.2016).

Datenerhebung und Nomenklatur

In allen 100 Rasterquadraten erfolgte zwischen dem 7. August 2016 und dem 11. September 2016 je 1 Aufnahme der Heuschrecken. Während dieser Jahreszeit weisen die Imagines der meisten Heuschreckenarten die höchsten Abundanzen auf (Baur et al. 2006). Die Feldarbeiten fanden jeweils zwischen 10.00 Uhr und 18.30 Uhr, einer Lufttemperatur von mindestens 20 °C, einer Windstärke von maximal 3 Beaufort und vorwiegendem Sonnenschein statt (sensu Marti 2005). In den Rasterquadraten wurde jeweils nur die im Fokus stehende landwirtschaftliche Nutzungseinheit (Extensivweide, Extensivwiese, Fettwiese oder Streuefläche) auf ihre Heuschreckenfauna hin untersucht. Dabei wurden wellenförmige Transekte in gemütlichem Schritttempo abgeschritten und die Individuen der festgestellten Heuschreckenarten in einem Streifen von ca. 5 m Breite durch Sichten und/oder Verhören aufsummiert. Die Transekte wurden direkt im Feld kartographisch festgehalten und danach im Büro nachgemessen. Die durchschnittliche Transektlänge pro Kartierobjekt schwankte in Abhängigkeit der Objektfläche zwischen durchschnittlich 129 m bei Extensivwiesen und 250 m bei Fettwiesen. Um Randeffekte zu minimieren, fanden im Übergangsbereich zwischen den angrenzenden Nutzungseinheiten in einer Pufferzone von beidseits mindestens 5 m keine Zählungen statt. Bei Bestimmungsunsicherheiten wurden die Tiere mit einem Kescher eingefangen und die Arten in einem Betrachtungsdöschen mit Hilfe einer Lupe verifiziert. Die Bestimmungen erfolgten nach Baur et al. (2006).

Innerhalb der Streueflächen erfassten wir die Heuschrecken mittels Teiltransekten jeweils getrennt in den Biotoptypen Pfeifengraswiese (basenreiche Variante des Molinion; n=19), Hochstaudenflur (Filipendulion; n=21), Kalk-Kleinseggenried (Caricion davallianae; n=11), Grossseggenried (Magnocaricion; n=11) sowie, pflanzensoziologisch übergreifend, in Teilflächen mit vorherrschendem Schilfbewuchs (n=7). Die durchschnittliche Transektlänge pro Kartierobjekt schwankte zwischen durchschnittlich 57 m bei Kleinseggenrieden und 81 m bei Pfeifengraswiesen. Die Zuordnung erfolgte aufgrund von visuellen Merkmalen oder durch die Bestimmung bestimmter floristischer Charakterarten gemäss Delarze and Gonseth (2008). Um den Randeffekt möglichst gering zu halten, fanden im Übergangsbereich zwischen den angrenzenden Pflanzengesellschaften in einer Pufferzone von beidseits 2.5 m keine Zählungen statt.

Die Nomenklatur der Heuschrecken richtet sich nach dem taxonomischen Index der Fauna Europaea (de Jong et al. 2014).

Datenanalyse

a) Heuschreckenkartierung 2016

Für den Vergleich der Heuschreckendiversität zwischen den landwirtschaftlichen Nutzungseinheiten bzw. zwischen den Biotoptypen der Streueflächen verwendeten wir die Rarefaction-Methode. Diese erlaubt die Berechnung von Erwartungswerten bei unterschiedlichen Stichprobengrössen anhand von Rarefaction-Kurven (Smith and Smith 2009). Als Diversitätsmass verwendeten wir die Simpson-Diversität (reziproker Wert des Simpson-Index), eine Messgrösse, welche auch bei kleinen Stichproben aussagekräftige Resultate liefert (Magurran 2004). Mittels Bootstrapping wurden die 95%-Konfidenzintervalle ermittelt. Nutzungseinheiten bzw. Biotoptypen, zwischen denen kein signifikanter Unterschied besteht, sind in den entsprechenden Abbildungen und Tabellen mit einem gemeinsamen Buchstaben gekennzeichnet.

Für den Vergleich der Heuschreckendichten zwischen den verschiedenen landwirtschaftlichen Nutzungseinheiten wurde mangels Normalverteilung der Daten ein Kruskal-Wallis-Rangsummentest durchgeführt. Die Normalverteilung wurde mit dem Shapiro-Wilk-Test und die Homoskedastizität mit dem Bartlett-Test und dem Levene-Test überprüft. Um signifikante Unterschiede zwischen den einzelnen Flächentypen zu erkennen, erfolgte anschliessend an den Kruskal-Wallis-Rangsummentest eine Post-Hoc-Analyse. Die jeweiligen Flächentypen wurden dabei jeweils paarweise mit einem Dunn-Test verglichen. Um eine α -Fehlerkumulation zu vermeiden, wurde das Signifikanzniveau ($\alpha = 0.05$) nach der Methode von Holm korrigiert. Flächentypen, zwischen denen gemäss der Post-hoc-Analyse kein signifikanter Unterschied besteht, sind in den Boxplots mit einem gemeinsamen Buchstaben gekennzeichnet.

Um auch graduelle Unterschiede zwischen den Heuschreckengemeinschaften feststellen zu können, führten wir eine ergänzende Gradientenanalyse durch. Die Korrespondenzanalyse (Correspondence analysis CA) gilt dabei als geeignetes Ordinationsverfahren zur Analyse unimodaler Verteilungen mit langen Gradienten (ter Braak and Šmilauer 2012). Die in einer vorgelagerten Detrended correspondence analysis (DCA) ermittelte maximale Gradientenlänge der ersten Ordinationsachse von 3.68 Standardabweichungen deutet auf eine solch unimodale Verteilung der Standortdaten hin. Die Eigenwerte bzw. die kumulierte erklärte Varianz der zugrundeliegenden Gradientenachsen dienten der Dateninterpretation, v.a. der Aussagerelevanz der ersten beiden dargestellten Diagrammachsen.

b) Entwicklungstendenzen der Heuschrecken seit 1990 in den Fettwiesen und Streueflächen

Während den Heuschrecken-Kartierungen 1990 und 2000 wurde der östliche Teil der Gemeinde Schönenberg ZH nicht kartiert (Lage vgl. Abb. 11 und Abb. 12, Anhang 1). Daher wurden aus unseren Erhebungen von 2016 nur jene Rasterquadrate berücksichtigt, welche sich innerhalb des Untersuchungsperimeters von 1990 und 2000 befinden (19 Fettwiesen und 27 Streueflächen).

Alle innerhalb des Kartierperimeters in Schönenberg vorhandenen Biotoptypen wurden durch die jeweiligen Kartierpersonen sowohl 1990 als auch 2000 auf einem Plan festgehalten. Die Abgrenzung der Biotoptypen erfolgte in die 5 Hauptkategorien Ackerland, Feuchtgebiet, Hochstaudenflur, Wiesland und Pionier-/Ruderalstandort, danach wiederum verfeinert in rund 30 Unterkategorien (z.B. Pfeifengraswiese innerhalb der Hauptkategorie Feuchtgebiet). Der ganze Kartierperimeter wurde sowohl 1990 als auch 2000 mittels schlangenförmiger Transekte je einmal pro Beobachtungsjahr auf seine Heuschreckenfauna hin untersucht (Peter 2001). Dabei fanden an Beobachtungspunkten, die in „zufälligen Abständen alle 10–50 Meter“ voneinander entfernt lagen, Abundanzschätzungen statt, welche dann dem entsprechenden Biotoptyp zugeordnet wurden. Folgende Dichteklassen kamen zur Anwendung (Radius 5 m): 1: 1–2 Individuen, 2: 3–9 Individuen, 3: 10+ Individuen. Die Beobachtungspunkte von 1990 und 2000 lagen nicht an denselben Stellen.

Wir errechneten die relative Häufigkeit jeder Heuschreckenart auf der Basis ihrer aufsummierten Dichteklassen separat für die Jahre 1990 und 2000 für die Nutzungseinheiten Fettwiese und Streuefläche. Für einen Vergleich der Extensivwiesen und -weiden war die Datengrundlage von 1990 und 2000 zu dünn. Die relativen Häufigkeiten von 1990 und 2000 wurden dann sowohl untereinander als auch mit denjenigen aus dem Jahr 2016 mit einem zweiseitigen Proportionentest (inkl. Kontinuitätskorrektur) auf signifikante Unterschiede geprüft. Da 2016 im Vergleich zu 1990 und 2000 eine verfeinerte Aufnahme der Heuschreckendichten erfolgte, die auf reinen Zähldaten basiert (Individuenzahl pro 100 Laufmeter Transektlänge), ist der Langzeitvergleich mit den relativen Häufigkeiten von 1990 und 2000 methodisch mit kleineren Unsicherheiten behaftet. Dies wurde jedoch bei der Dateninterpretation mitberücksichtigt.

Die statistischen Auswertungen erfolgten mit der Statistikumgebung R 3.3.3 (R Core Team 2016), die Berechnung der Rarefaction-Kurven und Konfidenzintervalle mit dem Package „iNEXT“ (Hsieh et al. 2016). Für die Gradientenanalyse verwendeten wir das Programm CANOCO 5.04 (ter Braak and Šmilauer 2012).

Resultate

Gesamtüberblick und Vergleich zwischen den landwirtschaftlichen Nutzungseinheiten

Während den Kartierungen 2016 stellten wir in den 100 Untersuchungsflächen 16 Heuschreckenarten mit total 3104 Individuen fest (Tab. 1). Gemäss Roter Liste der Schweizer Heuschrecken gelten *Conocephalus fuscus* (Fabricius, 1793), *Pseudochorthippus montanus* (Char-

Tab. 1. Liste der beobachteten Heuschreckenarten und -dichten in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. Die Heuschreckendichte entspricht der Anzahl Individuen pro 100 m Transektlänge und ca. 5 m Transektbreite. Grau markiert ist die jeweilige Nutzungseinheit mit der höchsten Dichte für die entsprechende Art. Rote Liste Status (Monnerat et al. 2007): LC = nicht gefährdet, NT = potenziell gefährdet, VU = verletzlich.

Art (alphab.)	RL	Abundanz	Heuschreckendichte: Abundanz pro 100 m Transektlänge			
			extensive Weiden	extensive Wiesen	Fettwiesen	Streueflächen
			(n = 10)	(n = 30)	(n = 30)	(n = 30)
Chorthippus albomarginatus	LC	101	0.21	0.18	1.19	0.04
Chorthippus biguttulus	LC	381	4.96	4.25	1.95	0
Chorthippus dorsatus	LC	360	0.85	1.91	0.12	5.75
Chrysochraon dispar	NT	165	0	0.08	0	3.51
Conocephalus fuscus	VU	106	0	0	0	2.30
Decticus verrucivorus	NT	150	0.21	0.70	0	2.60
Gomphocerippus rufus	LC	176	3.19	3.38	0	0
Mecostethus parapleurus	LC	144	0.64	1.70	0.24	1.11
Omocestus viridulus	LC	39	0	0.41	0.08	0.37
Pholidoptera griseoaptera	LC	32	0	0.05	0	0.65
Pseudochorthippus montanus	VU	296	0	0.28	0	6.18
Pseudochorthippus parallelus	LC	766	6.17	4.54	6.27	0.72
Pteronemobius heydenii	VU	6	0	0	0	0.13
Roeseliana roeselii	LC	199	1.28	2.47	0.68	0.74
Stethophyma grossum	VU	102	0	0	0	2.21
Tettigonia viridissima	LC	81	0.35	0.08	0	1.58
Heuschreckendichte pro 100 m Transektlänge			17.87	20.03	10.52	27.90
Anzahl Heuschreckenarten			9	13	7	14
Gesamte Transektlänge in m			1410	3880	7500	4610

pentier, 1825), *Pteronemobius heydenii* (Fischer, 1853) und *Stethophyma grossum* (Linnaeus, 1758) als verletzlich, *Chrysochraon dispar* (Germar, 1834) und *Decticus verrucivorus* (Linnaeus, 1758) als potenziell gefährdet (Monnerat et al. 2007). 781 von total 825 festgestellten Individuen der Heuschrecken der Roten Liste fanden sich in den Streueflächen (94.67%), 41 in den Extensivwiesen (4.97%) und 3 in den Extensivweiden (0.36%).

Die 1990 im Untersuchungsbiet noch in wenigen Einzelexemplaren nachgewiesen Arten *Stenobothrus lineatus* (Panzer, 1796) und *Tettigonia cantans* (Fuessli, 1775) konnten 2000 (Peter 2001) und 2016 nicht mehr beobachtet werden. *S. lineatus* war 1990 noch an drei Standorten und *T. cantans* an einem Standort mit je einem Exemplar vorhanden. Bei unseren Erhebungen konnte 2016 mit *Chorthippus albomarginatus* (De Geer, 1773) eine zusätzliche Art im Gebiet gefunden werden. Sie war vorwiegend in Fettwiesen präsent. Zudem konnte mit *Pteronemobius heydenii* 2016 eine weitere zusätzliche Art in zwei Streueflächen knapp ausserhalb des Untersuchungsperimeters von 1990/2000 nachgewiesen werden.

Die Streueflächen wiesen eine signifikant höhere Heuschreckendiversität auf als die Fettwiesen, Extensivwiesen und Extensivweiden (Rarefaction Simpson-Diversität, $P < 0.05$) (Abb. 2 und Tab. 2). Obschon Extensivwiesen tendenziell eine höhere Diversität zeigten als die Extensivweiden, ergaben sich zwischen diesen Nutzungseinheiten keine signifikanten Unterschiede. Hingegen zeigten beide Typen signifikant höhere Diversitätswerte als die Fettwiesen (Rarefaction Simpson-Diversität, $P < 0.05$).

Ein vergleichbares Signifikanzmuster ergab sich bei den beobachteten durchschnittlichen Heuschreckendichten, umgerechnet auf die Anzahl Individuen pro 100 Laufmeter (Abb. 3). Gesamthaft betrachtet unterschieden sich die landwirtschaftlichen Nutzungseinheiten signifikant voneinander (Kruskal-Wallis-Rangsummentest, $Chi^2 = 67.38$, $DF = 3$, $P < 0.001$). Bei paarweisen Vergleichen liessen Streueflächen signifikant höhere Dichten erkennen als die Fettwiesen, Extensivwiesen und Extensivweiden (Dunn-Test, $P < 0.001$, $P = 0.003$ bzw. $P = 0.003$). Zwischen den Extensivwiesen und Extensivweiden manifestierten sich keine signifikanten Unterschiede (Dunn-Test, $P = 0.365$), hingegen zeigten beide Typen signifikant höhere Heuschreckendichten als die Fettwiesen (Dunn-Test, $P < 0.001$ bzw. $P = 0.028$).

In den verschiedenen landwirtschaftlichen Nutzungseinheiten wurden in Bezug auf die Artenzusammensetzung und die Individuenzahlen der Heuschrecken graduelle Unterschiede festgestellt. Aus einer Korrespondenzanalyse (Correspondence analysis) geht deutlich hervor, dass die Streueflächen eine eigenständige Heuschreckenfauna aufwiesen (Abb. 4). Es wird aber auch ersichtlich, dass die erfassten Extensivweiden kaum einen Beitrag zur lokalen Diversität der Heuschrecken leisteten, da v.a. Extensivwiesen, zum Teil aber auch Fett-

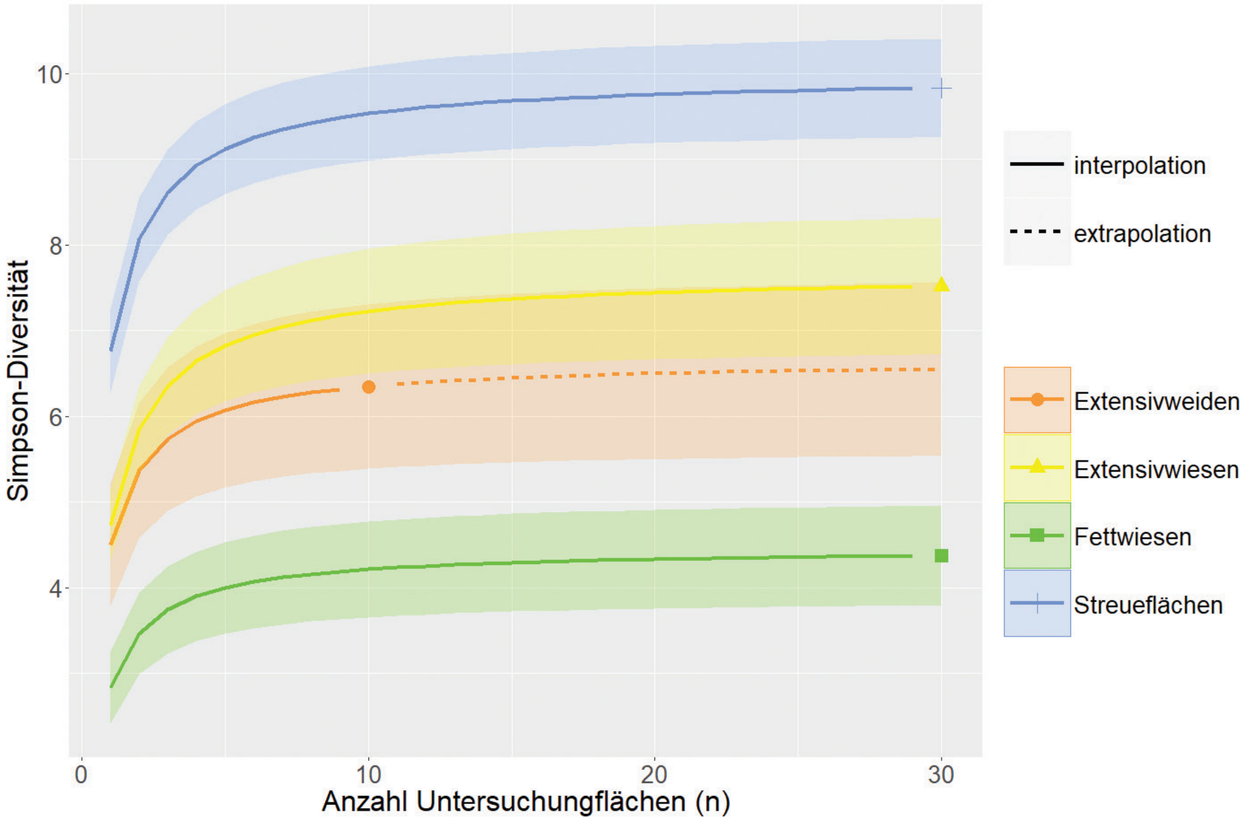

Abb. 2. Simpson-Diversität der Heuschrecken in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. Intrapolierte und extrapolierte Rarefaction-Kurven mit 95%-Konfidenzintervallen.

Tab. 2. Simpson-Diversität der Heuschrecken in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. Rarefaction mit 95% Konfidenzinvervallen, basierend auf Stichprobengrössen n=10 und n=30. b: Beobachtungswert; e: extrapolierter Wert, i: interpolierter Wert. Nutzungseinheiten ohne signifikante Unterschiede (P > 0.05) weisen einen gemeinsamen Buchstaben auf.

Nutzungseinheit	**Rarefaction Simpson-Diversität**			
	n = 10		n = 30	
Extensivweiden	6.35 ± 0.96 (b)	**A**	6.55 ± 1.01 (e)	**A**
Extensivwiesen	7.23 ± 0.73 (i)	**A**	7.52 ± 0.80 (b)	**A**
Fettwiesen	4.21 ±0.56 (i)	**B**	4.37 ± 0.58 (b)	**B**
Streueflächen	9.54 ± 0.55 (i)	**C**	9.83 ± 0.58 (b)	**C**

wiesen eine sehr ähnliche Zusammensetzung aufwiesen. Dies könnte jedoch mit dem geringeren Stichprobenumfang der Extensivweiden zusammenhängen.

Überblick und Vergleich zwischen den Biotoptypen der Streueflächen

5 Heuschreckenarten hatten ihre maximalen Dichten in den Hochstaudenfluren, darunter die Rote Liste-Arten *Chrysochraon dispar* und *Conocephalus fuscus* (Tab. 3). 4 Arten bevorzugten Kleinseggenriede, darunter die Rote Liste-Arten *Pseudochorthippus montanus* und *Pteronemobius heydenii*, 3 Arten die Pfeifengraswiesen, darunter die Rote Liste-Art *Decticus verrucivorus* und 2 Arten die Grosssseggenriede, darunter die Rote Liste-Art *Stethophyma grossum*.

Die Hochstaudenfluren und Pfeifengraswiesen zeichneten sich durch eine signifikant höhere Heuschreckendiversität aus als die Grossseggenriede, Kleinseggenriede und verschilften Flächen. Die Gross- und Kleinseggenriede hatten wiederum eine höhere Heuschreckendiversität als die verschilften Flächen (Rarefaction Simpson-Diversität, $P < 0.05$) (Abb. 5 und Tab. 4).

Die beobachteten durchschnittlichen Heuschreckendichten in den Biotoptypen der Streueflächen unterschieden sich, umgerechnet auf die Anzahl Individuen pro 100 Laufmeter, signifikant voneinander (Kruskal-Wallis-Rangsummentest, $\text{Chi}^2 = 18.84$, $DF = 4$, $P < 0.001$) (Abb. 6). Die Hochstaudenfluren und Pfeifengraswiesen hatten dabei signifikant höhere Dichten als die Grossseggenriede (Dunn-Test, $P = 0.001$ bzw. $P = 0.024$). Zwischen den anderen Biotoptypen waren hingegen keine signifikanten Unterschiede vorhanden.

Entwicklung der Heuschreckenfauna seit 1990

a) Fettwiesen

Die Simpson-Diversität der Heuschrecken in den Fettwiesen Schönenbergs ZH unterschied sich zwischen

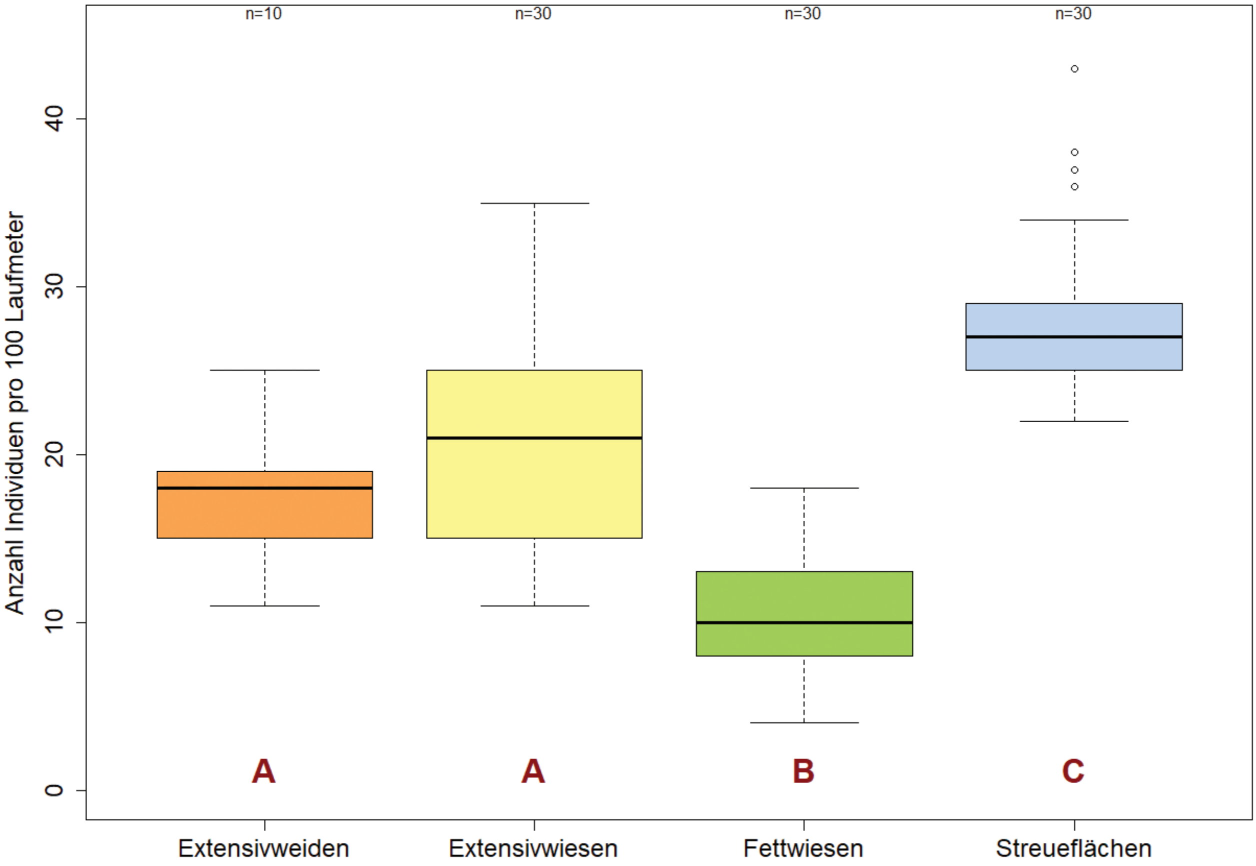

Abb. 3. Heuschreckendichten in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. Kruskal-Wallis-Rangsummentest ($Chi^2 = 67.38$, DF = 3, $P < 0.001$). Nutzungseinheiten ohne signifikante Unterschiede ($P > 0.05$), basierend auf paarweisen Post-hoc-Analysen, weisen einen gemeinsamen Buchstaben auf. Median mit fetter Linie dargestellt. Boxplots repräsentieren den Interquartilsabstand, Whiskers die Bandbreite der Daten exkl. Ausreisser (kleine Kreise).

den Untersuchungsjahren 1990 (4.52 ± 1.01), 2000 (3.79 ± 0.94) und 2016 (4.06 ± 0.56) nicht signifikant voneinander (Rarefaction Simpson-Diversität, $P > 0.05$, n=19).

Auf Artebene ergaben sich jedoch zum Teil signifikante Verschiebungen. In den Fettwiesen dominierten 1990, in absteigender Reihenfolge, die Heuschreckenarten *Pseudochorthippus parallelus* (Zetterstedt, 1821), *Chorthippus dorsatus* (Zetterstedt, 1821), *Chorthippus biguttulus* (Linnaeus, 1758) und *Roeseliana roeselii* (Hagenbach, 1822) (Abb. 7). 2000 zeigte erneut *P. parallelus* die höchste relative Häufigkeit, diesmal gefolgt von *Ch. biguttulus*, *Ch. dorsatus* und *R. roeselii*. 2016 war *P. parallelus* am häufigsten, gefolgt von *Ch. biguttulus*, *R. roeselii* sowie der 2016 erstmals aufgetretenen Art *Chorthippus albomarginatus*. Die Bestände von *Ch. dorsatus* setzten den negativen Trend, der schon zwischen 1990 und 2000 festzustellen war, fort und gingen 2016 so markant zurück, dass die relative Häufigkeit dieser Art in den Fettwiesen im Vergleich zu 1990 um mehr als das Zehnfache tiefer lag (Proportionentest 1990/2016, $Chi^2 = 41.0$, $DF = 1$, $P < 0.001$). Dafür verdoppelten sich die relativen Häufigkeiten von *Ch. biguttulus* in den Fettwiesen seit 1990 beinahe (Proportionentest 1990/2016, $Chi^2 = 7.32$, $DF = 1$, $P = 0.007$). Die relative Häufigkeit von *P. parallelus* schwankte im ganzen Zeitraum nur wenig und verharrte bei rund 60%. *R. roeselii* war ebenfalls ohne signifikanten Trend. Die relative Häufigkeit dieser Art bewegte sich im Bereich von ca. 6–8% (Abb. 7).

b) Streueflächen

Die Heuschreckendiversität der Streueflächen erwies sich 2016 (9.66 ± 0.69) im Vergleich zu 1990 (7.70 ± 0.65) als signifikant höher (Rarefaction Simpson-Diversität, $P < 0.05$, n=27). Die festgestellten Differenzen zwischen 1990 und 2000 (8.55 ± 0.64) bzw. 2000 und 2016 erwiesen sich als nicht signifikant (Abb. 8).

Auf Artebene fanden beträchtliche Verschiebungen der relativen Häufigkeiten statt. Unter den in Abb. 9 dargestellten Arten zeigten nur *Pseudochorthippus montanus*, die dominierende Art in den Streueflächen, und *Stethophyma grossum* keine signifikanten Veränderungen zwischen 1990 und 2016. Signifikante Zunahmen ihrer relativen Häufigkeiten manifestierten *Chrysochraon dispar*, *Decticus verrucivorus* und *Mecostethus parapleurus*, wobei letztere Art nur 2016 in den kartierten Flächen präsent war. *Ch. dispar* zeigte eine kontinuierlich starke Zunahme seit 1990 (Proportionen-

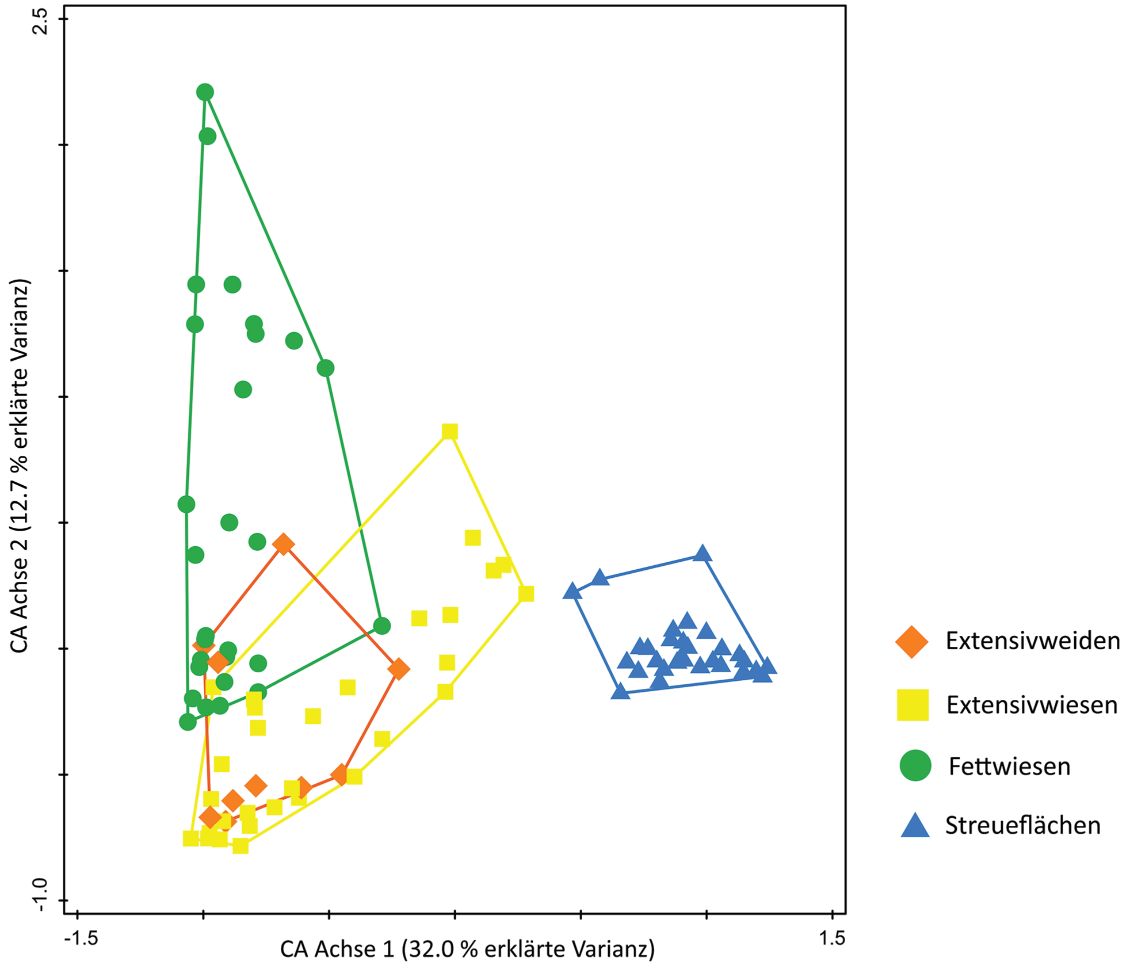

Abb. 4. Gradientenanalyse der Heuschreckenfauna in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. Korrespondenzanalyse (Correspondence analysis CA) mit Darstellung der ersten beiden Achsen mit der grössten Aussagekraft. Erklärte Varianz der Achse 1: 32.0%, der Achse 2: 12.7%.

Tab. 3. Liste der beobachteten Heuschreckenarten und –dichten in den Streueflächen Schönenbergs ZH. Die Heuschreckendichte entspricht der Anzahl Individuen pro 100 m Transektlänge und ca. 5 m Transektbreite. Grau markiert ist die jeweilige Pflanzengesellschaft mit der höchsten Dichte für die entsprechende Art.

		Heuschreckendichte: Abundanz pro 100 m Transektlänge				
Art (alphab.)	**Abundanz**	**Grossseggen**	**Hochstauden**	**Kleinseggen**	**Pfeifengras**	**Schilf**
		(n=11)	(n=21)	(n=11)	(n=19)	(n=7)
Chorthippus albomarginatus	2	0.00	0.00	0.32	0.00	0.00
Chorthippus dorsatus	265	6.90	6.17	4.13	5.52	5.65
Chrysochraon dispar	162	1.13	8.28	0.79	0.97	6.09
Conocephalus fuscus	106	2.54	5.63	0.32	0.78	0.43
Decticus verrucivorus	120	0.00	0.78	3.49	5.19	1.74
Mecostethus parapleurus	51	0.14	0.08	2.22	2.27	0.00
Omocestus viridulus	17	0.00	0.00	0.32	0.97	0.00
Pholidoptera griseoaptera	30	0.00	2.27	0.00	0.06	0.00
Pseudochorthippus montanus	285	1.55	0.47	11.75	10.19	8.04
Pseudochorthippus parallelus	33	0.14	0.00	1.59	1.30	0.43
Pteronemobius heydenii	6	0.00	0.00	0.63	0.00	0.43
Roeseliana roeselii	34	0.00	1.56	0.00	0.91	0.00
Stethophyma grossum	102	9.01	0.63	3.33	0.26	1.09
Tettigonia viridissima	73	0.56	4.77	0.00	0.52	0.00
Heuschreckendichte pro 100 m Transektlänge		21.97	30.63	28.89	28.96	23.91
Anzahl Heuschreckenarten pro Biotoptyp		8	10	11	12	8
Gesamte Transektlänge in m		710	1280	630	1540	460

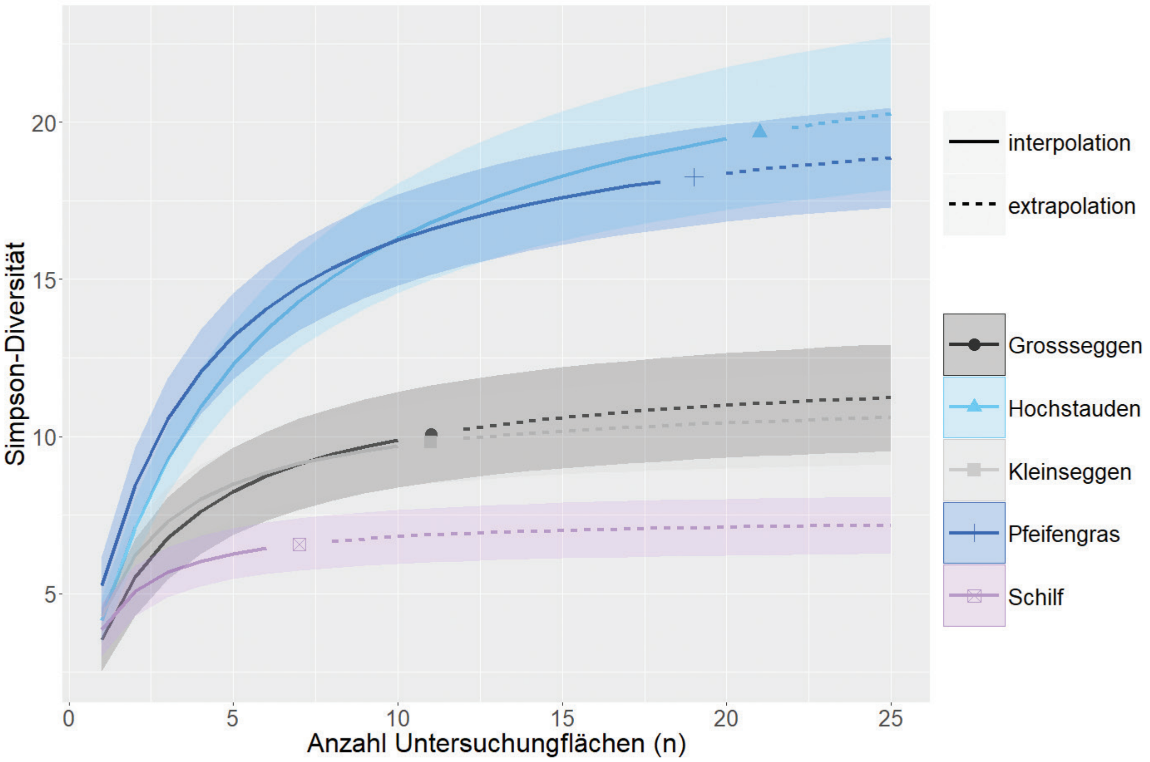

Abb. 5. Simpson-Diversität der Heuschrecken in den Streueflächen Schönenbergs ZH. Intrapolierte und extrapolierte Rarefaction-Kurven mit 95%-Konfidenzintervallen.

Tab. 4. Simpson-Diversität der Heuschrecken in den Streueflächen Schönenbergs ZH. Rarefaction mit 95% Konfidenzinvervallen, basierend auf Stichprobengrössen n=7 und n=21. b: Beobachtungswert; e: extrapolierter Wert, i: interpolierter Wert. Nutzungseinheiten ohne signifikante Unterschiede ($P > 0.05$) weisen einen gemeinsamen Buchstaben auf.

	Rarefaction Simpson-Diversität			
Biotoptyp	n = 7		n = 21	
Grossseggen	9.11 ± 1.43 (i)	**A**	11.04 ± 1.84 (e)	**A**
Hochstauden	14.30 ± 1.45 (i)	**B**	19.66 ± 1.99 (b)	**B**
Kleinseggen	9.14 ± 1.07 (i)	**A**	10.46 ± 1.28 (e)	**A**
Pfeifengras	14.78 ± 1.08 (i)	**B**	18.49 ± 1.49(e)	**B**
Schilf	6.57 ± 0.85 (b)	**C**	7.12 ± 0.98 (e)	**C**

test 1990/2016, $Chi^2 = 59.17$, $DF = 1$, $P < 0.001$), bei *D. verrucivorus* fand der Anstieg zwischen 1990 und 2000 statt und verharrte 2016 auf ungefähr demselben Niveau (Proportionentest 1990/2016, $Chi^2 = 20.26$, $DF = 1$, $P < 0.001$). Die relativen Häufigkeiten von *Chorthippus dorsatus* und *Conocephalus fuscus* nahmen hingegen massiv ab. Bei *Ch. dorsatus* fand der Rückgang vor allem zwischen 1990 und 2000 statt und setzte sich 2016 nur noch bedingt fort (Proportionentest 1990/2016, $Chi^2 = 34.01$, $DF = 1$, $P < 0.001$). Bei *C. fuscus* beschleunigte sich der Rückgang, der schon zwischen 1990 und 2000 festzustellen war (Proportionentest 1990/2016, $Chi^2 = 74.08$, $DF = 1$, $P < 0.001$).

Diskussion

Heuschreckenfauna der Grünland-Biodiversitätsförderflächen und Fettwiesen im Vergleich

Die beobachtete bzw. die mittels Rarefaction abgeschätzte Heuschreckendiversität war in den Streueflächen Schönenbergs ZH signifikant höher als in den Fettwiesen, den Extensivwiesen und den Extensivweiden. Ein vergleichbares Signifikanzmuster zeigte sich auch bei den Individuendichten. Dies korrespondiert mit den Aussagen von Swengel (2001), wonach in Wiesen mit einer hohen Schnittfrequenz generell weniger Insekten zu erwarten sind. Zufuhr von Dünger erwies sich in einer Studie von Chisté et al. (2016) in Deutschland als die Hauptursache für den Rückgang vieler Heuschreckenarten, gefolgt von kürzeren Mähintervallen und der Zunahme der Beweidungsintensität.

Obschon unter den Extensivwiesen Schönenbergs ZH auch Flächen mit etwas feuchterer Ausprägung miteinbezogen wurden, unterschieden sich deren Heuschreckengemeinschaften gesamthaft betrachtet dennoch deutlich von denjenigen der Streueflächen. Nur zu Extensivwiesen, welche direkt an Streueflächen grenzen, ergaben sich gewisse Ähnlichkeiten, was auf die Funde von einigen typischen Feuchtgebietsarten wie *Pseudochorthippus montanus, Decticus verrucivorus* und *Chrysochraon dispar* zurückzuführen ist. Diese Funde belegen, dass extensiv bewirtschaftetes Grünland in unmittelbarer Umgebung

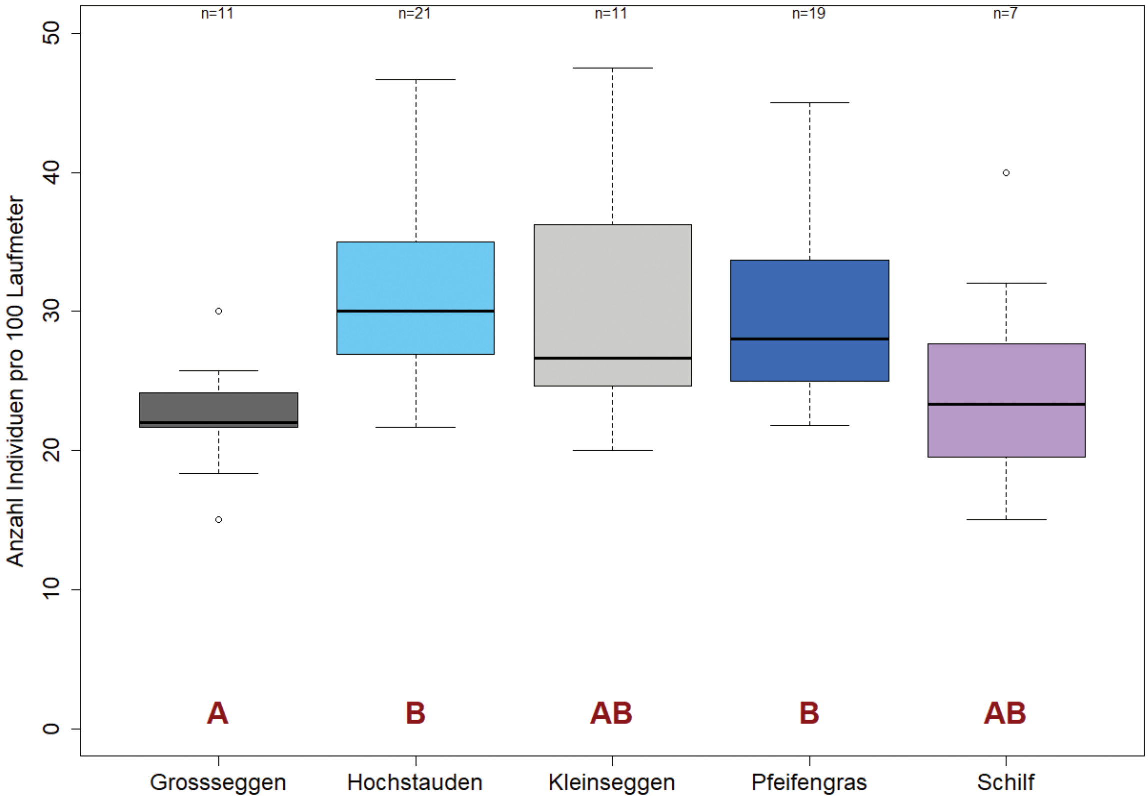

Abb. 6. Heuschreckendichten in den Streueflächen Schönenbergs ZH. Kruskal-Wallis-Rangsummentest (Chi^2 = 18.84, DF = 4, P < 0.001). Biotoptypen ohne signifikante Unterschiede (P > 0.05), basierend auf paarweisen Post-hoc-Analysen, weisen einen gemeinsamen Buchstaben auf. Median mit fetter Linie dargestellt. Boxplots repräsentieren den Interquartilsabstand, Whiskers die Bandbreite der Daten exkl. Ausreisser (kleine Kreise).

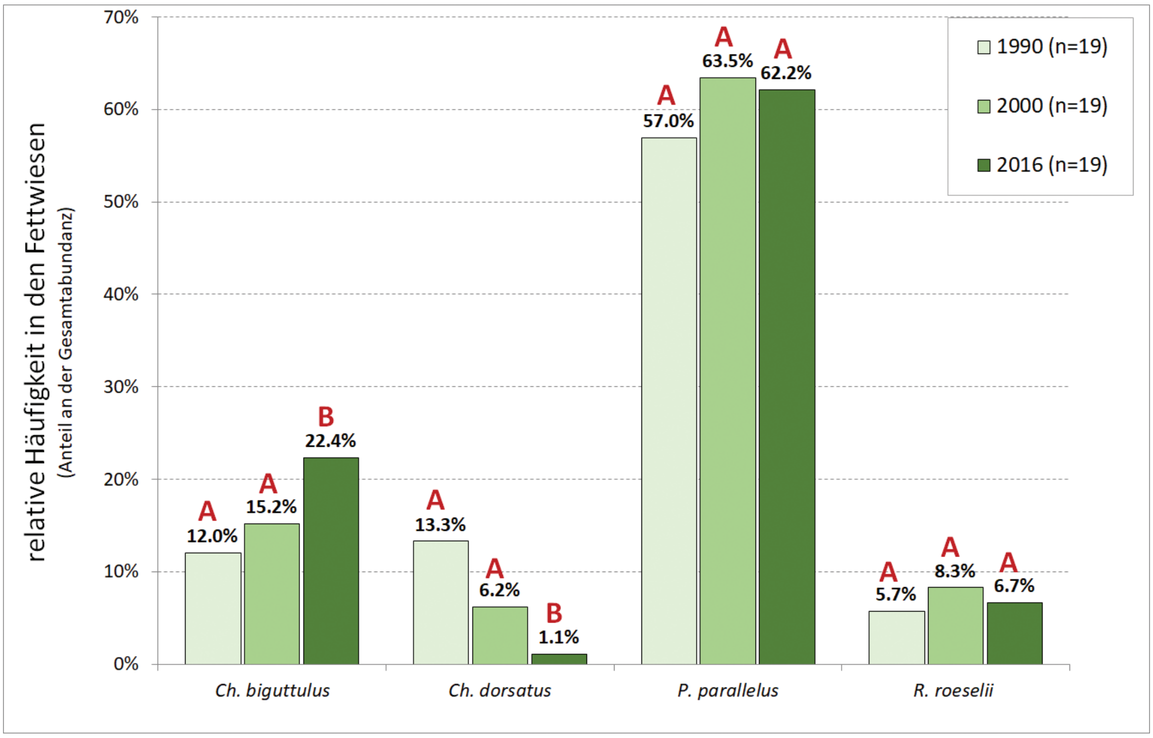

Abb. 7. Entwicklung der relativen Häufigkeiten ausgewählter Fettwiesen-Heuschreckenarten in den Untersuchungsjahren 1990, 2000 und 2016 in Schönenberg ZH. Paarweise Proportionentests. Untersuchungsjahre ohne signifikante Unterschiede der relativen Häufigkeiten (P > 0.05) weisen innerhalb derselben Art einen gemeinsamen Buchstaben auf.

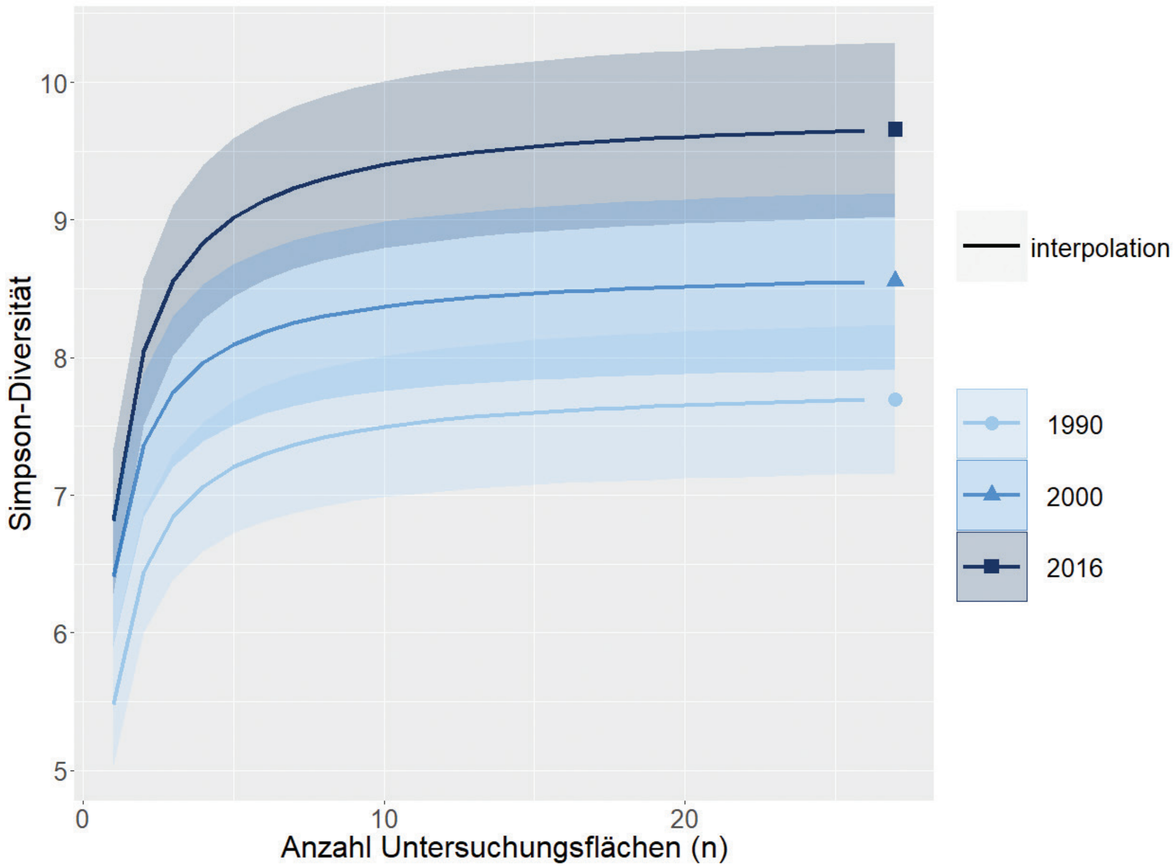

Abb. 8. Simpson-Diversität der Heuschrecken in den Streueflächen Schönenbergs ZH in den Jahren 1990, 2000 und 2016. Intrapolierte Rarefaction-Kurven mit 95%-Konfidenzintervallen.

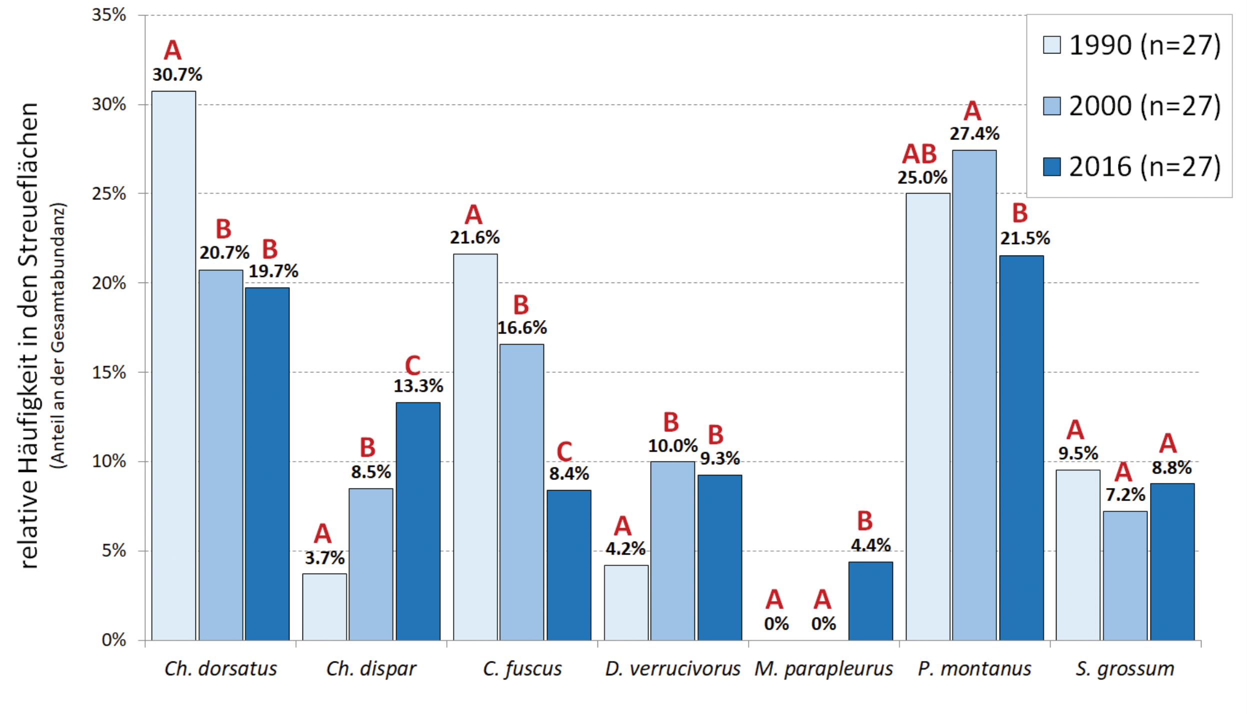

Abb. 9. Entwicklung der relativen Häufigkeiten ausgewählter Streueflächen-Heuschreckenarten in den Untersuchungsjahren 1990, 2000 und 2016 in Schönenberg ZH. Paarweise Proportionentests. Untersuchungsjahre ohne signifikante Unterschiede der relativen Häufigkeiten ($P > 0.05$) weisen innerhalb derselben Art einen gemeinsamen Buchstaben auf.

von Streueflächen von einigen Feuchtgebietsarten als Erweiterung ihres Hauptlebensraums genutzt werden kann.

Eine Korrespondenzanalyse veranschaulicht, dass sich Streueflächen und Extensivwiesen als Biodiversitätsförderflächen gegenseitig ergänzen und auf lokaler Ebene die Beta-Diversität der Heuschrecken in der voralpinen Kulturlandschaft zu erhöhen vermögen. Die Extensivweiden hingegen tragen in unserem Fall weit weniger zur Beta-Diversität bei, da ihre Heuschreckengemeinschaften hauptsächlich mit denjenigen von Extensivwiesen und, in einzelnen Fällen, auch von Fettwiesen vergleichbar sind. Die geringe Differenzierung könnte aber auch mit dem kleineren Stichprobenumfang bei den Extensivweiden zusammenhängen. In sieben der zehn untersuchten Extensivweiden stellten wir Ähnlichkeiten zu den Artenspektren bzw. den Häufigkeitsverteilungen von Extensivwiesen fest. In drei Fällen ergaben sich eher Ähnlichkeiten zu Fettwiesen.

Fettwiesen unterschieden sich von den Biodiversitätsförderflächen auf Artebene primär durch die Eudominanz von *Pseudochorthippus parallelus* und, in einzelnen Teilflächen, die relativ hohe Abundanz von *Chorthippus albomarginatus*. Extensivwiesen und Extensivweiden zeichneten sich durch hohe Dichten von *Gomphocerippus rufus* (Linnaeus, 1758) aus, einer Art, die als Imago 20–40 cm hohe Vegetation bevorzugt und während der Embryogenese auf halbtrockene, warme Böden angewiesen ist (Detzel 1998). *G. rufus* fehlte in den Fettwiesen und Streueflächen vollständig und kann deshalb in Schönenberg ZH als Charakterart für Extensivwiesen und Extensivweiden bezeichnet werden.

Heuschreckenfauna der Streueflächen: Einfluss der Pflanzengesellschaften

Die Feuchtigkeitsgradienten in den Streueflächen Schönenbergs ZH reichten von mässig feucht in einzelnen Hochstaudenfluren bis hin zu stark vernässt in den meisten Grossseggenrieden. Die Vegetationshöhe schwankte bei den Kartierungen im August/September 2016 zwischen durchschnittlich ca. 10–30 cm in intakten Kleinseggenrieden bis hin zu mehr als 2 m in verschilften Flächen.

Die grosse Heuschreckendiversität in den Pfeifengraswiesen hängt vermutlich mit der abwechslungsreichen Vegetationsstruktur und den kleinräumig variierenden Feuchtigkeitsverhältnissen zusammen. Bis zu 1 m hohe Horste des Pfeifengrases (*Molinia caerulea*) wechseln sich mit niedrigwüchsigen Pflanzenarten ab und bilden so ein heterogenes Mosaik (Delarze and Gonseth 2008). Diese Verhältnisse erlauben es auch einigen Generalisten unter den Heuschrecken, Pfeifengraswiesen zu besiedeln, die stark vernässte Bereiche meiden, z.B. *Omocestus viridulus* (Linnaeus, 1758).

Die ähnlichsten Heuschreckengemeinschaften wiesen Kleinseggenriede und Pfeifengraswiesen auf, auch wenn die leicht feuchteren Verhältnisse und die durch Sauergräser geprägte Vegetation der Kleinseggenriede (Delarze and Gonseth 2008) zu den graduellen Unterschieden in der Artenzusammensetzung und bei den artspezifischen Individuendichten beigetragen haben dürften. Die potenziell gefährdete Art *Pseudochorthippus montanus* stellte sich als Charakterart der Kleinseggenriede und Pfeifengraswiesen heraus. Gemäss Baur et al. (2006) besiedelt sie primär feuchte bis nasse Standorte. Ähnliche Lebensraumpräferenzen weist die auch potenziell gefährdete Art *Decticus verrucivorus* auf, welche in den Kleinseggenrieden und Pfeifengraswiesen ebenfalls ihre höchsten Dichten erreichte. *D. verrucivorus* benötigt für die Embryogenese viel Bodenfeuchtigkeit und vergleichsweise hohe Temperaturen (Detzel 1998), weshalb auch zu erklären ist, dass die Art bei uns nur vereinzelt in Flächen mit hoher Vegetation auftrat.

Als Charakterart der Grossseggenriede entpuppte sich *Stethophyma grossum*. Sie ist ausgesprochen hygrophil und benötigt besonders für die Eientwicklung viel Feuchtigkeit (Heydenreich 1999). Der Erhalt von Grossseggenrieden ist für den Fortbestand dieser gemäss Roter Liste verletzlichen Art von zentraler Bedeutung.

Flachmoore, die an intensiv genutztes Kulturland grenzen, wiesen oft nährstoffreichere Randzonen mit Hochstaudenfluren auf. Die häufig als Spierstaudenfluren ausgeprägten Säume werden in der Vegetationsökologie und im Naturschutz teilweise als Beeinträchtigung empfunden, weil sie die moortypischen Kleinseggenriede und ihre spezialisierte Flora verdrängen können (Bollens et al. 2001). Wie unsere Untersuchung zeigt, kann aber gerade solchen Hochstaudenfluren eine grosse faunistische Bedeutung zukommen, selbst für Vertreter der Roten Liste, wie den potenziell gefährdeten Arten *Chrysochraon dispar* und *Conocephalus fuscus*. *Chrysochraon dispar* ist leicht hygrophil (Klaiber et al. 2017) und bevorzugt hohe Vegetation, kann aber gemäss Baur et al. (2016) und eigenen Beobachtungen ausnahmsweise auch in langgrasiger Trockenvegetation auftreten. In Schönenberg ZH war *Ch. dispar* fast ausschliesslich in Hochstaudenfluren und verschilften Streueflächen anzutreffen. Strikt an vertikale Vegetationsstrukturen gebunden ist *Conocephalus fuscus*, eine Art, die sowohl in Feuchtgebieten als auch in anderen langgrasigen Wiesen mit ausreichender Feuchtigkeit und einer Vegetationshöhe von ca. 30–60 cm anzutreffen ist (Baur et al. 2006). Ihr Auftreten konzentrierte sich in unserem Projekt auf Hochstaudenfluren und, in geringerem Ausmass, auf Grossseggenriede.

Heuschreckenfauna von Schönenberg ZH gestern und heute: Trends seit 1990

Die durchschnittliche Heuschreckendiversität der Fettwiesen Schönenbergs ZH hat sich seit 1990 nicht signifikant verändert. Es ergaben sich jedoch zum Teil beträchtliche Verschiebungen in den relativen Häufigkeiten einzelner Arten, besonders augenfällig beim Artenpaar *Chorthippus biguttulus* und *Chorthippus dorsatus*. Die kontinuierliche Zunahme von *Ch. biguttulus* und der markante Rückgang von *Ch. dorsatus* zwischen 1990 und 2016 könnten auf trockenere Verhältnisse in den Fettwiesen hindeuten. *Ch. biguttulus* gilt als Art, welche trocken-warme Bedingungen bevorzugt und stark gedüngte Wiesen mit dichter Vegetation meidet, während *Ch. dorsatus* auf der Alpennordseite meist auf eine gewisse Feuchtigkeit und auf eher langgrasige Vegetation angewiesen ist (Baur et al. 2006). Bei den

Datenerhebungen im August und September 2016 herrschten hohe Temperaturen und Trockenheit vor. Die Vermutung, dass der Rückgang von *Ch. dorsatus* in den Fettwiesen auch dadurch bedingt sein könnte, dass 1990 mehr Fettwiesen kartiert wurden, welche näher bei Riedflächen lagen und somit eine Einwanderung in die Randzonen von Fettwiesen hätten begünstigen können, konnte nicht bestätigt werden. Die Minimaldistanzen zwischen den berücksichtigten Fettwiesen und Streueflächen unterschieden sich zwischen den Untersuchungsjahren 1990, 2000 und 2016 nicht signifikant voneinander (Kruskal-Wallis-Rangsummentest, $\mathrm{Chi}^2 = 3.00$, $DF = 2$, $P = 0.223$).

Die 1990 vereinzelt nachgewiesenen Arten *Stenobothrus lineatus* und *Tettigonia cantans* wurden sowohl in den Erhebungen von 2000 als auch in unserer Untersuchung nicht mehr festgestellt. Ob sie tatsächlich aus dem Untersuchungsperimeter verschwunden sind, müsste mit einer gezielten Nachsuche an den Fundorten von 1990 überprüft werden.

Von *Chorthippus albomarginatus* liegen aus den Kartierjahren 1990 und 2000 keine Beobachtungen vor. 2016 gehörte die eher anspruchslose und auch häufig in frisch geschnitten Wiesen auftretende Art (Keller et al. 2013b) zu den häufigeren Heuschrecken in den Fettwiesen Schönenbergs ZH. Im östlichen Schweizer Mittelland sind seit Mitte der Neunzigerjahre, vor allem aber seit der Jahrtausendwende, eine Vielzahl neuer Vorkommen bekannt geworden, was auf eine rezente Arealerweiterung hindeutet (CSCF 2017). Schönenberg ZH gehört dabei zu den am östlichsten liegenden aktuellen Vorposten von *Ch. albomarginatus* im Voralpenraum.

Die durchschnittliche Heuschreckendiversität der Streueflächen Schönenbergs ZH war 2016 signifikant höher als 1990 bzw. 2000. Dies ist primär auf das erstmalige Auftreten von *Ch. albomarginatus*, *M. parapleurus* und *P. heydenii* sowie auf die allgemein homogenere Artenverteilung im Kartierjahr 2016 zurückzuführen. Von *Pteronemobius heydenii* wurden 2016 insgesamt 6 rufende Individuen in zwei Streueflächen im östlichen Teil Schönenbergs ZH knapp ausserhalb des Untersuchungsperimeters von 1990 und 2000 vorgefunden. Noch Mitte der 1990er-Jahre war die Art im Kanton Zürich nur an wenigen Standorten präsent. Inzwischen besiedelt *P. heydenii* eine Vielzahl von Feuchtgebieten, so auch rund um den Zürichsee (CSCF 2017). Nebst hohen Anforderungen an die Feuchtigkeit weist die Art auch ein grosses Wärmebedürfnis auf (Detzel 1998). Wie andere thermophile Arten, die aufgrund des Klimawandels ihr Verbreitungsareal erweitern (Vittoz et al. 2013), könnte auch die Ausbreitung von *P. heydenii* zumindest teilweise auf wärmere Temperaturen zurückzuführen sein.

Die rückläufige Entwicklung von *C. fuscus* und *Ch. dorsatus* und die gleichzeitige Zunahme von *Ch. dispar* in den Streueflächen lässt sich nicht abschliessend erklären. Die Bestandessituation von *C. fuscus* und *Ch. dorsatus* in der Schweiz wird von Heuschrecken-Experten als eher stabil oder sogar als leicht zunehmend eingeschätzt (u.a. pers. Mitt. Florin Rutschmann und Christian Roesti vom 12.6.2018). Möglicherweise hatten die extreme Sommertrockenheit und die sehr hohen Temperaturen in der zweiten August- und ersten Septemberhälfte 2016 (MeteoSchweiz 2016) eine dezimierende Wirkung auf die genannten Arten, v.a. auf die dünnhäutigere und leichter dehydrierende Langfühlerschrecke *C. fuscus*. Es könnte sich aber zumindest teilweise auch um natürliche Bestandesfluktuationen oder, im Falle der nur sehr leise rufenden Art *C. fuscus*, um einen gewissen Bearbeitereffekt handeln.

Unsere Erfassungsmethoden unterschieden sich vom methodischen Vorgehen der Untersuchungsjahre 1990 und 2000, was bei den Resultaten zur Entwicklung der relativen Häufigkeiten mitberücksichtigt werden muss. Es ist davon auszugehen, dass die aufsummierten Dichteklassen von 1990 und 2000 die tatsächlichen relativen Häufigkeiten der Arten von damals nur ungefähr wiedergeben. Trotz dieser Unschärfe gehen wir davon aus, dass das verwendete Datenmaterial für die Feststellung von offensichtlichen Trends ausreicht. Dies insbesondere auch darum, weil die meisten dieser Trends eine Fortführung der bereits zwischen 1990 und 2000 festgestellten Tendenzen darstellen und statistisch signifikant bzw. hochsignifikant sind, so z.B. die kontinuierlichen Abnahmen der relativen Häufigkeiten von *Ch. dorsatus* und *C. fuscus* einerseits sowie die kontinuierlichen Zunahmen von *Ch. dispar* und *Ch. biguttulus* andererseits.

Schlussfolgerungen und Ausblick mit allgemeinen Empfehlungen zur Heuschreckenförderung

Die Vegetationsstruktur, die kleinräumige Vielfalt der Habitattypen sowie das Mikroklima sind für das Vorkommen vieler Heuschreckenarten ausschlaggebend (Essl and Dirnböck 2012, Guido and Gianelle 2001). Ebenfalls eine zentrale Bedeutung kommt einem intakten Lebensraumverbund zu, weil zwischen nahe liegenden Vorkommen ein stärkerer genetischer Austausch stattfindet. Bei *Stethophyma grossum*, einer Art mit mittlerem Ausbreitungspotenzial (Reinhardt et al. 2005), zeigte sich beispielsweise, dass die Lebensräume nur dann als vernetzt betrachtet werden können, wenn sie in einem Umkreis von ungefähr 3 km liegen (Keller et al. 2013a). Bei Arten mit geringem Ausbreitungspotenzial, wie etwa bei *Pteronemobius heydenii* und *Decticus verrucivorus* (Reinhardt et al. 2005), sind diese Distanzen wesentlich kleiner, bei den Männchen von *D. verrucivorus* nur ungefähr 40 m (Hjermann and Ims 1996). Besonders für wenig mobile Arten ist deshalb ein möglichst dichter Lebensraumverbund aus extensiv genutzten Grünlandflächen überlebenswichtig. Bei den Streueflächen Schönenbergs ZH ist dieses Verbundsystem im nördlichen und z.T. westlichen Teil bedeutend dichter als im östlichsten und südlichsten Teil. Zusammen mit den zahlreichen Flachmooren der benachbarten Gemeinden Hirzel (seit 1.1.2018 Teil der Gemeinde Horgen) und Wädenswil besteht ein dichtes Geflecht an Streueflächen, welches auch auf überkommunaler Ebene den Individuenaustausch wenig mobiler Heuschreckenarten zumindest teilweise erlauben dürfte. Bei den eher trockenen Extensivwiesen und Extensivweiden ist das Verbundsystem hingegen viel lückiger.

Die alleinige Ausscheidung und gesetzeskonforme Bewirtschaftung von Biodiversitätsförderflächen, wie beispielsweise Streueflächen, Extensivwiesen und Extensivweiden, reichen für den Schutz und die Förderung von Heuschrecken oftmals nicht aus (Kampmann et al. 2008). Zwar sind gemäss Direktzahlungsverordnung des Bundes zum Beispiel der Verzicht auf Düngerzufuhr und der jeweils früheste Schnitttermin vorgegeben (Schweizer Bundesrat 2013), es gibt jedoch auf Bundesebene keine verbindlichen Bestimmungen über zeitlich gestaffelten Schnitt bzw. das Belassen von Altgrasinseln. Grossflächig homogen genutztes Grünland weist eine kleinere Mikrohabitat-Heterogenität auf, was sich Taxa-übergreifend negativ auf die Artenvielfalt auswirkt, wie Stein et al. (2014) in einer Metastudie darlegten. Habitatheterogenität in der Kulturlandschaft kann die Artenvielfalt der Heuschrecken erhöhen, unabhängig von Arealgrösse und Mobilität der einzelnen Arten (Marini et al. 2010). Synchrone und grossflächige Mahd von Grünland verkleinern Populationsgrössen und Artenvielfalt von Arthropoden durch direkte Mortalität während der Mahd bzw. der Schnittgutentfernung sowie durch plötzliche Degradation der Lebensräume (Cizek et al. 2012). Die meisten Heuschreckenarten legen ihre Eier in den Boden ab, es gibt aber auch Arten, bei welchen die Eiablage oberirdisch in Pflanzenteile erfolgt. Dies gilt beispielsweise für die in unserer Untersuchung festgestellten, fast ausschliesslich in Streueflächen vorgefundenen Arten *Chrysochraon dispar,* bei der die Eiablage in gekammerte oder markhaltige Pflanzenstängel erfolgt, oder *Conocephalus fuscus*, welche die Eier in Blattscheiden oder Pflanzenstängel ablegt (Baur et al. 2006). Bei flächiger und gleichzeitiger Mahd von Streueflächen im Herbst werden die Eier dieser Arten vernichtet. Im Kanton Zürich wird diesem Umstand Rechnung getragen, indem in den Kern- und Regenerationszonen aller überkommunalen Naturschutzgebiete seit 2002 die Vorgabe gilt, in der Regel 5–10% der Fläche als Nutzungsbrache/Rückzugsstreifen stehen zu lassen, um von ergänzenden Bonuszahlungen des Kantons zu profitieren (ALN 2014). In Schönenberg ZH trifft dies auf die meisten Streueflächen zu. Solche Altgrasinseln ermöglichen nicht nur eine ungestörte Ei- und Embryonalentwicklung, sondern bieten vielen Heuschrecken während und/oder nach der Mahd Ersatzlebensräume und Versteckmöglichkeiten und wirken sich generell positiv aus auf Artenzahlen und Dichten von Heuschrecken (Buri et al. 2013, Humbert et al. 2012, Müller and Bosshard 2010). Zudem ist im Kanton Zürich bei der Mahd der Naturschutzzonen I und der Regenerationszonen die Verwendung von Sensen oder Messerbalken obligatorisch und die Verwendung jeglicher Rotationsmähgeräte untersagt (ALN 2014). Diese Empfehlung zur schonenden Mahd gilt seit 2008 und ist seit 2014 obligatorisch, damit Bonuszahlungen des Kantons entrichtet werden (pers. Mitt. Martin Graf, Fachstelle Naturschutz Kt. ZH, vom 24.11.2017). Wie sich in einer Untersuchung von Oppermann and Krismann (2003) herausstellte, können schonende Bewirtschaftungsverfahren die Mortalität von Heuschrecken um rund das Vierfache verkleinern. Auch wenn es methodisch nicht möglich ist, die seit 1990 signifikant angestiegene Heuschreckendiversität bzw. Individuendichte der Heuschrecken in den Streueflächen Schönenbergs ZH direkt auf die genannten Bewirtschaftungsvorgaben zurückzuführen, gehen wir davon aus, dass dieser Faktor mitverantwortlich war für den gesamthaft gesehen positiven Trend.

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Anhang 1

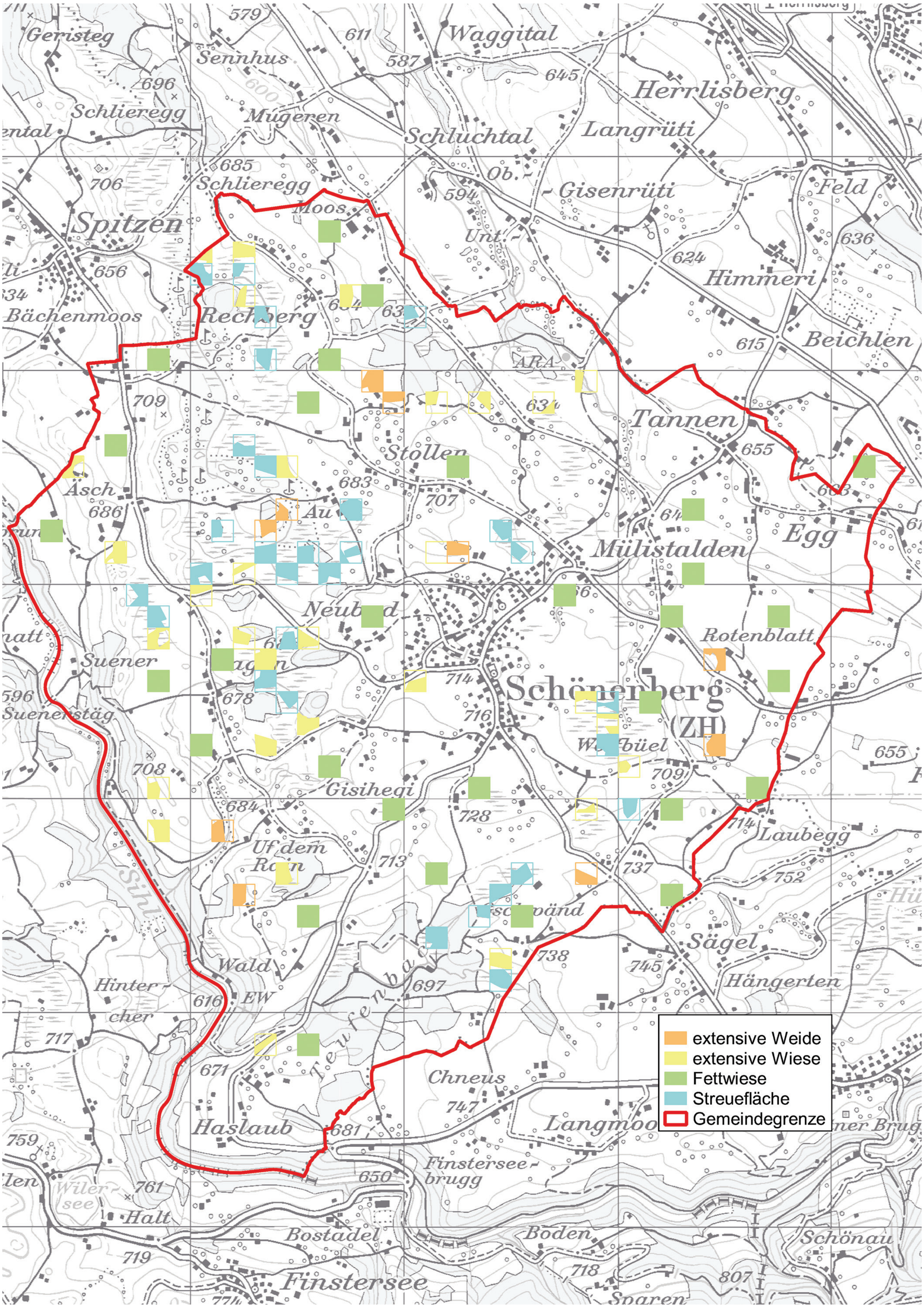

Abb. 10. Untersuchungsflächen zur Ermittlung der Heuschrecken 2016 in der Gemeinde Schönenberg ZH. Total 100 Rasterquadrate (je 100 m × 100 m) mit 10 Extensivweiden, 30 Extensivwiesen, 30 Fettwiesen und 30 Streueflächen. SWISSIMAGE Bundesamt für Landestopographie, abgerufen via Geodatensatz ARE (2017).

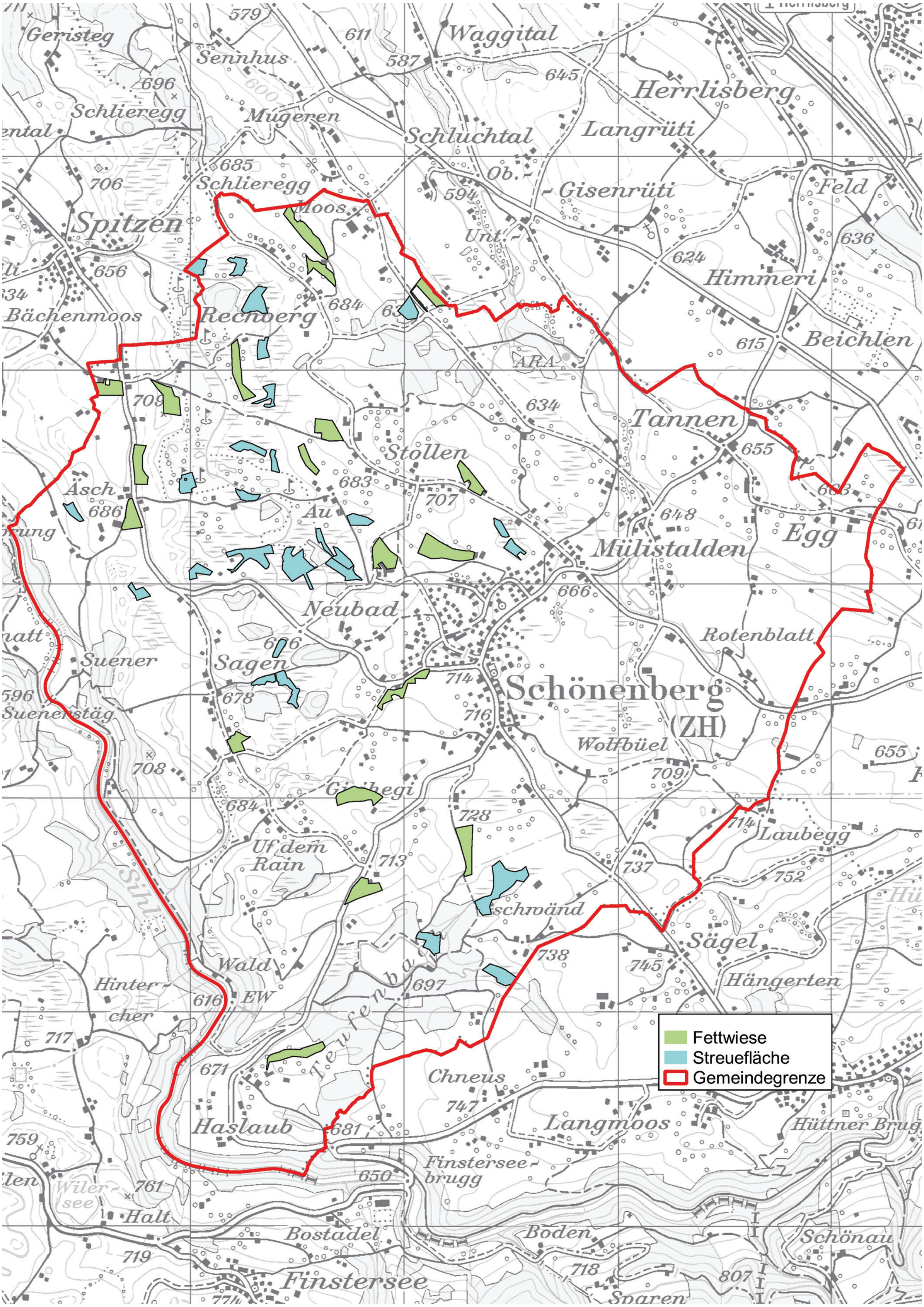

Abb. 11. Flächenauswahl aus den Heuschreckenkartierungen von 2000 in der Gemeinde Schönenberg ZH als Grundlage für den Vergleich mit den Kartierjahren 1990 und 2016. 19 Fettwiesen und 27 Streueflächen. SWISSIMAGE Bundesamt für Landestopographie, abgerufen via Geodatensatz ARE (2017).

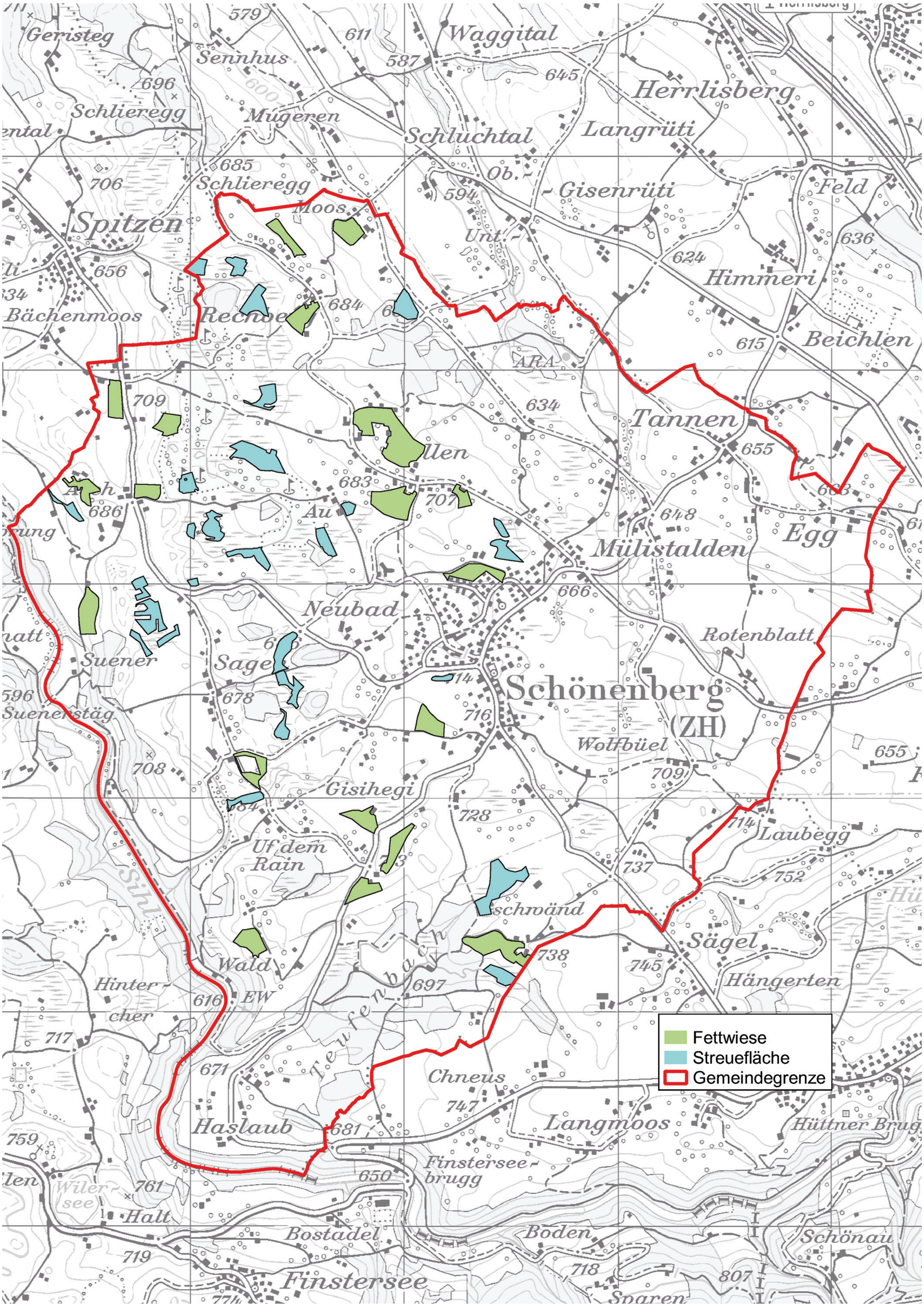

Abb. 12. Flächenauswahl aus den Heuschreckenkartierungen von 1990 in der Gemeinde Schönenberg ZH als Grundlage für den Vergleich mit den Kartierjahren 2000 und 2016. 19 Fettwiesen und 27 Streueflächen. SWISSIMAGE Bundesamt für Landestopographie, abgerufen via Geodatensatz ARE (2017).

Anhang 2

Tab. 5. Rohdatensatz zu den beobachteten Heuschrecken 2016 in den landwirtschaftlichen Nutzungseinheiten Schönenbergs ZH. F = Fettwiesen, Wi = Extensivwiesen, We = Extensivweiden, S = Streueflächen.

ID	*Chorthippus albomarginatus*	*Chorthippus biguttulus*	*Chorthippus dorsatus*	*Chrysochraon dispar*	*Conocephalus fuscus*	*Decticus verrucivorus*	*Gomphocerippus rufus*	*Mecostethus parapleurus*	*Omocestus viridulus*	*Pholidoptera griseoaptera*	*Pseudochorthippus montanus*	*Pseudochorthippus parallelus*	*Pteronemobius heydenii*	*Roeseliana roeselii*	*Stethophyma grossum*	*Tettigonia viridissima*	**Total**
F1	0	0	5	0	0	0	0	3	0	0	0	14	0	4	0	0	**26**
F2	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	**10**
F3	0	12	0	0	0	0	0	0	0	0	0	4	0	0	0	0	**16**
F4	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	**20**
F5	2	0	0	0	0	0	0	0	0	0	0	11	0	4	0	0	**17**
F6	0	9	0	0	0	0	0	0	0	0	0	6	0	0	0	0	**15**
F7	13	0	0	0	0	0	0	2	0	0	0	22	0	9	0	0	**46**
F8	7	2	0	0	0	0	0	0	6	0	0	20	0	3	0	0	**38**
F9	11	0	0	0	0	0	0	2	0	0	0	22	0	5	0	0	**40**
F10	0	4	0	0	0	0	0	4	0	0	0	17	0	0	0	0	**25**
F11	10	4	0	0	0	0	0	0	0	0	0	19	0	0	0	0	**33**
F12	7	5	0	0	0	0	0	0	0	0	0	15	0	0	0	0	**27**
F13	0	12	0	0	0	0	0	1	0	0	0	7	0	0	0	0	**20**
F14	5	0	0	0	0	0	0	0	0	0	0	12	0	3	0	0	**20**
F15	8	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	**27**
F16	2	15	0	0	0	0	0	0	0	0	0	5	0	0	0	0	**22**
F17	2	4	0	0	0	0	0	4	0	0	0	18	0	4	0	0	**32**
F18	16	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	**39**
F19	5	0	4	0	0	0	0	0	0	0	0	12	0	4	0	0	**25**
F20	1	12	0	0	0	0	0	0	0	0	0	17	0	0	0	0	**30**
F21	0	6	0	0	0	0	0	0	0	0	0	28	0	3	0	0	**37**
F22	0	11	0	0	0	0	0	0	0	0	0	21	0	0	0	0	**32**
F23	0	7	0	0	0	0	0	0	0	0	0	16	0	0	0	0	**23**
F24	0	4	0	0	0	0	0	0	0	0	0	19	0	0	0	0	**23**
F25	0	10	0	0	0	0	0	0	0	0	0	16	0	4	0	0	**30**
F26	0	3	0	0	0	0	0	0	0	0	0	14	0	2	0	0	**19**
F27	0	14	0	0	0	0	0	0	0	0	0	7	0	1	0	0	**22**
F28	0	6	0	0	0	0	0	0	0	0	0	31	0	0	0	0	**37**
F29	0	6	0	0	0	0	0	2	0	0	0	9	0	5	0	0	**22**
F30	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	**16**
Wi1	0	0	4	0	0	5	0	11	5	0	0	7	0	0	0	0	**32**
Wi2	0	0	7	0	0	0	0	3	4	0	0	6	0	0	0	0	**20**
Wi3	0	0	0	0	0	2	0	6	7	0	4	4	0	1	0	0	**24**
Wi4	0	5	3	0	0	0	15	8	0	0	0	8	0	3	0	0	**42**
Wi5	2	3	0	0	0	0	9	2	0	0	0	0	0	3	0	3	**22**
Wi6	2	7	0	0	0	0	8	0	0	0	0	4	0	8	0	0	**29**
Wi7	0	4	0	0	0	0	7	0	0	0	0	8	0	0	0	0	**19**
Wi8	0	0	7	0	0	0	0	1	0	0	0	6	0	2	0	0	**16**
Wi9	0	12	0	0	0	0	0	2	0	0	0	3	0	10	0	0	**27**
Wi10	0	5	1	0	0	1	0	4	0	0	4	2	0	0	0	0	**17**
Wi11	0	7	0	0	0	2	5	4	0	0	0	7	0	0	0	0	**25**
Wi12	0	12	0	0	0	0	0	6	0	0	0	8	0	0	0	0	**26**
Wi13	0	0	5	0	0	2	0	0	0	0	0	3	0	0	0	0	**10**
Wi14	0	4	0	0	0	0	4	0	0	0	0	3	0	2	0	0	**13**
Wi15	3	0	8	0	0	4	0	1	0	0	0	6	0	0	0	0	**22**
Wi16	0	10	0	0	0	0	4	5	0	0	0	3	0	2	0	0	**24**
Wi17	0	0	13	0	0	0	0	0	0	0	0	4	0	3	0	0	**20**
Wi18	0	8	0	2	0	0	8	0	0	0	0	10	0	1	0	0	**29**

ID	*Chorthippus albomarginatus*	*Chorthippus biguttulus*	*Chorthippus dorsatus*	*Chrysochraon dispar*	*Conocephalus fuscus*	*Decticus verrucivorus*	*Gomphocerippus rufus*	*Mecostethus parapleurus*	*Omocestus viridulus*	*Pholidoptera griseoaptera*	*Pseudochorthippus montanus*	*Pseudochorthippus parallelus*	*Pteronemobius heydenii*	*Roeseliana roeselii*	*Stethophyma grossum*	*Tettigonia viridissima*	**Total**
Wi19	0	8	0	0	0	0	0	2	0	0	0	8	0	4	0	0	**22**
Wi20	0	5	0	0	0	0	3	0	0	0	0	12	0	5	0	0	**25**
Wi21	0	7	0	0	0	0	8	2	0	0	0	6	0	0	0	0	**23**
Wi22	0	14	5	0	0	4	5	1	0	0	3	9	0	12	0	0	**53**
Wi23	0	9	0	0	0	0	5	0	0	0	0	3	0	3	0	0	**20**
Wi24	0	5	11	1	0	3	0	0	0	0	0	6	0	2	0	0	**28**
Wi25	0	5	0	0	0	0	16	3	0	0	0	4	0	5	0	0	**33**
Wi26	0	7	2	0	0	0	0	2	0	2	0	10	0	5	0	0	**28**
Wi27	0	3	0	0	0	0	10	3	0	0	0	4	0	7	0	0	**27**
Wi28	0	13	0	0	0	0	6	0	0	0	0	12	0	4	0	0	**35**
Wi29	0	10	8	0	0	4	10	0	0	0	0	4	0	8	0	0	**44**
Wi30	0	2	0	0	0	0	8	0	0	0	0	6	0	6	0	0	**22**
We1	0	6	0	0	0	0	12	3	0	0	0	14	0	0	0	0	**35**
We2	0	0	0	0	0	0	6	2	0	0	0	9	0	2	0	0	**19**
We3	0	4	0	0	0	0	0	0	0	0	0	10	0	1	0	0	**15**
We4	0	7	0	0	0	0	7	0	0	0	0	8	0	3	0	0	**25**
We5	0	3	3	0	0	0	0	0	0	0	0	5	0	2	0	2	**15**
We6	3	5	4	0	0	0	2	0	0	0	0	8	0	0	0	0	**22**
We7	0	12	5	0	0	3	8	1	0	0	0	6	0	2	0	0	**37**
We8	0	10	0	0	0	0	4	1	0	0	0	6	0	2	0	3	**26**
We9	0	4	0	0	0	0	0	0	0	0	0	13	0	0	0	0	**17**
We10	0	19	0	0	0	0	6	2	0	0	0	8	0	6	0	0	**41**
S1	0	0	9	0	0	8	0	11	5	0	16	4	0	0	0	0	**53**
S2	0	0	11	2	2	6	0	8	3	0	15	0	0	0	5	0	**52**
S3	0	0	8	5	5	3	0	0	0	0	14	0	0	0	0	0	**35**
S4	0	0	11	3	0	6	0	5	0	0	7	0	0	2	0	7	**41**
S5	0	0	17	6	1	4	0	7	0	0	14	3	0	3	4	6	**65**
S6	0	0	12	10	0	3	0	0	0	0	9	0	0	0	0	0	**34**
S7	0	0	6	12	3	5	0	0	0	0	6	0	0	3	5	0	**40**
S8	0	0	10	6	4	5	0	0	0	0	8	4	0	0	6	0	**43**
S9	0	0	4	8	7	0	0	0	0	0	4	0	0	0	6	0	**29**
S10	0	0	7	12	13	0	0	0	0	0	0	0	0	0	7	6	**45**
S11	0	0	10	3	3	4	0	4	0	0	16	5	0	0	8	0	**53**
S12	0	0	9	4	5	0	0	0	0	0	6	2	0	0	0	3	**29**
S13	0	0	7	3	3	3	0	2	0	0	8	4	0	0	0	3	**33**
S14	0	0	9	14	3	0	0	0	0	0	2	0	0	0	11	5	**44**
S15	0	0	5	0	5	9	0	0	0	0	19	1	0	3	11	4	**57**
S16	0	0	9	4	5	5	0	0	0	0	14	0	0	0	5	2	**44**
S17	0	0	12	2	4	8	0	2	0	0	16	0	0	0	7	0	**51**
S18	0	0	14	5	3	6	0	4	0	0	10	0	0	3	5	0	**50**
S19	0	0	7	4	7	3	0	2	4	0	6	0	0	0	4	9	**46**
S20	0	0	11	8	4	3	0	0	0	0	11	4	0	0	0	1	**42**
S21	0	0	9	11	9	1	0	0	0	0	0	0	0	0	0	11	**41**
S22	0	0	0	12	5	0	0	1	0	10	4	2	0	3	8	3	**48**
S23	0	0	13	0	8	3	0	0	0	0	6	0	0	2	0	2	**34**
S24	0	0	10	7	0	7	0	0	0	0	16	2	2	0	0	3	**47**
S25	0	0	10	0	0	2	0	0	5	0	12	0	4	0	0	4	**37**
S26	2	0	9	6	0	6	0	0	0	3	12	2	0	4	2	0	**46**
S27	0	0	14	0	2	5	0	5	0	0	8	0	0	0	4	0	**38**
S28	0	0	4	6	0	5	0	0	0	0	6	0	0	3	0	0	**24**
S29	0	0	0	3	0	0	0	0	0	17	12	0	0	7	0	0	**39**
S30	0	0	8	6	5	10	0	0	0	0	8	0	0	1	4	4	**46**
Total	**101**	**381**	**360**	**165**	**106**	**150**	**176**	**144**	**39**	**32**	**296**	**766**	**6**	**199**	**102**	**81**	**3104**

Anhang 3

Tab. 6. Rohdatensatz zu den beobachteten Heuschrecken 2016 in den Streueflächen Schönenbergs ZH. S = Streueflächen.

ID	Gesellschaft	*Chorthippus albomarginatus*	*Chorthippus dorsatus*	*Chysochraon dispar*	*Conocephalus fuscus*	*Decticus verrucivorus*	*Mecostethus parapleurus*	*Omocestus viridulus*	*Pholidoptera griseoaptera*	*Pseudochorthippus montanus*	*Pseudochorthippus parallelus*	*Pteronemobius heydenii*	*Roeseliana roeselii*	*Stethophyma grossum*	*Tettigonia viridissima*	**Total**
S1	Pfeifengras	0	5	0	0	5	8	4	0	6	0	0	0	0	0	**28**
S1	Kleinseggen	0	4	0	0	3	3	1	0	10	4	0	0	0	0	**25**
S2	Pfeifengras	0	9	0	2	4	6	3	0	9	0	0	0	0	0	**33**
S2	Kleinseggen	0	2	2	0	2	2	0	0	6	0	0	0	5	0	**19**
S3	Pfeifengras	0	4	2	4	3	0	0	0	7	0	0	0	0	0	**20**
S3	Kleinseggen	0	4	3	1	0	0	0	0	7	0	0	0	0	0	**15**
S4	Hochstauden	0	7	3	0	2	1	0	0	6	0	0	2	0	7	**28**
S4	Kleinseggen	0	4	0	0	4	4	0	0	1	0	0	0	0	0	**13**
S5	Grossseggen	0	7	0	0	0	0	0	0	2	0	0	0	4	0	**13**
S5	Hochstauden	0	0	6	1	0	0	0	0	0	0	0	2	0	5	**14**
S5	Pfeifengras	0	10	0	0	4	7	0	0	12	3	0	1	0	1	**38**
S6	Schilf	0	6	4	0	2	0	0	0	9	0	0	0	0	0	**21**
S6	Hochstauden	0	6	6	0	1	0	0	0	0	0	0	0	0	0	**13**
S7	Kleinseggen	0	0	0	0	2	0	0	0	3	0	0	0	4	0	**9**
S7	Hochstauden	0	3	7	3	0	0	0	0	0	0	0	0	0	0	**13**
S7	Schilf	0	3	5	0	0	0	0	0	0	0	0	0	1	0	**9**
S7	Pfeifengras	0	0	0	0	3	0	0	0	3	0	0	3	0	0	**9**
S8	Pfeifengras	0	5	2	0	5	0	0	0	7	4	0	0	0	0	**23**
S8	Hochstauden	0	1	4	4	0	0	0	0	0	0	0	0	0	0	**9**
S8	Grossseggen	0	4	0	0	0	0	0	0	1	0	0	0	6	0	**11**
S9	Schilf	0	2	8	2	0	0	0	0	4	0	0	0	0	0	**16**
S9	Grossseggen	0	2	0	5	0	0	0	0	0	0	0	0	6	0	**13**
S10	Grossseggen	0	3	0	1	0	0	0	0	0	0	0	0	6	0	**10**
S10	Hochstauden	0	4	12	12	0	0	0	0	0	0	0	0	1	6	**35**
S11	Grossseggen	0	6	2	3	0	0	0	0	2	1	0	0	8	0	**22**
S11	Pfeifengras	0	4	1	0	4	4	0	0	14	4	0	0	0	0	**31**
S12	Grossseggen	0	7	1	3	0	0	0	0	0	0	0	0	0	0	**11**
S12	Pfeifengras	0	2	3	2	0	0	0	0	6	2	0	0	0	3	**18**
S13	Pfeifengras	0	3	0	0	3	2	0	0	8	4	0	0	0	0	**20**
S13	Hochstauden	0	4	3	3	0	0	0	0	0	0	0	0	0	3	**13**
S14	Grossseggen	0	4	3	0	0	0	0	0	0	0	0	0	11	0	**18**
S14	Hochstauden	0	3	8	3	0	0	0	0	0	0	0	0	0	5	**19**
S14	Schilf	0	2	3	0	0	0	0	0	2	0	0	0	0	0	**7**
S15	Grossseggen	0	2	0	1	0	0	0	0	4	0	0	0	11	0	**18**
S15	Hochstauden	0	2	0	3	1	0	0	0	0	0	0	0	0	4	**10**
S15	Pfeifengras	0	1	0	1	8	0	0	0	15	1	0	3	0	0	**29**
S16	Pfeifengras	0	5	1	0	5	0	0	0	14	0	0	0	0	1	**26**
S16	Hochstauden	0	4	3	5	0	0	0	0	0	0	0	0	5	1	**18**
S17	Pfeifengras	0	9	2	3	8	1	0	0	11	0	0	0	0	0	**34**
S17	Kleinseggen	0	3	0	1	0	1	0	0	5	0	0	0	7	0	**17**
S18	Hochstauden	0	6	2	3	3	0	0	0	0	0	0	3	0	0	**17**
S18	Schilf	0	5	3	0	0	0	0	0	6	0	0	0	2	0	**16**
S18	Kleinseggen	0	3	0	0	3	4	0	0	4	0	0	0	3	0	**17**
S19	Pfeifengras	0	3	0	0	3	2	4	0	6	0	0	0	2	2	**22**
S19	Hochstauden	0	2	2	7	0	0	0	0	0	0	0	0	0	7	**18**
S19	Schilf	0	2	2	0	0	0	0	0	0	0	0	0	2	0	**6**
S20	Hochstauden	0	10	8	4	0	0	0	0	0	0	0	0	0	1	**23**
S20	Kleinseggen	0	1	0	0	3	0	0	0	11	4	0	0	0	0	**19**

ID	Gesellschaft	*Chorthippus albomarginatus*	*Chorthippus dorsatus*	*Chrysochraon dispar*	*Conocephalus fuscus*	*Decticus verrucivorus*	*Mecostethus parapleurus*	*Omocestus viridulus*	*Pholidoptera griseoaptera*	*Pseudochorthippus montanus*	*Pseudochorthippus parallelus*	*Pteronemobius heydenii*	*Roeseliana roeselii*	*Stethophyma grossum*	*Tettigonia viridissima*	**Total**
S21	Hochstauden	0	9	11	9	1	0	0	0	0	0	0	0	0	11	**41**
S22	Grossseggen	0	0	2	3	0	1	0	0	1	0	0	0	8	0	**15**
S22	Pfeifengras	0	0	2	0	0	0	0	1	3	2	0	2	0	1	**11**
S22	Hochstauden	0	0	8	2	0	0	0	9	0	0	0	1	0	2	**22**
S23	Pfeifengras	0	6	0	0	3	0	0	0	6	0	0	2	0	0	**17**
S23	Hochstauden	0	7	0	8	0	0	0	0	0	0	0	0	0	2	**17**
S24	Hochstauden	0	4	4	0	1	0	0	0	0	0	0	0	0	3	**12**
S24	Schilf	0	6	3	0	6	0	0	0	16	2	2	0	0	0	**35**
S25	Grossseggen	0	7	0	0	0	0	0	0	0	0	0	0	0	4	**11**
S25	Kleinseggen	0	0	0	0	0	0	1	0	3	0	4	0	0	0	**8**
S25	Pfeifengras	0	3	0	0	2	0	4	0	9	0	0	0	0	0	**18**
S26	Kleinseggen	2	5	0	0	5	0	0	0	12	2	0	0	2	0	**28**
S26	Hochstauden	0	4	6	0	1	0	0	3	0	0	0	4	0	0	**18**
S27	Grossseggen	0	7	0	2	0	0	0	0	1	0	0	0	4	0	**14**
S27	Pfeifengras	0	7	0	0	5	5	0	0	7	0	0	0	0	0	**24**
S28	Hochstauden	0	0	6	0	0	0	0	0	0	0	0	1	0	0	**7**
S28	Pfeifengras	0	4	0	0	5	0	0	0	6	0	0	2	0	0	**17**
S29	Kleinseggen	0	0	0	0	0	0	0	0	12	0	0	0	0	0	**12**
S29	Hochstauden	0	0	3	0	0	0	0	17	0	0	0	7	0	0	**27**
S30	Pfeifengras	0	5	2	0	10	0	0	0	8	0	0	1	2	0	**28**
S30	Hochstauden	0	3	4	5	0	0	0	0	0	0	0	0	2	4	**18**
Total		**2**	**265**	**162**	**106**	**120**	**51**	**17**	**30**	**285**	**33**	**6**	**34**	**102**	**73**	**1286**

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Pollen host selection by predominantly alpine bee species of the genera *Andrena*, *Panurginus*, *Dufourea*, *Megachile*, *Hoplitis* and *Osmia* (Hymenoptera, Apoidea)

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Abstract

The pollen host selection by 19 bee species, which have their main Central European distribution in the Alps, was assessed by microscopical analysis of the scopal contents of about 900 females from museum and private collections. The results of the pollen analyses were complemented by a literature survey as well as by field observations. The examined species widely vary in pollen host spectrum and specialization, revealing a fascinating diversity in bee host plant use. Observed patterns of host plant choice range from narrow specialists, which exclusively collect pollen from the flowers of a single plant genus, to pronounced generalists, which harvest pollen from the flowers of up to 17 different plant families. A quantitative character is given to separate the morphologically very similar females of *Panurginus herzi* and *P. montanus*.

Zusammenfassung

Die Pollenwirtswahl von 19 Bienenarten, welche ihren zentraleuropäischen Verbreitungsschwerpunkt in den Alpen haben, wurde mittels mikroskopischer Analyse der Pollenladungen von rund 900 Weibchen aus Museums- und Privatsammlungen ermittelt. Die Ergebnisse der Pollenanalysen wurden durch eine Literaturauswertung sowie durch Feldbeobachtungen ergänzt. Die untersuchten Arten unterscheiden sich stark hinsichtlich Wirtspflanzenspektrum und Spezialisierungsgrad und umfassen sowohl enge Spezialisten, welche den Pollen ausschliesslich auf einer einzigen Pflanzengattung sammeln, als auch ausgeprägte Generalisten, welche bis zu 17 verschiedene Pflanzenfamilien als Pollenquellen nutzen. Ein quantitatives Merkmal zur Unterscheidung der äusserlich sehr ähnlichen Weibchen von *Panurginus herzi* und *P. montanus* wird gegeben.

Introduction

Bees are herbivores using nectar and pollen as the predominant food source for their larvae. While no floral specificity is known with respect to the collection of nectar, many bee species restrict pollen harvesting to closely related plant taxa (Robertson 1925, Westrich 1989). The degree of host plant specialization among bees widely varies: “monolectic” bee species are entirely dependent on the pollen of a single plant species even in the presence of sympatric species of the same genus, “oligolectic” species consistently collect pollen from flowers of a single plant genus, tribe or family, “mesolectic” species harvest pollen from flowers of two or three plant families and “polylectic” species exploit flowers of more than three plant families (Cane and Sipes 2006, Müller and

Kuhlmann 2008). Even in polylectic species, host plant choice is usually limited to some degree and - as in more specialized taxa - governed by constraints with respect to pollen digestion, flower recognition or flower handling (Sedivy et al. 2008, Haider et al. 2014). Detailed knowledge of pollen host use is important for species conservation, the reconstruction of bee host range evolution and our understanding of the fascinating interrelationships between flowers and their pollinators.

The pollen host preferences of Western, Central and Northern European bee species are fairly well known thanks to several studies, which analyzed pollen loads of collected females by light microscopy (Chambers 1968, Raw 1974, Westrich 1989, Müller 1996, Michez et al. 2008, Müller and Kuhlmann 2008, Sedivy et al. 2008, 2013, Haider et al. 2014, Wood et al. 2016, Wood and Roberts 2017). Gaps of knowledge, however, exist for numerous species, which exclusively or predominantly occur in the Alps. Among the bee species, which have their main Central European distribution in the Alpine arc, pollen host preferences have been thoroughly analysed so far only for *Colletes floralis* Eversmann, *Colletes impunctatus* Nylander, *Anthidium montanum* Morawitz, *Chelostoma grande* (Nylander), *Hoplitis lepeletieri* (Pérez), *Hoplitis loti* (Morawitz) and *Hoplitis tuberculata* (Nylander) (Müller and Kuhlmann 2008, Müller 1996, 2015, Sedivy et al. 2008, 2013, Westrich 1989, 1993). For many other predominantly alpine species, information on host plant use either completely lacks, is based on field observations, which do not differentiate between nectar uptake and pollen collection, or relies on pollen analysis of female scopal loads without quantification, resulting in a list of pollen sources not considering their relative significance in the species' larval diet.

The present publication aims to fill the knowledge gap still existing on the host plant preferences of 19 predominantly alpine bee species, which are either endemic to the Alps or have a boreoalpine or boreomontane distribution. For that purpose, pollen stored in the scopae of females from museum and private collections originating from across the Alpine arc was removed and microscopically analysed.

Methods

The pollen host spectra of 19 bee species belonging to the six genera *Andrena* and *Panurginus* (Andrenidae), *Dufourea* (Halictidae) and *Megachile*, *Hoplitis* and *Osmia* (Megachilidae) were assessed by microscopical analysis of the scopal pollen contents of 877 female specimens deposited in museum and private collections and captured between the beginning of the 20th century and 2018. For each species, the aim was to analyze a minimum of 40 and a maximum of 50 pollen loads all originating from the Alpine arc. This goal was not attained for *Osmia alticola* Benoist and *Osmia steinmanni* Müller due to their rarity and poor representation in collections. For *Panurginus herzi* Morawitz, the pollen samples analysed by Vögeli (2001) were included in the present study and supplemented with numerous new samples. To account for potentially deviating pollen host use by specimens from different populations, pollen samples from females collected at as many different localities as possible were analysed. Specimens with identical information on the collection label (i.e. locality, date and collector) were regarded as originating from the same locality. Before removing pollen from the female scopae, the degree to which they were filled was estimated. The amount of pollen in the scopae was assigned to five classes, ranging from 1/5 (filled to one-fifth) to 5/5 (full load). The pollen grains were stripped off the scopae with a fine needle and embedded in glycerol gelatine on a microscopic slide. When a pollen load was composed of different pollen types, their percentages were estimated by counting the grains along two transects chosen randomly across the cover slip at a magnification of 400×. Pollen types represented by less than 5% of the counted grains were excluded to prevent a potential bias caused by contamination. For pollen loads consisting of two or more different pollen types, the proportion of the different types was corrected by their volume (Buchmann and O'Rourke 1991, Silveira 1991). For that purpose, the relative volumina of all pollen types within the sample were estimated by eye and the counted numbers of each type multiplied by a factor that corresponded to its volume. After assigning different weights to scopae according to their degree of filling (full loads were weighted five times more strongly than scopae filled to only one-fifth), the estimated percentages were summed up over all pollen samples for each species. To characterize the degree of host plant association, such as oligolecty, mesolecty or polylecty, definitions and methods proposed by Müller and Kuhlmann (2008) were applied. The pollen grains were identified down to family or, if possible, to subfamily, tribal or genus level at a magnification of 400× or 1000× with the aid of the literature cited in Westrich and Schmidt (1986), Beug (2004) and an extensive reference collection. Flower records written on the collection labels often facilitated pollen identification to a taxonomic level lower than the plant family. Difficult pollen types were identified by the palynologist Katharina Bieri (Biological Institute for Pollen Analysis, Kehrsatz). Certain closely related plant genera could not be properly identified with the method applied in the present study, such as *Sedum* and *Sempervivum* (Crassulaceae), *Fragaria* and *Potentilla* (Rosaceae), *Euphrasia* and *Rhinanthus* (Orobanchaceae) and *Campanula* and *Phyteuma* (Campanulaceae). Pollen grains of these taxa, however, were assigned to genus level if altitude, phenology or habitat excluded the alternative genus or if own field observations, literature data or label records all invariably suggest only one of the two genera. Such non-morphologically based pollen identifications are marked with "cf." in Table 1. The distinction of pollen from *Rhododendron* and *Vaccinium* (Ericaceae) and from *Euphrasia* and *Veronica* (Plantaginaceae) is difficult. For the former pair the thickness of the exine and for the latter pair the shape of the swollen grains was used as distinctive characters. However, these characters could only be recognised in grains that were specifically oriented within the gelatine layer and/or completely swollen. If only typical *Rhododendron* (or *Vaccinium*) grains or typical *Euphrasia* (or *Veronica*) grains were present in a pollen sample, all grains for which the distinctive characters were not discernible were assigned to *Rhododendron* (or *Vaccinium*) and *Euphrasia* (or *Veronica*), respectively. Data based on a comprehensive literature survey on confirmed pollen hosts and observed flower visits as well as field observations made by the author during the last three decades were used to complement the results obtained by the microscopical analysis of scopal pollen loads.

The taxonomy of *Panurginus* in Central Europe is still under discussion. While the validity of *P. herzi* Morawitz as a biological species is undisputed, there is no consensus yet whether *P. sericatus* (Warncke) is a species of its own (e.g. Schwarz and Gusenleitner 1997, Amiet et al. 2010) or should rather be treated as a western subspecies of *P. montanus* Giraud (e.g. Warncke 1972, Ebmer 2001). No morphological characters are known to discriminate between the females of these latter two taxa. In contrast, the males slightly differ in the shape of the gonostylus (Amiet et al. 2010). However, there are populations in eastern Switzerland, which show an intermediate gonostylus shape (Amiet et al. 2010). Due to these morphological transitions, the two taxa are regarded as conspecific in the present study. The characters given by Amiet et al. (2010) to separate the females of *P. herzi* from those of *P. montanus* proved to be partly unreliable. The shape of the head, however, was recently found to be a reliable character allowing for the unambiguous identification of *P. herzi* (Hopfenmüller 2017). To quantify this character, the ratio of head length to head width (sensu Michener 2007) was measured under a stereomicroscope for 150 *Panurginus* females originating from 78 different localities in Switzerland, Austria and Germany. The measurements revealed an almost non-overlapping bimodal distribution in the head length to head width ratio (Fig. 1), corroborating the reliability of this character to separate the females of *P. herzi* and *P. montanus*. For the present study, *Panurginus* females with a head length to head width ratio of 0.76–0.82 were identified as *P. herzi* and those with a ratio of 0.84–0.90 as *P. montanus*. Pollen loads of females with a ratio of 0.83 were not considered for pollen analysis.

Results

***Andrena* (*Andrena*) *fucata* Smith, 1847**

Andrena fucata harvested the pollen of 17 plant families, among which Rosaceae, Apiaceae and *Helianthemum* (Cistaceae) predominated (Tab. 1, Fig. 2). Pollen of these three plant taxa contributed 77.7% to the total pollen grain volume. Herbs, shrubs and trees were among the exploited hosts (Tabs 1, 2), which suggests a high flexibility of the female bees to use different vegetation strata for pollen collection. The seven plant families listed by Chambers (1968) and Westrich (1989) as pollen hosts of *A. fucata* were all confirmed in the present study. Rhamnaceae were recently demonstrated to be an additional pollen source (Wood and Roberts 2017), and observations of flower visits on *Berberis* and *Lysimachia* (Stoeckhert 1933, Dylewska 1987, BWARS 2018) suggest that Berberidaceae and Primulaceae might be two further plant families occasionally exploited for pollen. The high significance of Rosaceae in the host plant spectrum of *A. fucata* as found in the present study is confirmed by two British studies, which identified Rosaceae pollen to be the most important constituent of the collected pollen, representing 80.3% and 57.9%, respectively, of the total pollen grain volume (Chambers 1968, Wood and Roberts 2017). According to several authors, *Rubus idaeus* L. is a preferred pollen host among the Rosaceae (Alfken 1913, Stoeckhert 1933, Amiet et al. 2010).

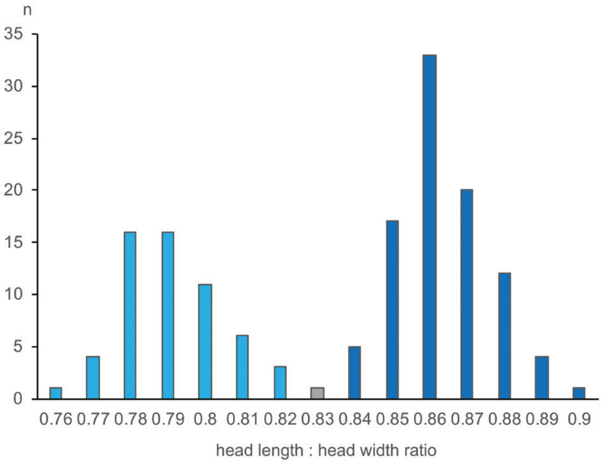


Figure 1. Head length to head width ratio in females of *Panurginus herzi* (light blue) and *P. montanus* (dark blue) (n = 150). Definitions for head length and head width according to Michener (2007).

***Andrena* (*Andrena*) *lapponica* Morawitz, 1872**

Andrena lapponica had the narrowest pollen diet among the three *Andrena* species of the subgenus *Andrena* investigated in the present study. Although it collected the pollen of 16 plant families (Tab. 1), flowers of the Ericaceae were strongly preferred. Among the Ericaceae, both *Vaccinium* and *Rhododendron* were exploited. As revealed by field observations, *Vaccinium myrtillus* L. is the most important pollen host in the Swiss Alps (Fig. 3), albeit the pollen of other *Vaccinium* species such as *V. vitis-idaea* L., *V. uliginosum* L. or *V. oxycoccos* L. is occasionally also collected (Stoeckhert 1933, Westrich 1989). As the flowering period of the main host is short and hardly extends over a period of more than few weeks, many of the alternative non-Ericaceae hosts might have acted as replacement pollen sources before and after the

Table 1. Pollen host spectrum of 19 predominantly alpine bee species of the genera *Andrena* and *Panurginus* (Andrenidae), *Dufourea* (Halictidae) and *Megachile*, *Hoplitis* and *Osmia* (Megachilidae). Subgeneric classification according to Michener (2007). n = total number of pollen loads, N = number of pollen loads from different localities. Countries: A = Austria, CH = Switzerland, D = Germany, F = France, FL = Liechtenstein, IT = Italy. Plant families: ACE = Aceraceae, ALL = Alliaceae, API = Apiaceae, AQU = Aquifoliaceae, ASP = Asparagaceae, AST = Asteraceae, BER = Berberidaceae, BOR = Boraginaceae, BRA = Brassicaceae, CAM = Campanulaceae, CAP = Caprifoliaceae, CAR = Caryophyllaceae, CIS = Cistaceae, CLU = Clusiaceae, COR = Cornaceae, CRA = Crassulaceae, DIP = Dipsacaceae, ERI = Ericaceae, EUP = Euphorbiaceae, FAB = Fabaceae, GEN = Gentianaceae, GER = Geraniaceae, JUN = Juncaceae, LAM = Lamiaceae, LIL = Liliaceae, LIN = Linaceae, ORO = Orobanchaceae, OXA = Oxalidaceae, PLA = Plantaginaceae, POL = Polygonaceae, PRI = Primulaceae, PYR = Pyrolaceae, RAN = Ranunculaceae, RES = Resedaceae, RHA = Rhamnaceae, ROS = Rosaceae, SAL = Salicaceae, SAN = Santalaceae, SAX = Saxifragaceae, SCR = Scrophulariaceae, TIL = Tiliaceae. Definitions of bee host ranges after Müller and Kuhlmann (2008).

Bee species	n	N	Origin (and number) of pollen loads	% pollen grain volume (number of loads)	Preferred host(s)	% pollen grain volume of preferred host	% pure loads of preferred host	% loads with preferred host	Host range
Andrena (*Andrena*) *fucata* Smith, 1847	50	40	CH (48), D (1), IT (1)	ROS (other) 41.3% (34), ROS (*Sanguisorba officinalis*) 1.7% (2), ROS (cf. *Potentilla*) 0.4% (2), API 17.6% (16), CIS (*Helianthemum*) 16.6% (14), CAP (*Lonicera*) 4.3% (2), PLA (*Plantago*) 4.2% (7), BRA 2.8% (1), CAM 2.1% (1), POL (*Polygonum bistorta*) 2.0% (2), RAN 1.6% (1), ACE (*Acer*) 1.4% (1), AQU (*Ilex*) 1.0% (1), JUN 1.0% (2), COR (*Cornus*) 0.5% (1), AST (Carduoideae) 0.4% (1), ERI (*Vaccinium*) 0.4% (1), EUP (*Euphorbia*) 0.2% (1), SAN (*Thesium*) 0.2% (1), unknown 0.3% (2)	Rosaceae, Apiaceae and *Helianthemum*	77.7%	58.0%	92.0%	polylectic (17 plant families) with affinity for Rosaceae, Apiaceae and *Helianthemum* (Cistaceae)
Andrena (*Andrena*) *lapponica* Morawitz, 1872	50	46	CH (49), FL (1)	ERI (*Vaccinium*) 75.7% (41), ERI (*Rhododendron*) 5.8% (5), ROS (cf. *Potentilla*) 0.9% (6), ROS (*Geum*) 0.6% (1), ROS (other) 2.1% (3), AST (Carduoideae) 2.4% (1), AST (Asteroideae) 0.4% (1), PYR (*Moneses*) 1.9% (1), CIS (*Helianthemum*) 1.5% (1), RAN 1.4% (1), PRI (*Soldanella*) 1.3% (2), OXA (*Oxalis*) 1.2% (3), SAL (*Salix*) 1.1% (4), CAR 0.8% (1), LIL 0.6% (1), PLA (*Plantago*) 0.4% (2), SAX (*Saxifraga*) 0.2% (1), ACE (*Acer*) 0.1% (1), LAM (Nepetoidea) 0.1% (1), GEN 0.1% (1), unknown 1.4% (4)	Ericaceae	81.5%	58.0%	92.0%	polylectic (16 plant families) with strong preference for Ericaceae
Andrena (*Andrena*) *rogenhoferi* Morawitz, 1872	50	47	CH (42), A (3), D (2), F (2), FL (1)	GEN (cf. *Gentiana*) 18.0% (12), SAX (*Saxifraga*) 17.2% (13), CIS (*Helianthemum*) 13.7% (12), ERI (*Rhododendron*) 9.3% (8), ERI (*Vaccinium*) 3.5% (2), SAL (*Salix*) 9.5% (7), ROS (*Geum*) 2.6% (3), ROS (cf. *Potentilla*) 0.1% (1), ROS (other) 4.8% (9), ACE (*Acer*) 7.1% (5), TIL (*Tilia*) 3.9% (4), API 3.4% (6), CAM 1.2% (4), RAN (*Pulsatilla*) 1.1% (1), BER (*Berberis*) 1.0% (2), CRA 0.5% (1), AST (Cichorioideae) 0.3% (2), BRA 0.2% (1), CAP (*Lonicera*) 0.2% (1), RHA (*Frangula*) 0.1% (1), unknown 2.3% (4)	–	–	–	–	polylectic (17 plant families)
Andrena (*Cnemidandrena*) *freygessneri* Alfken, 1904	50	29	CH (43), IT (5), A (1), F (1)	CRA (cf. *Sempervivum*) 78.2% (42), SAX (*Saxifraga*) 5.7% (8), CIS (*Helianthemum*) 5.5% (6), LAM (Nepetoideae) 2.4% (4), ROS (cf. *Potentilla*) 1.5% (4), ROS (other) 0.9% (2), AST (Asteroideae) 1.7% (4), ERI (*Calluna*) 1.2% (1), GEN 1.1% (2), BRA 0.9% (1), CAR 0.6% (3), unknown 0.3% (1)	*Sempervivum*	78.2%	54.0%	84.0%	polylectic (10 plant families) with strong preference for *Sempervivum* (Crassulaceae)
Andrena (*Oreomelissa*) *coitana* (Kirby, 1802)	50	41	CH (44), A (4), D (1), FL (1)	AST (Carduoideae) 10.2% (11), AST (Cichorioideae) 8.6% (14), AST (Asteroideae) 5.8% (8), CAM 24.2% (18), ROS (cf. *Potentilla*) 14.2% (19), ROS (*Sanguisorba officinalis*) 0.9% (1), ROS (other) 3.2% (5), CIS (*Helianthemum*) 6.0% (6), API 6.0% (8), SCR 5.7% (8), LAM (Lamioideae) 3.7% (4), LAM (Nepetoideae) 1.6% (3), ORO (cf. *Euphrasia*) 3.5% (5), CRA 2.6% (2), PLA (*Veronica*) 1.8% (3), PLA (*Plantago*) 0.6% (1), GEN 0.8% (1), RAN 0.3% (2), unknown 0.3% (5)	–	–	–	–	polylectic (12 plant families)
Panurginus herzi Morawitz, 1891	50	27	CH (48), A (1), D (1)	ROS (cf. *Potentilla*) 99.2% (50), CIS (*Helianthemum*) 0.5% (1), ERI (*Vaccinium*) 0.3% (1)	*Potentilla*	99.2%	96.0%	100%	narrowly oligolectic on *Potentilla* (Rosaceae)
Panurginus montanus Giraud, 1861	50	35	CH (47), FL (3)	ROS (cf. *Potentilla*) 50.4% (39), CIS (*Helianthemum*) 39.3% (31), RAN 2.8% (9), BRA 2.3% (3), ORO (cf. *Euphrasia*) 1.6% (2), CAR 1.5% (4), SAX (*Saxifraga*) 0.3% (1), CRA 0.3% (1), API 0.3% (1), AST (Cichorioideae) 0.2% (2), unknown 1.0% (1)	*Potentilla* and *Helianthemum*	89.7%	66.0%	98.0%	polylectic (10 plant families) with affinity for *Potentilla* (Rosaceae) and *Helianthemum* (Cistaceae)

Bee species	n	N	Origin (and number) of pollen loads	% pollen grain volume (number of loads)	Preferred host(s)	% pollen grain volume of preferred host	% pure loads of preferred host	% loads with preferred host	Host range
Dufourea alpina Morawitz, 1865	50	35	CH (41), FL (9)	CAM 80.1% (46), AST (Cichorioideae) 7.8% (22), ORO (cf. *Euphrasia*) 6.1% (10), CIS (*Helianthemum*) 2.7% (2), LAM (Nepetoideae) 1.7% (3), CAR 1.1% (4), LIN (*Linum*) 0.5% (1)	Campanulaceae	80.1%	42.0%	92.0%	polylectic (7 plant families) with strong preference for Campanulaceae
Dufourea paradoxa (Morawitz, 1867)	46	36	CH (42), A (1), F (1), IT (2)	CRA 26.4% (16), ORO (cf. *Euphrasia*) 24.7% (21), LAM (Nepetoideae) 12.6% (13), CIS (*Helianthemum*) 9.6% (9), AST (Cichorioideae) 4.9% (9), AST (Carduoideae) 2.4% (3), AST (Asteroideae) 2.0% (4), CAR 9.2% (14), GEN 4.2% (4), ROS (cf. *Potentilla*) 2.1% (5), PRI (*Soldanella*) 1.0% (1), SAX (*Saxifraga*) 0.5% (1), SAL (*Salix*) 0.1% (1), FAB 0.1% (1), CAM 0.1% (1), unknown 0.1% (1)	–	–	–	–	polylectic (13 plant families)
Megachile (*Megachile*) *alpicola* Alfken, 1924	50	50	CH (40), A (1), D (9)	FAB (*Lotus*) 33.3% (33), FAB (*Trifolium*) 3.2% (3), FAB (Genisteae) 2.7% (1), FAB (*Medicago*) 0.5% (2), FAB (*Vicia/Lathyrus*) 0.4% (1), FAB (other) 3.9% (3), AST (Cichorioideae) 13.2% (16), AST (Asteroideae) 12.8% (13), AST (Carduoideae) 4.4% (4), CIS (*Helianthemum*) 4.6% (7), ASP (*Anthericum*) 4.2% (1), BRA 2.7% (2), RAN 2.5% (4), CLU (*Hypericum*) 2.0% (3), CRA 2.0% (4), ORO (*Odontites*) 1.7% (1), PLA (*Veronica*) 1.5% (1), ALL (*Allium*) 1.3% (2), ROS (cf. *Potentilla*) 0.9% (2), DIP (*Scabiosa*) 0.8% (1), LAM (Nepetoideae) 0.4% (1), SAL (*Salix*) 0.2% (1), CAM 0.1% (1), unknown 0.7% (4)	Fabaceae and Asteraceae	74.5%	44.0%	44%	polylectic (16 plant families) with affinity for Fabaceae and Asteraceae
Megachile (*Xanthosarus*) *analis* Nylander, 1852	50	49	CH (48), D (1), IT (1)	CAM 61.6% (36), FAB (*Lotus*) 25.0% (26), FAB (*Hippocrepis*) 5.1% (7), FAB (*Onobrychis*) 3.6% (2), CIS (*Helianthemum*) 3.1% (2), ORO (*Odontites*) 1.1% (1), RES (*Reseda*) 0.4% (1), CRA 0.1% (1)	Campanulaceae and Fabaceae	95.3%	92.0%	100%	mesolectic on Campanulaceae and Fabaceae
Hoplitis (*Anthocopa*) *villosa* (Schenck, 1853)	50	46	CH (44), F (4), A (1), D (1)	AST (Cichorioideae) 72.8% (46), AST (Carduoideae) 22.4% (16), AST (Asteroideae) 0.3% (3), GER (*Geranium*) 2.4% (2), CIS (*Helianthemum*) 2.1% (5)	Cichorioideae and Carduoideae	95.2%	88.0%	100%	broadly oligolectic on Cichorioideae and Carduoideae (Asteraceae)
Osmia (*Helicosmia*) *labialis* Pérez, 1879	50	48	CH (46), D (2), F (2)	AST (Carduoideae) 95.7% (48), AST (Cichorioideae) 2.6% (4), AST (Asteroideae) 1.5% (1), CIS (*Helianthemum*) 0.2% (1)	Carduoideae	95.7%	90.0%	96%	broadly oligolectic on Carduoideae (Asteraceae)
Osmia (*Melanosmia*) *alticola* Benoist, 1922	16	15	CH (16)	FAB (*Lotus*) 38.4% (12), FAB (*Hippocrepis*) 36.0% (7), FAB (*Anthyllis*) 8.8% (3), FAB (*Trifolium*) 5.5% (2), FAB (other) 11.1% (2), unknown 0.2% (1)	Fabaceae	99.8%	93.8%	100%	broadly oligolectic on Fabaceae
Osmia (*Melanosmia*) *inermis* (Zetterstedt, 1838)	50	43	CH (41), A (7), D (2)	FAB (*Lotus*) 70.4% (45), FAB (*Hippocrepis*) 20.0% (17), FAB (*Anthyllis*) 1.3% (3), ERI (*Vaccinium*) 5.0% (2), ROS (cf. *Potentilla*) 1.7% (1), LAM (Lamioideae) 1.6% (1)	Loteae (*Anthyllis*, *Hippocrepis*, *Lotus*)	91.7%	92.0%	96.0%	polylectic (4 plant families) with strong preference for Loteae (Fabaceae)
Osmia (*Melanosmia*) *parietina* Curtis, 1828	50	44	CH (50)	FAB (*Lotus*) 61.6% (48), FAB (*Hippocrepis*) 22.5% (25), FAB (*Trifolium*) 7.4% (11), FAB (*Anthyllis*) 1.4% (2), LAM (Lamioideae) 2.4% (2), LAM (Nepetoideae) 1.5% (2), CIS (*Helianthemum*) 1.9% (2), ROS (cf. *Potentilla*) 1.0% (2), GEN 0.3 (1)	Loteae (*Anthyllis*, *Hippocrepis*, *Lotus*)	85.5%	72.0%	100%	polylectic (5 plant families) with strong preference for Loteae (Fabaceae)
Osmia (*Melanosmia*) *steinmanni* Müller, 2002	15	6	CH (14), F (1)	FAB (*Lotus*) 61.9% (13), FAB (*Hippocrepis*) 34.4% (9), FAB (*Trifolium*) 1.5% (1), ERI (*Rhododendron*) 2.2% (1)	Loteae (*Hippocrepis*, *Lotus*)	96.3%	86.7%	100%	probably mesolectic on Fabaceae and Ericaceae with strong preference for Loteae (Fabaceae)
Osmia (*Melanosmia*) *uncinata* Gerstaecker, 1869	50	41	CH (43), D (4), A (1), FL (1), IT (1)	FAB (*Lotus*) 46.4% (38), FAB (*Hippocrepis*) 11.4% (19), FAB (*Trifolium*) 7.9% (12), FAB (*Onobrychis*) 3.4% (3), FAB (*Medicago*) 2.8% (4), FAB (*Vicia/Lathyrus*) 1.9% (2), FAB (*Anthyllis*) 1.7% (1), FAB (other) 2.2% (6), ROS (cf. *Potentilla*) 3.6% (3), ROS (other) 6.3% (3), LAM (Lamioideae) 6.3% (5), LAM (Nepetoideae) 0.6% (1), PLA (*Plantago*) 1.3% (5), PLA (*Veronica*) 0.3% (1), ALL (*Allium*) 1.2% (2), RAN 0.8% (2), CAP (*Lonicera*) 0.7% (1), GEN 0.3% (1), BOR (*Echium*) 0.3% (1), CRA 0.1% (1), CIS (*Helianthemum*) 0.1% (1), unknown 0.4% (1)	Fabaceae	77.7%	56.0%	90.0%	polylectic (11 plant families) with strong preference for Fabaceae
Osmia (*Melanosmia*) *xanthomelana* (Kirby, 1802)	50	50	CH (44), F (3), IT (3)	FAB (*Hippocrepis*) 83.4% (49), FAB (*Lotus*) 16.6% (21)	*Hippocrepis* and *Lotus*	100%	100%	100%	narrowly oligolectic on *Hippocrepis* and *Lotus* (Fabaceae)

bloom of *V. myrtillus*. However, several records of *A. lapponica* from Switzerland originate from localities lacking larger Ericaceae stands, which suggests that this species might occasionally also reproduce in the absence of *Vaccinium* or *Rhododendron*. In fact, a strong population of *A. lapponica* exists on Mt. Snežnik in southern Slovenia, where Ericaceae are completely lacking (Gogala 2011). Here, pollen is collected on *Helianthemum* (Cistaceae) and *Salix* (Salicaceae). Thus, the pollen specialization of *A. lapponica* appears to be less strict than was formerly assumed, e.g. by Westrich (1989).

***Andrena* (*Andrena*) *rogenhoferi* Morawitz, 1872**

Andrena rogenhoferi harvested the pollen of 17 plant families (Tab. 1). As in *A. fucata*, pollen was collected on herbs, shrubs and trees (Tabs 1, 2). Important host plant taxa, whose pollen contributed 10% or more to the total pollen grain volume, were *Gentiana* (Gentianaceae), *Saxifraga* (Saxifragaceae, Fig. 4), *Helianthemum* (Cistaceae), Ericaceae and *Salix* (Salicaceae). As revealed by literature data, label records and field observations, species among these main host plant taxa known to be exploited for pollen are *Gentiana acaulis* L., *G. lutea* L. and *G. punctata* L. (Alfken 1942, Stoeckhert 1954, Dylewska 1987), *Saxifraga aizoides* L., *S. oppositifolia* L., *S. rudolphiana* Hornsch. and *S. sedoides* L. (Frey-Gessner 1899–1907, Alfken 1942, Stoeckhert 1954, Dylewska 1987, 1993, Kreisch 1996, Ebmer 2003, Zettel et al. 2008), *Helianthemum nummularium* (L.) Mill., *Rhododendron ferrugineum* L. (Dylewska 1993), *Vaccinium vitis-idaea* L. (Ebmer 1997) and *Salix helvetica* Vill., *S. reticulata* L. and *S. waldsteiniana* Willd. (Schedl 1982, Ebmer 1997).

***Andrena* (*Cnemidandrena*) *freygessneri* Alfken, 1904**

Andrena freygessneri collected the pollen of 10 plant families (Tab. 1). However, it exhibited a strong preference for Crassulaceae. Field observations indicate that species of *Sempervivum*, such as *S. arachnoideum* L., *S. montanum* L. and *S. tectorum* L., are the main or even the exclusive hosts among the Crassulaceae (Fig. 5). As Crassulaceae pollen cannot reliably be assigned to genus level by the method applied in the present study, it cannot be excluded that other Crassulaceae taxa, such as *Sedum*, are occasionally also exploited. The preference for *Sempervivum* as demonstrated by this study is supported by observations by De Beaumont (1958), Ebmer et al. (1994), Ebmer (2001, 2003) and Amiet et al. (2010), who recorded *A. freygessneri* visiting flowers of *Sempervivum* in the Swiss and Austrian Alps.

***Andrena* (*Oreomelissa*) *coitana* (Kirby, 1802)**

Andrena coitana harvested the pollen of 12 plant families (Tab. 1). More than 95% of the pollen recorded in the female scopae originated from herbs (Tabs 1, 2), suggesting that the species usually does not collect pollen on shrubs and trees except for *Rubus* (Rosaceae), but restricts pollen harvesting to the herbal layer. Important host plant taxa, whose pollen represented more than 10% of the total pollen grain volume, were Asteraceae (Fig. 6), Campanulaceae and Rosaceae. All three subfamilies of the Asteraceae were exploited and *Potentilla* was the most important host among the Rosaceae. Literature data, label records and field observations indicate that among the Campanulaceae flowers of *Campanula*, *Jasione* and *Phyteuma* are all exploited for pollen (Tab. 2). Chambers (1968) and Westrich (1989) list pollen hosts belonging to five and seven plant families, respectively, among which only Caryophyllaceae were not recorded in the pollen loads analysed in the present study.

***Panurginus herzi* Morawitz, 1891**

Panurginus herzi exclusively collected pollen on *Potentilla* (Rosaceae) except for two specimens, whose pollen loads additionally contained marginal amounts of pollen of *Helianthemum* (Cistaceae) and *Vaccinium* (Ericaceae), respectively (Tab. 1). Field observations revealed that *Potentilla aurea* L. and *P. erecta* (L.) Raeusch. are among the most important pollen hosts in the Swiss Alps (Fig. 7). These results are in line with Vögeli (2001), who supposed *P. herzi* to be a *Potentilla* oligolege, and with Romankova and Astafurova (2011), who mention a flower visiting record of *P. herzi* on *Potentilla chrysantha* Trevir. in western Siberia.

***Panurginus montanus* Giraud, 1861**

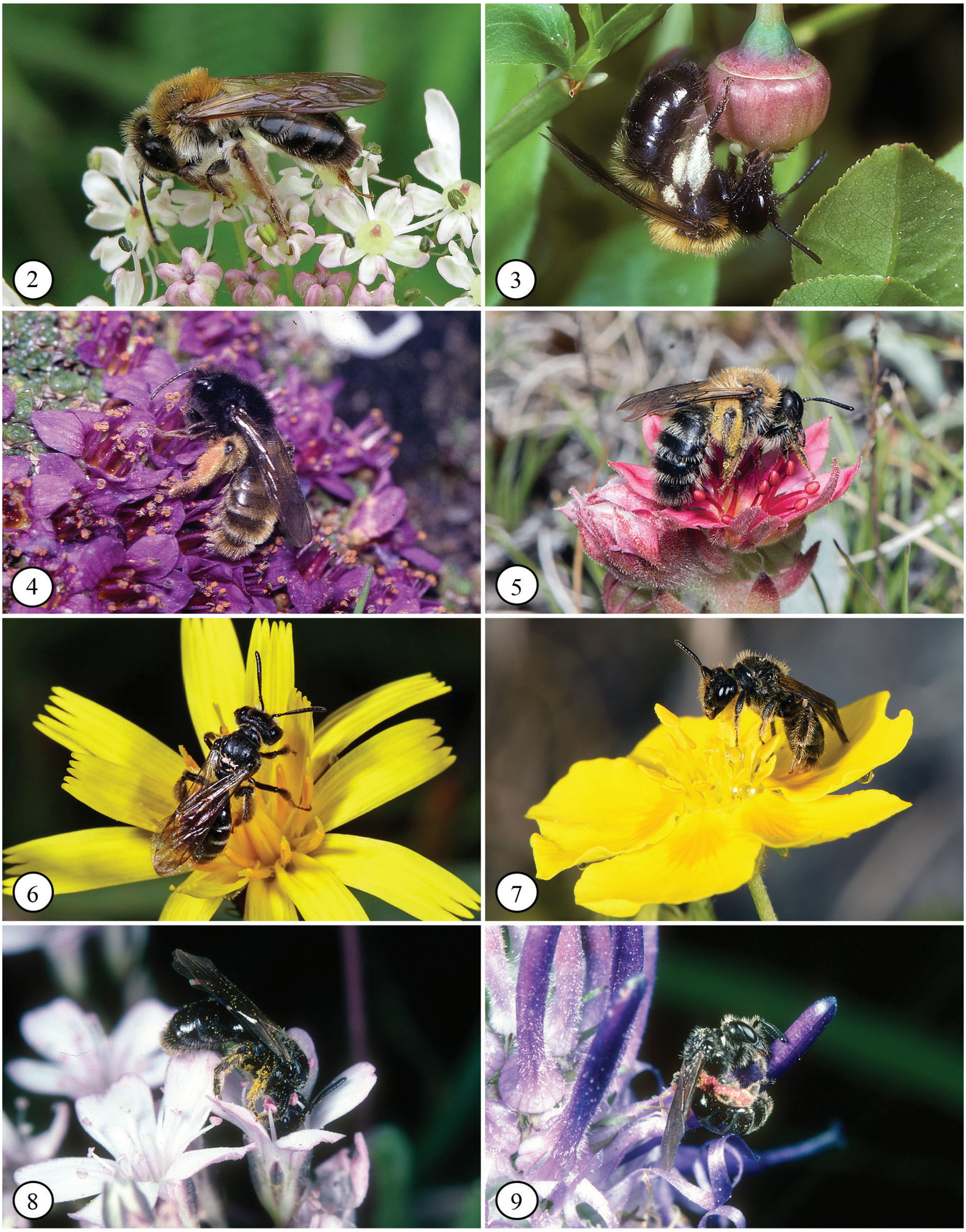
Panurginus montanus had a distinctly broader diet than *P. herzi* and collected the pollen of 10 plant families (Tab. 1, Fig. 8). *Potentilla* (Rosaceae) and *Helianthemum* (Cistaceae) were by far the most important hosts. Pollen of these two taxa contributed 89.7% to the total pollen grain volume. As numerous pollen loads contained mixtures of *Potentilla* and *Helianthemum* pollen, the existence of two cryptic species each specialized to a different host can be excluded. The results of this study contradict the assumption that *P. montanus* is specialized to Asteraceae (Westrich 1989). Blüthgen (1952) observed several females visiting the flowers of *Geranium sylvaticum* L. (Geraniaceae), suggesting that *Geranium* might be an additional pollen host.

***Dufourea alpina* Morawitz, 1865**

Dufourea alpina collected the pollen of 7 plant families (Tab. 1), but exhibited a strong preference for the pollen of Campanulaceae (Fig. 9). Field observations showed that among the Campanulaceae flowers of both *Campanula* and *Phyteuma* are exploited for pollen. These results support Friese (1898) and Westrich (1989), who assumed a preference of pollen collecting females of *D. alpina* for *Phyteuma* and *Campanula*, respectively.

***Dufourea paradoxa* (Morawitz, 1867)**

Dufourea paradoxa had a distinctly broader diet than *D. alpina* and collected the pollen of 13 plant families, among which Crassulaceae, Orobanchaceae and Lamiaceae predominated (Tab. 1). Pollen of these three plant families contributed 63.7% to the total pollen grain volume. Literature data, label records and field observations indicate



Figures 2–9. (**2**) *Andrena fucata* on Apiaceae spec. (photo S. Falk). (**3**) *Andrena lapponica* on *Vaccinium myrtillus* L. (photo P. Westrich). (**4**) *Andrena rogenhoferi* on *Saxifraga rudolphiana* Hornsch. (photo W. Kreisch). (**5**) *Andrena freygessneri* on *Sempervivum arachnoideum* L. (photo D. Bénon, www.swisswildbees.ch). (**6**) *Andrena coitana* on *Leontodon autumnalis* L. (photo H.-J. Martin). (**7**) *Panurginus herzi* on *Potentilla aurea* L. (**8**) *Panurginus montanus* on *Gypsophila repens* L. (**9**) *Dufourea alpina* on *Phyteuma betonicifolium* Vill.

Table 2. Confirmed or most probable pollen host genera of 19 predominantly alpine bee species of the genera *Andrena* and *Panurginus* (Andrenidae), *Dufourea* (Halictidae) and *Megachile*, *Hoplitis* and *Osmia* (Megachilidae) based on the present study (= p.s.) and the literature. Subgeneric classification according to Michener (2007). The plant families are arranged according to their significance in the species' pollen host spectrum (see Tab. 1), the plant genera within each family are arranged in alphabetical order.

Bee species	Pollen host genera
Andrena (*Andrena*) *fucata* Smith, 1847	**Rosaceae:** *Crataegus* (Stoeckhert 1933, BWARS 2018), *Fragaria* (Dylewska 1987), *Potentilla* (Chambers 1968, Westrich 1989, p.s.), *Prunus* (BWARS 2018), *Rosa* (Chambers 1968, Westrich 1989, Dylewska 1993), *Rubus* (Alfken 1913, Stoeckhert 1933, Chambers 1968, Westrich 1989, Dylewska 1993, Ebmer 2003, Amiet et al. 2010), *Sanguisorba* (p.s.); **Apiaceae:** *Chaerophyllum* (Chambers 1968, Westrich 1989); *Oenanthe* (BWARS 2018); **Cistaceae:** *Helianthemum* (Chambers 1968, Westrich 1989, p.s.); **Caprifoliaceae:** *Lonicera* (p.s.); **Plantaginaceae:** *Plantago* (p.s.), *Veronica* (Chambers 1968, Westrich 1989); **Brassicaceae:** *Barbarea* (Chambers 1968, Westrich 1989), *Brassica* (Westrich 1989), *Sinapis* (Chambers 1968, Westrich 1989); **Campanulaceae:** *Jasione* (Stoeckhert 1933); **Polygonaceae:** *Polygonum* (p.s.), *Rumex* (Chambers 1968); **Ranunculaceae:** *Ranunculus* (Chambers 1968, Westrich 1989); **Aceraceae:** *Acer* (Wood and Roberts 2017, p.s.); **Aquifoliaceae:** *Ilex* (Wood and Roberts 2017, p.s.); **Cornaceae:** *Cornus* (p.s.); **Asteraceae:** *Crepis* (Dylewska 1987), *Taraxacum* (Dylewska 1987), *Tussilago* (Frey-Gessner 1899–1907); **Ericaceae:** *Vaccinium* (BWARS 2018, p.s.); **Euphorbiaceae:** *Euphorbia* (BWARS 2018, p.s.); **Santalaceae:** *Thesium* (p.s.); **Rhamnaceae:** *Frangula* (Stoeckhert 1933); **Berberidaceae:** *Berberis* (Stoeckhert 1933, Dylewska 1987); **Primulaceae:** *Lysimachia* (BWARS 2018).
Andrena (*Andrena*) *lapponica* Morawitz, 1872	**Ericaceae:** *Rhododendron* (Frey-Gessner 1899–1907, Pittioni and Schmidt 1943, Dylewska 1993, p.s.), *Vaccinium* (Frey-Gessner 1899–1907, Stoeckhert 1933, Westrich 1989, Dylewska 1993, p.s.); **Rosaceae:** *Filipendula* (Pittioni and Schmidt 1943), *Geum* (p.s.), *Potentilla* (p.s.), *Rosa* (Dylewska 1993), *Rubus* (Ebmer 2003); **Asteraceae:** *Hieracium* (Dylewska 1993), *Taraxacum* (Dylewska 1993, Westrich 1989); **Pyrolaceae:** *Moneses* (p.s.); **Cistaceae:** *Helianthemum* (Ebmer 2003, Gogala 2011, p.s.); **Primulaceae:** *Soldanella* (p.s.); **Oxalidaceae:** *Oxalis* (p.s.); **Salicaceae:** *Salix* (Dylewska 1993, Gogala 2011, p.s.); **Plantaginaceae:** *Plantago* (p.s.); *Veronica* (Westrich 1989); **Saxifragaceae:** *Saxifraga* (Frey-Gessner 1899–1907, p.s.); **Aceraceae:** *Acer* (p.s.).
Andrena (*Andrena*) *rogenhoferi* Morawitz, 1872	**Gentianaceae:** *Gentiana* (Alfken 1942, Stoeckhert 1954, Dylewska 1987, p.s.); **Saxifragaceae:** *Saxifraga* (Frey-Gessner 1899–1907, Alfken 1942, Stoeckhert 1954, Dylewska 1987, 1993, Kreisch 1996, Ebmer 2003, Zettel et al. 2008, p.s.); **Cistaceae:** *Helianthemum* (Ebmer 2003, p.s.); **Ericaceae:** *Rhododendron* (Frey-Gessner 1899–1907, Dylewska 1987, 1993, Westrich 1989, p.s.), *Vaccinium* (Ebmer 1997, p.s.); **Salicaceae:** *Salix* (Schedl 1982, Dylewska 1993, Ebmer 1997, Gogala 2011 p.s.); **Rosaceae:** *Dryas* (Ebmer 2003, Zettel et al. 2008), *Geum* (p.s.), *Potentilla* (Franz 1982, p.s.), *Rosa* (Gogala 2011); **Aceraceae:** *Acer* (Westrich 1989, p.s.); **Tiliaceae:** *Tilia* (p.s.); **Apiaceae:** *Astrantia* (Zettel et al. 2008); **Ranunculaceae:** *Pulsatilla* (p.s.); **Berberidaceae:** *Berberis* (Frey-Gessner 1899–1907, Dylewska 1987, 1993, p.s.); **Asteraceae:** *Taraxacum* (Trautmann and Trautmann 1924, Ebmer 1997); **Caprifoliaceae:** *Lonicera* (p.s.); **Rhamnaceae:** *Frangula* (p.s.).
Andrena (*Cnemidandrena*) *freygessneri* Alfken, 1904	**Crassulaceae:** *Sempervivum* (De Beaumont 1958, Ebmer et al. 1994, Ebmer 2001, 2003, Amiet et al. 2010, p.s.); **Saxifragaceae:** *Saxifraga* (Frey-Gessner 1899–1907, p.s); **Cistaceae:** *Helianthemum* (Ebmer 2001, p.s.); **Lamiaceae:** *Thymus* (p.s.); **Rosaceae:** *Potentilla* (p.s.); **Ericaceae:** *Calluna* (p.s.).
Andrena (*Oreomelissa*) *coitana* (Kirby, 1802)	**Asteraceae:** *Achillea* (Peeters et al. 2012), *Centaurea* (Stoeckhert 1933, Chambers 1968, Dylewska 1993, Westrich 1989, Falk and Lewington 2015), *Cichorium* (Stoeckhert 1933, Westrich 1989), *Cirsium* (Chambers 1968, Westrich 1989, Falk and Lewington 2015), *Crepis* (Chambers 1968, Westrich 1989, Falk and Lewington 2015), *Hieracium* (Stoeckhert 1933, Dylewska 1993), *Hypochoeris* (Falk and Lewington 2015), *Leontodon* (Chambers 1968, Westrich 1989, Dylewska 1993), *Picris* (Westrich 1989), *Senecio* (Falk and Lewington 2015), *Solidago* (Stoeckhert 1933); **Campanulaceae:** *Campanula* (Stoeckhert 1933, Chambers 1968, Westrich 1989, Falk and Lewington 2015), *Jasione* (Westrich 1989), *Phyteuma* (p.s.); **Rosaceae:** *Potentilla* (Stoeckhert 1933, Westrich 1989, Falk and Lewington 2015, p.s), *Rosa* (Dylewska 1993), *Rubus* (Stoeckhert 1933, Chambers 1968, Peeters et al. 2012), *Sanguisorba* (p.s.); **Cistaceae:** *Helianthemum* (p.s.); **Apiaceae:** *Angelica* (Westrich 1989, Peeters et al. 2012), *Daucus* (Stoeckhert 1933, Westrich 1989), *Heracleum* (Stoeckhert 1933, Chambers 1968, Westrich 1989, Falk and Lewington 2015); **Lamiaceae:** *Prunella* (Stoeckhert 1933), *Salvia* (Westrich 1989); **Orobanchaceae:** *Euphrasia* (Stoeckhert 1933, Westrich 1989, p.s.); **Plantaginaceae:** *Plantago* (p.s.), *Veronica* (p.s.); **Gentianaceae:** *Centaurium* (Chambers 1968); **Ranunculaceae:** *Ranunculus* (Falk and Lewington 2015); **Caryophyllaceae:** *Dianthus* (Westrich 1989), *Stellaria* (Falk and Lewington 2015).
Panurginus herzi Morawitz, 1891	**Rosaceae:** *Potentilla* (p.s.); **Cistaceae:** *Helianthemum* (p.s.); **Ericaceae:** *Vaccinium* (p.s.)
Panurginus montanus Giraud, 1861	**Rosaceae:** *Potentilla* (Dylewska 1993, p.s.); **Cistaceae:** *Helianthemum* (p.s.); **Ranunculaceae:** *Ranunculus* (Dylewska 1993); **Orobanchaceae:** *Euphrasia* (p.s.); **Caryophyllaceae:** *Gypsophila* (p.s.); **Saxifragaceae:** *Saxifraga* (p.s.); **Asteraceae:** *Hieracium* (Dylewska 1993), *Leontodon* (Dylewska 1993).
Dufourea alpina Morawitz, 1865	**Campanulaceae:** *Campanula* (Ebmer 1984, Westrich 1989, Dylewska 1993, p.s.), *Phyteuma* (Friese 1898, Ebmer 2003, Bossert 2014, p.s.); **Asteraceae:** *Hieracium* (Ebmer 1984, Westrich 1989), *Leontodon* (Schedl 1982, Bossert 2014), *Solidago* (Stoeckhert 1954); **Orobanchaceae:** *Euphrasia* (p.s.); **Cistaceae:** *Helianthemum* (p.s.); **Lamiaceae:** *Acinos* (Ebmer 1984), *Thymus* (Ebmer 1984); **Linaceae:** *Linum* (p.s.).
Dufourea paradoxa (Morawitz, 1867)	**Crassulaceae:** *Sempervivum* (p.s.); **Orobanchaceae:** *Euphrasia* (Friese 1898, Ebmer 2003, p.s.); **Lamiaceae:** *Thymus* (p.s.); **Asteraceae:** *Hieracium* (Frey-Gessner 1899–1907, Ebmer 1984, Dylewska 1993), *Leontodon* (Bossert 2014); **Cistaceae:** *Helianthemum* (p.s.); **Caryophyllaceae:** *Silene* (Friese 1898); **Rosaceae:** *Potentilla* (Dylewska 1993, p.s.); **Primulaceae:** *Soldanella* (p.s.); **Saxifragaceae:** *Saxifraga* (p.s.); **Salicaceae:** *Salix* (p.s.); **Campanulaceae:** *Phyteuma* (Ebmer 1984); **Plantaginaceae:** *Veronica* (Friese 1898).
Megachile (*Megachile*) *alpicola* Alfken, 1924	**Fabaceae:** *Lathyrus* (Dorn and Weber 1988, p.s.), *Lotus* (Stoeckhert 1933, Dorn and Weber 1988, Westrich 1989, p.s.), *Medicago* (Dorn and Weber 1988, p.s.), *Trifolium* (p.s.), *Vicia* (Dorn and Weber 1988, p.s.); **Asteraceae:** *Centaurea* (Dylewska 1993), *Cirsium* (Westrich 1989), *Hieracium* (Westrich 1989), *Leontodon* (Westrich 1989, Dylewska 1993); **Cistaceae:** *Helianthemum* (p.s.); **Asparagaceae:** *Anthericum* (p.s.); **Ranunculaceae:** *Ranunculus* (Dorn and Weber 1988); **Clusiaceae:** *Hypericum* (p.s.); **Orobanchaceae:** *Odontites* (p.s.); **Plantaginaceae:** *Plantago* (Westrich 1989), *Veronica* (p.s.); **Alliaceae:** *Allium* (p.s.); **Rosacae:** *Potentilla* (p.s.); **Dipsacaceae:** *Scabiosa*) (p.s.); **Lamiaceae:** *Thymus* (Stoeckhert 1933, Dorn and Weber 1988, Westrich 1989); **Salicaceae:** *Salix* (p.s.).
Megachile (*Xanthosarus*) *analis* Nylander, 1852	**Campanulaceae:** *Campanula* (Alfken 1913, Stoeckhert 1933, Dorn and Weber 1988, Westrich 1989, p.s.), *Phyteuma* (p.s.); **Fabaceae:** *Hippocrepis* (p.s.), *Lotus* (Alfken 1913, Stoeckhert 1933, Dorn and Weber 1988, Westrich 1989, p.s.), *Onobrychis* (Westrich 1989, p.s.), *Trifolium* (Dorn and Weber 1988, Westrich 1989), *Vicia* (Dorn and Weber 1988); **Cistaceae:** *Helianthemum* (p.s.); **Orobanchaceae:** *Odontites* (p.s.); **Resedaceae:** *Reseda* (p.s.); **Ericaceae:** *Erica* (Alfken 1913, Benno 1952, Dorn and Weber 1988, Westrich 1989).
Hoplitis (*Anthocopa*) *villosa* (Schenck, 1853)	**Asteraceae:** *Centaurea* (Stoeckhert 1954, Franz 1982, Westrich 1989, p.s.), *Cichorium* (Westrich 1989), *Cirsium* (Westrich 1989), *Crepis* (Westrich 1989), *Hieracium* (Westrich 1989), *Leontodon* (Westrich 1989, Dylewska 1993, Bossert 2014), *Picris* (Westrich 1989), *Tanacetum* (Westrich 1989), *Tragopogon* (Zettel et al. 2005); **Geraniaceae:** *Geranium* (p.s); **Cistaceae:** *Helianthemum* (p.s.).
Osmia (*Helicosmia*) *labialis* Pérez, 1879	**Asteraceae:** *Carduus* (Tkalců 1975, Ebmer 2001, Herrmann 2010), *Centaurea* (Ebmer 2001, Herrmann 2010, Kraus 2010, p.s.), *Hieracium* (Ebmer 2001); **Cistaceae:** *Helianthemum* (p.s.).
Osmia (*Melanosmia*) *alticola* Benoist, 1922	**Fabaceae:** *Anthyllis* (p.s.), *Hippocrepis* (p.s.), *Lotus* (p.s.), *Trifolium* (p.s.).

Bee species	Pollen host genera
Osmia (*Melanosmia*) *inermis* (Zetterstedt, 1838)	**Fabaceae:** *Anthyllis* (p.s.), *Astragalus* (Elfving 1968), *Hippocrepis* (Stoeckhert 1933, Westrich 1989, p.s.), *Lotus* (Frey-Gessner 1908–1912, Schedl 1982, Westrich 1989, p.s.), *Onobrychis* (Westrich 1989); **Ericaceae:** *Vaccinium* (Elfving 1968, Hicks 2009, Stoeckhert 1933, Westrich 1989, p.s.); **Rosaceae:** *Geum* (Elfving 1968, Schedl 1982), *Potentilla* (Frey-Gessner 1908–1912, p.s.); **Salicaceae:** *Salix* (Stubbs in Hicks 2009).
Osmia (*Melanosmia*) *parietina* Curtis, 1828	**Fabaceae:** *Anthyllis* (p.s.), *Hippocrepis* (Stoeckhert 1933, Westrich 1989, p.s.), *Lotus* (Westrich 1989, p.s.), *Trifolium* (Blüthgen 1952, p.s.); **Lamiaceae:** *Ajuga* (Stoeckhert 1933); **Cistaceae:** *Helianthemum* (p.s.); **Rosaceae:** *Fragaria* (Blüthgen 1952), *Potentilla* (p.s.); **Crassulaceae:** *Sedum* (Westrich 1989).
Osmia (*Melanosmia*) *steinmanni* Müller, 2002	**Fabaceae:** *Hippocrepis* (p.s.), *Lotus* (p.s.), *Trifolium* (p.s.); **Ericaceae:** *Rhododendron* (p.s.).
Osmia (*Melanosmia*) *uncinata* Gerstaecker, 1869	**Fabaceae:** *Anthyllis* (p.s.), *Hippocrepis* (Westrich 1989, p.s.), *Lotus* (Stoeckhert 1933, Westrich 1989, Dylewska 1993, p.s.), *Lathyrus* (Stoeckhert 1933, Westrich 1989, p.s.), *Medicago* (p.s.), *Onobrychis* (Westrich 1989, p.s.), *Trifolium* (Westrich 1989, p.s.), *Vicia* (Westrich 1989, p.s.); **Rosaceae:** *Fragaria* (Stoeckhert 1933, *Potentilla* (Stoeckhert 1933, Westrich 1989, p.s.), *Rosa* (Stoeckhert 1933), *Rubus* (Westrich 1989); **Lamiaceae:** *Ajuga* (Stoeckhert 1933), *Glechoma* (Westrich 1989), *Salvia* (Westrich 1989); **Plantaginaceae:** *Plantago* (p.s.), *Veronica* (p.s.); **Alliaceae:** *Allium* (p.s.); **Ranunculaceae:** *Ranunculus* (Westrich 1989); **Caprifoliaceae:** *Lonicera* (p.s.); **Boraginaceae:** *Echium* (p.s.), *Pulmonaria* (Westrich 1989); **Cistaceae:** *Helianthemum* (Westrich 1989, p.s.); **Asteraceae:** *Hieracium* (Stoeckhert 1933), *Leontodon* (Dylewska 1993), *Taraxacum* (Stoeckhert 1933, Westrich 1989); **Cornaceae:** *Cornus* (Westrich 1989); **Ericaceae:** *Vaccinium* (Stoeckhert 1933, Westrich 1989); **Salicaceae:** *Salix* (Stoeckhert 1933, Westrich 1989).
Osmia (*Melanosmia*) *xanthomelana* (Kirby, 1802)	**Fabaceae:** *Hippocrepis* (Stoeckhert 1933, Westrich 1989, p.s.), *Lotus* (Stoeckhert 1933, Westrich 1989, p.s.).

that among these three families flowers of *Sempervivum*, *Euphrasia* and *Thymus*, respectively, are the most important pollen hosts. In strong contrast to *Dufourea alpina*, flowers of Campanulaceae are only exceptionally exploited. Friese (1898) observed females visiting the flowers of *Veronica* (Plantaginaceae), suggesting that this genus is probably an additional pollen source.

Megachile (*Megachile*) *alpicola* Alfken, 1924

Megachile alpicola collected the pollen of 16 plant families (Tab. 1). Almost 75% of the pollen recorded in the female scopae originated from the flowers of Fabaceae and Asteraceae (Fig. 10). Among the Fabaceae, *Lotus* was by far the most important host, but pollen was also collected on several other genera. Among the Asteraceae, species of all three subfamilies were exploited for pollen. The four plant families listed by Westrich (1989) as pollen hosts were all confirmed in the present study.

Megachile (*Xanthosarus*) *analis* Nylander, 1852

Megachile analis had a distinctly narrower pollen diet than *M. alpicola* and restricted pollen collection mainly to species of Campanulaceae and Fabaceae (Tab. 1). Pollen of these two plant families contributed 95.3% to the total pollen grain volume. Field observations revealed that among the Campanulaceae both *Campanula* and *Phyteuma* are exploited for pollen. Among the Fabaceae, *Lotus* was by far the most important host, but pollen was also collected on other genera, such as *Hippocrepis* or *Onobrychis*. The strong preference of *M. analis* for Campanulaceae and Fabaceae as found in the present study conforms to field observations and pollen analytical studies by other authors (Alfken 1913, Benno 1952, Westrich 1989). In northern Europe, *M. analis* often visits the flowers of *Erica tetralix* L. (Ericaceae), which are forcefully exploited for nectar and possibly also serve as pollen source (Alfken 1913, Benno 1952, Haeseler 1980). In the pollen loads from the Alps, however, no pollen of Ericaceae was recorded.

Hoplitis (*Anthocopa*) *villosa* (Schenck, 1853)

Hoplitis villosa almost exclusively collected pollen on Asteraceae. In seven pollen loads, however, pollen of *Helianthemum* (Cistaceae) or *Geranium* (Geraniaceae) was recorded in addition to that of Asteraceae (Tab. 1), suggesting that pollen is rarely harvested also on plant taxa other than Asteraceae. Among Asteraceae, species of the subfamily Cichorioideae were by far the most important pollen hosts (Fig. 11), followed by representatives of the subfamily Carduoideae, whereas pollen of the subfamily Asteroideae was only exceptionally collected. These results are in line with pollen analytical studies by Westrich (1989), who categorized *H. villosa* as an Asteraceae oligolege that preferentially exploits species of the Cichorioideae.

Osmia (*Helicosmia*) *labialis* Pérez, 1879

Osmia labialis exclusively collected pollen on Asteraceae except for one specimen, whose pollen load additionally contained marginal amounts of pollen of *Helianthemum* (Cistaceae) (Tab. 1). Among the Asteraceae, it showed a near exclusive preference for pollen of the Carduoideae (Fig. 12) and only very rarely collected pollen on Cichorioideae and Asteroideae. All published flower records of *O. labialis* refer to species of the Carduoideae (Tkalců 1975, Ebmer 2001, Herrmann 2010, Kraus 2010), supporting the high importance of this subfamily in the species' larval diet. *O. labialis* appears to have a narrower pollen diet than its closest relative *Osmia leaiana* (Kirby), which also restricts pollen collection to the Asteraceae, but often also exploits Cichorioideae in addition to Carduoideae (Raw 1974, Westrich 1989, A. Müller unpublished data).

Osmia (*Melanosmia*) *alticola* Benoist, 1922

Osmia alticola exclusively harvested pollen on Fabaceae (Tab. 1). In contrast to the closely related *O. xanthomelana*, which only collected the pollen of *Hippocrepis* and *Lotus* (see below), the diet of *O. alticola* was broader and encompassed the pollen of additional Fabaceae genera, such as *Anthyllis*, *Trifolium* and others. Due to the low number of pollen samples available, the categorization of *O. alticola* as a Fabaceae oligolege (Tab. 1) may appear premature. However, the fact that eight out of the 16 pollen loads analyzed consisted of mixtures of pollen of several Fabaceae genera clearly points to a strict pollen specialization at the family level.

***Osmia* (*Melanosmia*) *inermis* (Zetterstedt, 1838)**

Osmia inermis collected the pollen of four plant families, but exhibited a strong preference for Loteae, particularly for *Lotus* and *Hippocrepis* (Tab. 1). These results are in line with Westrich (1989), who categorized *O. inermis* as being narrowly polylectic with a preference for Fabaceae, but do not support Stoeckhert (1933), who assumed *Vaccinium* to be the preferred pollen host. In Atlantic Canada and the northeastern United States, however, the species appears to be dependent primarily on Ericaceae (Hicks 2009). There, it occasionally also collects pollen on *Salix* (Salicaceae) (Stubbs in Hicks 2009).

***Osmia* (*Melanosmia*) *parietina* Curtis, 1828**

Osmia parietina harvested the pollen of five plant families (Tab. 1). However, it exhibited a strong preference for Loteae, particularly for *Lotus* and *Hippocrepis* (Tab. 1, Fig. 13). Among the Fabaceae, *Trifolium* was also regularly exploited; its pollen was recorded in eleven pollen loads and contributed 7.4% to the total pollen grain volume. *Sedum* (Crassulaceae) is listed as an additional pollen source by Westrich (1989), and *Veronica* (Plantaginaceae) might possibly be a further pollen host based on the observations by Blüthgen (1952).

***Osmia* (*Melanosmia*) *steinmanni* Müller, 2002**

Osmia steinmanni had a strong affinity for Fabaceae (Tab. 1) and collected pollen mainly on *Hippocrepis* and *Lotus*, more rarely on *Trifolium*. One load additionally contained substantial amounts of pollen of *Rhododendron* (Ericaceae). In spite of the low number of pollen loads available, these findings suggest that *O. steinmanni* has very similar pollen host preferences as its close relative *O. inermis* (see above). More pollen loads are needed both to clarify the significance of Ericaceae in the pollen diet of *O. steinmanni* and to examine whether pollen of plant families other than Fabaceae and Ericaceae is occasionally also harvested.

***Osmia* (*Melanosmia*) *uncinata* Gerstaecker, 1869**

Osmia uncinata harvested the pollen of eleven plant families (Tab. 1), but exhibited a strong preference for Fabaceae, which - however - was less pronounced than in the other *Osmia* species of the subgenus *Melanosmia* investigated in the present study. Among the Fabaceae, *Lotus*, *Hippocrepis* and *Trifolium* were the predominant pollen sources, but other Fabaceae genera were also exploited. Moderately important pollen hosts were species of Rosaceae and Lamiaceae, whose pollen contributed about 10% and 7%, respectively, to the total pollen grain volume (Fig. 14). Thus, *O. uncinata* is the least specialized species of the subgenus *Melanosmia* both in terms of the number of plant families and the number of Fabaceae genera exploited. Westrich (1989) lists pollen hosts belonging to ten plant families, among which Asteraceae, Cornaceae, Ericaceae and Salicaceae were not recorded in the pollen loads analysed in the present study. Based on the observations by Stoeckhert (1933), pollen might occasionally also be collected on *Polygala* (Polygalaceae) and *Viola* (Violaceae).

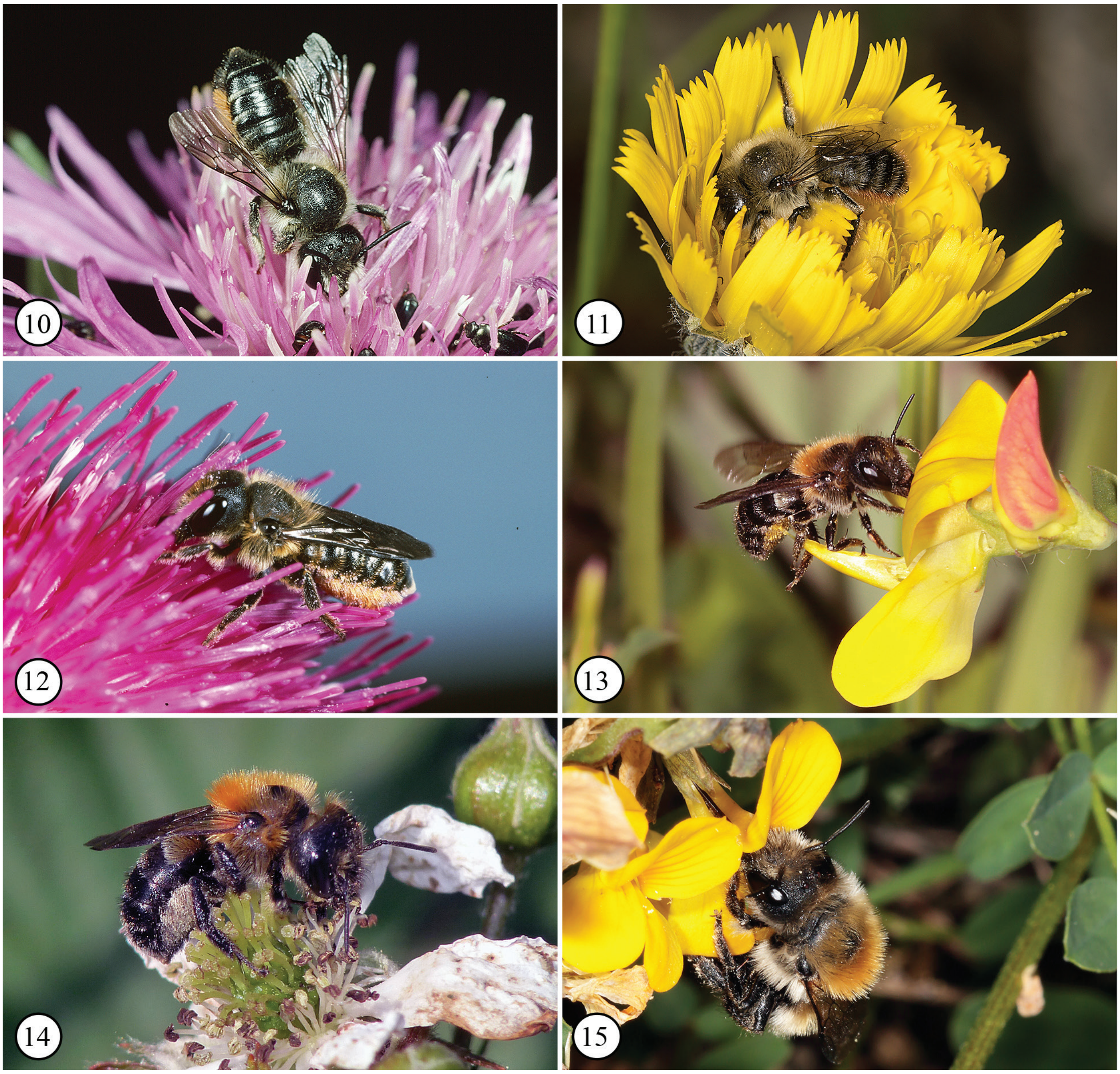
***Osmia* (*Melanosmia*) *xanthomelana* (Kirby, 1802)**

Osmia xanthomelana exclusively collected pollen on *Hippocrepis* and *Lotus* (Fabaceae) (Tab. 1, Fig. 15), rendering this species the most specialized among the *Osmia* (*Melanosmia*) species examined in the present study. The strict dependence of *O. xanthomelana* on only two Fabaceae genera of the tribe Loteae was already supposed by Westrich (1989). In contrast, the assumption of Stoeckhert (1933) that *O. xanthomelana* also harvests pollen on other taxa than *Hippocrepis* and *Lotus* is not supported by the results of the present study.

Discussion

The 19 bee species investigated in the present study widely vary in their pollen host spectra and degree of host plant specialization, revealing a fascinating diversity in bee pollen host use (Tab. 1). The examined set of species encompasses i) narrowly oligolectic species, which exclusively collect pollen on a single plant genus, ii) broadly oligolectic species, which harvest pollen on a single plant family, iii) mesolectic species, which are dependent on two plant families, iv) polylectic species, which exhibit a strong but not exclusive preference for a single plant taxon, and v) polylectic species, which do not prefer any single plant taxon and exploit up to 17 different plant families.

Comparison of pollen host use among closely related species of the same subgenus or the same monotypic genus reveals different patterns (see species accounts above and Tab. 1). The six *Osmia* species of the subgenus *Melanosmia* all exhibit a pronounced affinity for the pollen of Fabaceae, supporting other studies which demonstrated that host plant preferences are often conserved in clades of closely related bee species (Müller 1996, Wcislo and Cane 1996, Michez et al. 2004, Sipes and Tepedino 2005, Patiny et al. 2007, Larkin et al. 2008, Michez et al. 2008, Sedivy et al. 2008, 2013). However, the degree of dependence on Fabaceae pollen differs among the *O.* (*Melanosmia*) species, ranging from a narrow specialization on Fabaceae as in *O. xanthomelana*, which collects pollen solely from the flowers of two closely related Fabaceae genera, to a moderately strong dependence on Fabaceae as in *O. uncinata*, which exploits the flowers of at least 14 additional plant families. In contrast to *O.* (*Melanosmia*), the three *Andrena* species of the subgenus *Andrena* wide-



Figures 10–15. (**10**) *Megachile alpicola* on *Centaurea jacea* L. (photo A. Krebs). (**11**) *Hoplitis villosa* on *Taraxacum* spec. (photo P. Westrich). (**12**) *Osmia labialis* on *Carduus nutans* L. (photo A. Krebs). (**13**) *Osmia parietina* on *Lotus corniculatus* L. (photo R. Prosi). (**14**) *Osmia uncinata* on *Rubus* spec. (photo A. Jacobs). (**15**) *Osmia xanthomelana* on *Hippocrepis comosa* L. (photo R. Prosi).

ly differ in their pollen host use as do the two *Dufourea* species. While the differences between *A. fucata* and *A. rogenhoferi* are potentially due to deviating distribution and habitat selection with *A. fucata* restricted to forested areas of the montane and subalpine zone and *A. rogenhoferi* colonizing a wide spectrum of habitats from the submontane to the alpine zone (SwissBeeTeam 2018), the pronounced preference of *A. lapponica* for Ericaceae pollen might possibly be genetically based as it is the case for other bee species with a specialized diet (Praz et al. 2008). A genetic basis for the differing pollen host choice is also suggested for the two *Dufourea* species, which often colonize the same habitats in the Alps, where they encounter a similar flower supply but nevertheless collect the pollen of different plant taxa. For both *Panurginus* species, pollen of *Potentilla* (Rosaceae) plays an important role in the larval diet. Interestingly, *P. herzi* is entirely dependent on *Potentilla*, whereas *P. montanus* is capable of exploiting several additional hosts. If future studies show that the polylectic habit of *P. montanus* is evolutionary derived, this would support the view that many generalist bee species that evolved from specialized ancestors had broadened their diet under maintenance of the exclusive host of their ancestors (Sedivy et al. 2008).

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New records of Agromyzidae (Diptera) from Switzerland and an updated checklist

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Abstract

Here, we investigate about 5500 previously unidentified specimens from the collection of Gerhard Bächli. A total of 108 agromyzid species were added to the fauna of Switzerland. Consequently, the species richness of the Swiss agromyzids was increased to 395 species. The checklist of Agromyzidae of Switzerland was updated, and the complete list presented in appendix.

Key Words

Agromyzidae
Diptera
new record
distribution
host plants
Switzerland
checklist

Introduction

The acalyptrate Diptera family Agromyzidae (leaf miner flies) is economically important because a rather large number of its species are known to damage crop plants (Spencer 1973). It is one of the largest families in the Order Diptera, containing more than 930 species in Europe and more than 3050 worldwide. However, according to the Swiss Diptera checklist (Martinez 1998) and the three supplements (Merz et al. 2001, 2006; Bächli et al. 2014), only 280 species are listed for Switzerland. This number is obviously rather low and even as much as 20 years ago Martinez (1998), who listed only 140 species, stated that the Swiss fauna was poorly known. Since then, Černý (2005a, 2009, 2013) and Černý and Merz (2005, 2006, 2007, 2012) have improved the situation by studying additional collections.

One of the reasons why agromyzid flies are poorly studied is that in most cases, only males can be identified based on the basis of very laborious preparations of terminalia. In addition, many species have been named solely on the plant species from which they emerged. Many more species lack even this information because they were described on the basis of specimens collected by standard methods, e.g. netting. For most of these species, their ecology and life history remain unknown.

By studying several thousand specimens of the private collection of G. Bächli, we here aim to improve our knowledge on the local agromyzid fauna. Although this significantly enhances our understanding of the Swiss

Agromyzidae, we feel that much more work needs to be done in order to reach a tenable or even tolerable standard of knowledge.

Material and methods

This study is based on about 5500 specimens (mostly male), of more than 300 species, deposited in the collection of GB. Some duplicates are in the private collection of MČ. Most of the specimens were caught by net sweeping from vegetation and from flowers. Some specimens were accidentally found around *Drosophila* banana baits, in canopy beer-wine traps, etc. In such cases, it is unlikely that they were attracted by the bait, but simply represent by-catch. All material was stored at first in alcohol and pinned and dried afterwards. All specimens were collected by GB if not otherwise stated.

Species identification in this group of flies is based almost completely on male genital structures and therefore, females are not taken into account here. In several specimens, it was possible to identify the diagnostic structures of the postabdomen without any preparation. When necessary, male terminalia were studied after detaching them, then softening and macerating the terminalia in hot 10% KOH, washing in water and dissecting the whole abdomen in a droplet of glycerine under a binocular microscope MBS 10-100. After examination, all the parts dissected were placed in a droplet of the medium "glycerin plus gum resin" on a piece of card pinned below the relevant specimen. Some collection details not mentioned on the labels were added in square brackets ([ ]). All the material examined was identified by MČ. The identifications were based on Černý (1992, 2007a,b), Griffiths (1963, 1967, 1972a,b, 1973, 1974, 1976a,b, 1977, 1980), Hendel (1920, 1924, 1931–36), Hering (1925, 1926, 1927, 1928, 1931, 1932), Papp and Černý (2015, 2016, 2017), and Spencer (1964, 1966a,b, 1969, 1972, 1976, 1977, 1990).

The nomenclature used for the Agromyzidae was based on Fauna Europaea (Martinez 2013) and Papp and Černý (2015, 2016, 2017). The host plants were treated according to Spencer (1973, 1990) and Benavent-Corai et al. (2005).

Genera and species were arranged alphabetically in the two subfamilies Agromyzinae and Phytomyzinae.

For host plants, names of genera are given when, as fas known, all respective species were found to be involved. Mentioning early stages may refer to eggs, larvae or puparia.

The localities were grouped according to cantons (districts) of Switzerland (Fig. 1) and the following abbreviations used: **AG** = Aargau; **BE** = Bern; **BL** = Basel-Landschaft; **GE** = Genève; **GL** = Glarus; **GR** = Graubünden; **JU** = Jura; **LU** = Luzern; **NE** = Neuchâtel; **SH** = Schaffhausen; **SO** = Solothurn; **SZ** = Schwyz; **TG** = Thurgau; **TI** = Ticino; **UR** = Uri; **VD** = Vaud; **VS** = Valais; **ZG** = Zug; **ZH** = Zürich.

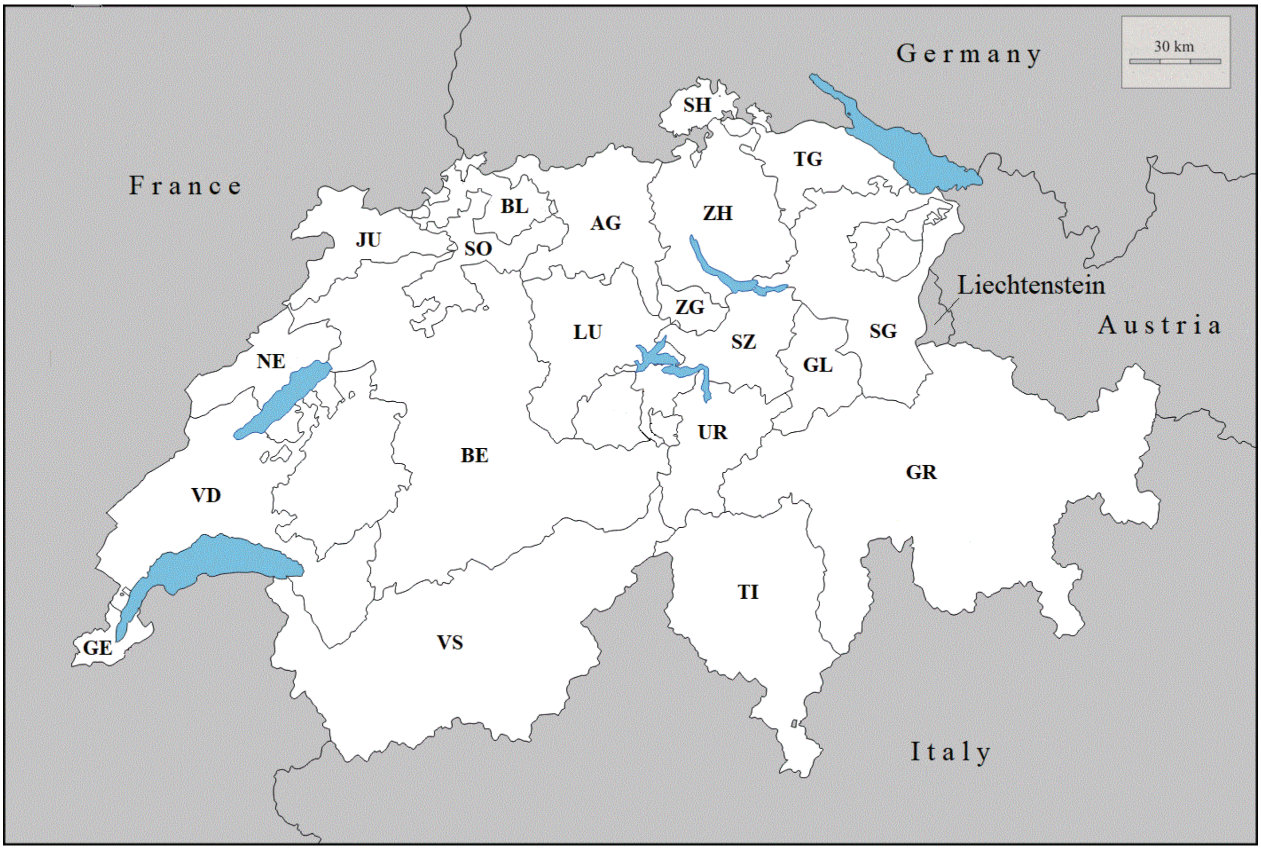

Figure 1. Map showing all the cantons in Switzerland sampled.

List of species

Subfamily Agromyzinae

Agromyza albitarsis Meigen, 1830

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l, banana bait], 1 ♂, 6.–11.vi.1973.

Distribution. Europe: Albania, Austria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece (Černý 2011), Hungary (Papp and Černý 2015), Italy, Lithuania, Netherlands, Norway, Poland, Slovakia, Sweden; Asia: Japan, Turkey. First record from Switzerland.

Biology. Host plants *Populus*, *Salix*.

Agromyza anderssoni Spencer, 1976

Material examined. TI: Biasca [46°21'N, 8°58'E, 300m a.s.l., banana bait], 1 ♂, 16.–20.vi.1995; Bolle di Magadino [46°09'N, 8°52'E, 200m a.s.l., tent trap], 1 ♂, 17.–20.vi.1995, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Estonia, Hungary, Slovakia, Sweden; Asia: South Korea, Turkey (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant unknown.

Agromyza conjuncta Spencer, 1966

Material examined. GR: Scuol [46°48'N, 10°18'E, 1200m a.s.l., banana bait], 1 ♂, 9.–12.viii.1978; Zernez-Gondas [46°42'N, 10°06'E, 1500m a.s.l., banana bait], 1 ♂, 4.–7.viii.1996, B. Merz & G. Bächli leg. **VS**: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 17.vi.1996, B. Merz & G. Bächli leg.; Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 1 ♂, 31.vii.–8.viii.1976. **ZH**: Hönggerberg [47°25'N, 8°30'E, 520m a.s.l., banana bait], 1 ♂, 3.–7.vii.1998.

Distribution. Europe: Belgium, Czech Republic, France, Germany, Great Britain, Greece incl. Crete, Hungary, Italy incl. Sicily, Poland, Portugal (Černý et al. 2018), Serbia, Slovakia, Spain, Sweden (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant unknown.

Agromyza drepanura (Mamonov, 1929)

Material examined. AG: Würenlingen, Bärengraben [47°31'N, 8°15'E, 420m a.s.l.], 1 ♂, 13.v.1998. **GR**: S-chanf-Flin [46°36'N, 9°59'E, 1650m a.s.l.], 1 ♂, 7.viii.1996, B. Merz & G. Bächli leg.; Zuoz-Nüd [46°36'N, 9°58'E, 1700m a.s.l.], 1 ♂, 7.viii.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, France, Germany, Hungary, Russia, Ukraine; Asia: Armenia, Kazakhstan, Kyrgyzstan, Uzbekistan (Nartshuk and von Tschirnhaus 2017, Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Medicago sativa*.

Agromyza filipendulae Spencer, 1976

Material examined. AG: Rheinfelden [47°33'N, 7°48'E, 270m a.s.l.], 1 ♂, 12.vi.2010. **GE**: Jussy, Prés de Villette, 475m a.s.l., [46°14'N, 6°16'E], 1 ♂, 8.viii.2000, B. Merz & G. Bächli leg. **LU**: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006.

Distribution. Europe: Czech Republic, Germany, Great Britain, France, Hungary, Ireland, Latvia, Lithuania, Montenegro, Poland, Norway; Asia: Asian Russia (Nartshuk and von Tschirnhaus 2017, Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Filipendula, Potentilla, Rubus, Sanguisorba*.

Agromyza longiphallus L. Papp in Papp & Černý, 2015

Material examined. GR: Zernez [46°42'N, 10°05'E, 1450m a.s.l., banana bait], 2 ♂♂, 15.–18.viii.1978. **VS**: Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 3 ♂♂, 31.vii.–8.viii.1976.

Distribution. Europe: Slovakia. First record from Switzerland.

Biology. Host plant unknown.

Agromyza seticercus L. Papp in Papp & Černý, 2015

Material examined. GE: Chancy [46°09'N, 5°58'E, 350m a.s.l.], 2 ♂♂, 25.vii.2004.

Distribution. Europe: Hungary. First record from Switzerland.

Biology. Host plant unknown.

Agromyza spenceri Griffiths, 1963

Material examined. VS: Grône, Poutafontana, 500m a.s.l., [46°15'N, 7°27'E], 1 ♂, 1.vii.2001; Pfynwald [46°38'N, 7°37'E, 600m a.s.l., canopy trap], 1 ♂, 2.–6.viii.1999.

Distribution. Europe: Bulgaria, Czech Republic, France, Hungary, Italy, Lithuania, Poland, Portugal (Černý et al. 2018), Republica of Malta, Spain; Africa: Morocco; Asia: Turkey, Uzbekistan (Černý 2013, Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Phragmites australis*.

Agromyza woerzi Groschke & Hering, 1957

Material examined. GR: Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂, 23.vi.2017.

Distribution. Europe: Belarus, Czech Republic, Germany, Latvia, Lithuania, Norway, Poland, Slovakia; Asia: Turkey (Dursun *et al.* 2015, Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Knautia arvensis*, *K. drymeia*.

Hexomyza cecidogena (Hering, 1927)

Material examined. TI: Biasca [46°21'N, 8°58'E, 300m a.s.l., banana bait], 3 ♂♂, 16.–20.vi.1995, B. Merz & G. Bächli leg.

Distribution. Europe: Austria, Belgium, Czech Republic, Denmark, France, Germany, Hungary, Italy, Lithuania, Poland, Portugal (Černý et al. 2018), Slovakia, Ukraine; Asia: China, Japan (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Salix aurita*, *S. repens*.

Melanagromyza arnicarum Hering, 1942

Material examined. GR: Dischmatal [46°45'N, 9°54'E, 1600m a.s.l.], 1 ♂, 16.–30.vi.1990, 1 ♂, 22.v.1991, P. Brodmann leg.

Distribution. Europe: Denmark, Germany, Italy, Lithuania; Asia: China. First record from Switzerland.

Biology. Host plant *Arnica montana*.

Melanagromyza eriolepidis Spencer, 1961

Material examined. GR: Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 1 ♂, 27.vi.2015.

Distribution. Europe: Germany, Great Britain. First record from Switzerland.

Biology. Host plant *Cirsium eriophorum*.

Melanagromyza eupatorii Spencer, 1957

Material examined. GE, Chancy [46°09'N, 5°58'E, 350m a.s.l.], 1 ♂, 25.vii.2004. **NE**: St. Blaise, Les Rièdes [47°01'N, 6°59'E, 440m a.s.l.], 1 ♂, 19.v.2001. **VS**: Visp [46°18'N, 7°53'E, 650m a.s.l.], 1 ♂, 2001, P. Duelli leg.

Distribution. Europe: Czech Republic, France, Germany, Great Britain, Hungary, Lithuania, Montenegro, Poland, Slovakia, Spain (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Eupatorium*, *Senecio*, *Inula*, *Chrysanthemum*.

Melanagromyza nibletti Spencer, 1957

Material examined. LU: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006.

Distribution. Europe: Czech Republic, Great Britain, Spain (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Silaum silaus.*

Melanagromyza pubescens Hendel, 1923

Material examined. GE: Chancy [46°09'N, 5°58'E, 350m a.s.l.], 1 ♂, 25.vii.2004. **TI**: Biasca [46°21'N, 8°58'E, 300m a.s.l.], 1 ♂, 17.vi.1995, B. Merz & G. Bächli leg. **VS**: Grône, Poutafontana, 500m a.s.l., [46°15'N, 7°27'E], 1 ♂, 1.vii.2001; Leuk-Platten [46°19'N, 7°42'E, 600m a.s.l.], 2 ♂♂, 1.viii.1998, 1 ♂, 3.viii.1998, 1 ♂, 19.v.1996, B. Merz & G. Bächli leg.; Pfynwald [46°38'N, 7°37'E, 600m a.s.l., canopy trap], 1 ♂, 2.–6.viii.1999, B. Merz & G. Bächli leg.

Distribution. Europe: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Germany, Great Britain, Greece, Hungary, Italy, Lithuania, Poland, Portugal (Černý et al. 2018), Romania, Russia, Spain, Sweden, Ukraine; Asia: Asian Russia, China, Japan, Mongolia, Nepal, North Korea, Kuril Islands, Turkey (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Artemisia vulgaris.*

Melanagromyza sativae Spencer, 1957

Material examined. GE: Dardagny, 400m a.s.l., [46°12'N, 6°00'E], 1 ♂, 11.viii.2000, B. Merz & G. Bächli leg. **GR**: Santa Maria [Müstair], 1850m a.s.l., [46°36'N, 10°25'E], 2 ♂♂, 26.vi.2015; Sur, 1600m a.s.l., [46°31'N, 9°38'E], 3 ♂♂, 3.vi.2000; Tschlin, 1500m a.s.l., [46°52'N, 10°26'E], 1 ♂, 25.vi.2016. **VS**: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 17.vi.1996; Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 15.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Germany, Great Britain, Greece, Hungary, Lithuania, Slovakia; Asia: Cyprus, Iran, Turkey (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Angelica*, *Anthriscus*, *Pastinaca*, *Pimpinella*, *Torilis*.

Melanagromyza tripolii Spencer, 1957

Material examined. VS: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 17.v.1996, B. Merz & G. Bächli leg., 1

♂, 24.vi.2000; Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 19.vi.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Denmark, France, Germany, Great Britain, Hungary, Italy, Netherlands, Slovakia, Spain, Ukraine; Asia: Turkey (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Aster tripolium*.

Melanagromyza zlobini Pakalniškis, 1996

Material examined. GR: Santa Maria [Müstair], 1850m a.s.l., [46°36'N, 10°25'E], 3 ♂♂, 26.vi.2015; Sur, 1550m a.s.l., [46°31'N, 9°38'E], 1 ♂, 3.vi.2000.

Distribution. Europe: Czech Republic, Germany, Greece, Hungary, Lithuania (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant unknown.

Ophiomyia alliariae Hering, 1954

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l.], 1 ♂, 27.vii.2001. **GR**: Rothenbrunnen [46°46'N, 9°26'E, 630m a.s.l.], 1 ♂, 8.viii.1996, B. Merz & G. Bächli leg. **VS**: Visp [46°18'N, 7°53'E, 650m a.s.l.], 1 ♂, 2000, P. Duelli leg.

Distribution. Europe: Andorra, Austria, Czech Republic, France, Germany, Great Britain, Greece, Hungary, Italy incl. Sardinia, Latvia, Lithuania, Portugal (Černý et al. 2018), Republica of Malta, Slovakia, Spain, Ukraine (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Alliaria*, *Bertorea*, *Brassica*, *Capsella*, *Cardamine*, *Erysimum*, *Raphanus*, *Sinapis*, *Sisymbrium*.

Ophiomyia eucodonus Hering, 1960

Material examined. GR: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2005, P. Duelli leg. **VS**: Jeizinen [46°20'N, 7°44'E, 1500m a.s.l.], 1 ♂, 26.vi.1999; Visperterminen [46°15'N, 7°54'E, 1500m a.s.l.], 1 ♂, 21.vii.2004.

Distribution. Europe: Czech Republic, France, Germany, Hungary, Poland, Russia, Slovakia, Spain (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Campanula* spp.

Ophiomyia hungarica Černý in Papp & Černý, 2015

Material examined. VS: Baltschieder [46°15'N, 7°54'E, 650m a.s.l.], 1 ♂, 17.vi.1996, B. Merz & G. Bächli leg; Visperterminen, 1400m a.s.l., [46°15'N, 7°54'E], 1 ♂, 31.vii.1998, B. Merz & G. Bächli leg.

Distribution. Europe: Hungary. First record from Switzerland.

Biology. Host plant unknown.

Ophiomyia maura (Meigen, 1838)

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l.], 1 ♂, 6.vii.2000. **VS**: Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 19.v.1996, B. Merz & G. Bächli leg.

Distribution. North America: Canada; Europe: Andorra, Austria, Belarus, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Italy incl. Sicily, Latvia, Lithuania, Netherlands, Norway, Poland, Russia, Slovakia, Spain incl. Canary Islands, Sweden, Ukraine, former Yugoslavia; Asia: China, Japan, Oman, Turkey, Yemen (Papp and Černý 2015). First record from Switzerland.

Biology. Host plants *Aster*, *Erigeron*, *Solidago*.

Ophiomyia mohelensis Černý, 1994

Material examined. GR: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2004, P. Duelli leg.

Distribution. Europe: Czech Republic, Hungary, Ukraine (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant unknown.

Ophiomyia pannonica Černý in Papp & Černý 2015

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l.], 3 ♂♂, 6.–11.vi.1973 [banana bait], 3 ♂♂, 14.viii.1997, 1 ♂, 31.viii.1999. **TI**: Cardada, Alpe, 1500m a.s.l., [46°12'N, 8°48'E], 1 ♂, 23.viii.2013. **ZH**: Flaach [47°35'N, 8°37'E, 350m a.s.l.], 1 ♂, 7.viii.2001.

Distribution. Europe: Hungary, Slovakia. First record from Switzerland.

Biology. Host plant unknown.

Ophiomyia rostrata (Hendel, 1920)

Material examined. VS: Leuk-Rotafen [46°19'N, 7°41'E, 850m a.s.l.], 1 ♂, 16.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Austria, Bulgaria, Czech Republic, France, Germany, Great Britain, Hungary, Lithuania, Netherlands, Poland, Spain; Asia: Uzbekistan (Papp and Černý 2015). First record from Switzerland.

Biology. Host plant *Convolvulus arvensis.*

Ophiomyia vanyushai Guglya, 2014

Material examined. GR: Zernez [46°42'N, 10°05'E, 1450m a.s.l.], 1 ♂, 6.viii.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Ukraine. First record from Switzerland.

Biology. Host plant unknown.

Subfamily Phytomyzinae

Amauromyza (*Cephalomyza*) *karli* (Hendel, 1927)

Material examined. VS: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 2.viii.1998, B. Merz & G. Bächli leg.; Pfynwald [46°38'N, 7°37'E, 600m a.s.l., canopy trap], 1 ♂, 3.–6.viii.1999.

Distribution. North America: Canada; Europe: Czech Republic, Finland, France, Germany, Greece, Hungary, Poland, Romania, Spain, Sweden; Asia: Mongolia (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Amauromyza (*Cephalomyza*) *luteiceps* (Hendel, 1920)

Material examined. GE: Cartigny, Moulin de Vert, 350m a.s.l., [46°11'N, 6°01'E], 1 ♂, 6.viii.2000, B. Merz & G. Bächli leg.

Distribution. North America: Canada; Europe: Belgium, Czech Republic, Great Britain, Denmark, Finland, France, Germany, Greece, Lithuania, Netherlands, Poland, Portugal (Černý et al. 2018), Republica of Malta, Spain, Sweden, Norway; Asia: Iran, Turkey (Papp and Černý 2016, Ranji *et al.* 2015). First record from Switzerland.

Biology. Host plant *Atriplex calotheca.*

Cerodontha (*Butomomyza*) *caricivora* (Groschke, 1954)

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l, banana bait], 2 ♂♂, 6.–11.vi.1973. **VS**: Morgins, Vieze [46°14'N, 6°51'E, 1400m a.s.l.], 1 ♂, 27.vii.2004.

Distribution. Europe: Austria, Belgium, Denmark, Estonia, Finland, Germany, Hungary, Poland, Slovakia, Sweden; Asia: Japan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Carex* spp.

Cerodontha (*Butomomyza*) *falcata* Černý in Papp & Černý, 2016

Material examined. TI: Biasca [46°21'N, 8°58'E, 300m a.s.l.], 1 ♂, 17.vi.1995. **ZH**: Marthalen [47°38'N, 8°39'E, 370m a.s.l.], 2 ♂♂, 8.vi.2008, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Hungary. First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (*Butomomyza*) *mellita* Spencer, 1971

Material examined. SZ: Alpthal [47°04'N, 8°43'E, 1150m a.s.l.], 1 ♂, 2001, P. Duelli leg.

Distribution. Europe: Belgium, Czech Republic, Great Britain, Poland, Portugal (Černý et al. 2018), Slovakia (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Carex* spp.

Cerodontha (Butomomyza) pseuderrans (Hendel, 1931)

Material examined. AG: Rottenschwil [47°19'N, 8°22'E, 390m a.s.l.], 1 ♂, 14.vi.2008; Wohlen [47°21'N, 8°18'E, 450m a.s.l.], 1 ♂, 21.v.2011. **GE**: Dardagny, Essertines, 400m a.s.l., [46°12'N, 6°00'E], 1 ♂, 11.viii.2000; Jussy, Prés de Villette, 475m a.s.l., [46°14'N, 6°16'E], 1 ♂, 8.viii.2000, all B. Merz & G. Bächli leg. **LU**: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006. **ZH**: Sihlwald [47°16'N, 8°33'E, 550m a.s.l.], 2 ♂♂, 16.viii.1997.

Distribution. Europe: Andorra, Austria, Czech Republic, Denmark, Germany, Great Britain, Greece, Hungary, Italy, Lithuania, Poland, Sweden; Asia: Turkey, Japan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant *Carex hirta.*

Cerodontha (Cerodontha) alpestris Martinez, 1987

Material examined. GR: Santa Maria [Müstair], 1850 m a.s.l., [46°36'N, 10°25'E], 1 ♂, 26.vi.2015; S-chanf-Flin [46°36'N, 9°59'E, 1650 m a.s.l.], 1 ♂, 7.viii.1996, B. Merz & G. Bächli leg.; Zernez-Gondas [46°42'N, 10°06'E, 1500 m a.s.l.], 1 ♂, 4.–8.viii.1996, B. Merz & G. Bächli leg.

Distribution. Europe: France, Germany, Italy (Černý 2013). First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (Cerodontha) coxalis Martinez, 1987

Material examined. GR: Santa Maria [46°36'N, 10°25'E, Müstair], 1850m a.s.l., 2 ♂♂, 26.vi.2015. **ZH**:

Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait] 1 ♂, 16.–20.vii.1992.

Distribution. Europe: Czech Republic, France, Hungary, Romania (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (Cerodontha) phragmitophila Hering, 1935

Material examined. LU: Luzern [47°01'N, 08°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006. **VS**: Grône, Poutafontana [46°15'N, 07°27'E, 520m a.s.l.], 1 ♂, 18.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Belgium, Bulgaria, Croatia, Czech Republic, France incl. Corsica, Great Britain, Greece, Hungary, Italy, Poland, Portugal (Černý et al. 2018), Spain incl. Canary Islands, former Yugoslavia; Africa: Egypt; Asia: Cyprus, Israel, Kazakhstan, Pakistan, Uzbekistan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Arundo*, *Phragmites*.

Cerodontha (Dizygomyza) brisiaca Nowakowski, 1973

Material examined. GL: Elm, Wichlen, 1300m a.s.l., [46°55'N, 9°10'E], 1 ♂, 15.viii.2001. **GR**: Marmorera, 1600m a.s.l., [46°31'N, 9°38'E, 1 ♂, 2.vi.2000; Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂, 23.vi.2017; Sur, 1600m a.s.l., [46°31'N, 9°38'E], 1 ♂, 2.vi.2000; Tinizong, 1350m a.s.l., [46°35'N, 9°37'E], 1 ♂, 4.viii.2007. **TG**: Lommis, Immenberg [47°32'N, 8°59'E, 700m a.s.l.], 1 ♂, 4.viii.2007. **TI**: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 2 ♂♂, 22.–24.vi.2001.

Distribution. Europe: Austria, Czech Republic, Germany, Lithuania, Poland; Africa: Morocco (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (Dizygomyza) chaixiana (Hering, 1956)

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l., banana bait], 6 ♂♂, 6.–11.vi.1973. **GR**: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2004, P. Duelli leg.; Tschlin, 1600m a.s.l., [46°52'N, 10°26'E], 1 ♂, 24.vi.2016. **LU**: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006. **NE**: Marin, Les Tertres, [47°28'N, 6°59'E, 450m a.s.l.] 1 ♂, 19.v.2001. **TI**: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 17.–20.vii.1998. **VS**: Grône, Poutafontana [46°15'N, 7°27'E, 520m a.s.l.], 1 ♂, 18.vi.1996, B. Merz & G. Bächli leg. **ZH**: Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait], 1 ♂, 10.–14.viii.1982, 1 ♂, 19.–23.vii.1990, 1 ♂, 16.–20.vii.1992; Hönggerberg [47°25'N, 8°30'E, 520m a.s.l., banana bait], 1 ♂, 2.–6.viii.1997, 1 ♂, 3.–7.vii.1998, 1 ♂, 29.vi.–3.vii.1999, 1 ♂, 3.–7.vii.2000, 1 ♂, 19.vii.2008, 1 ♂, 1.vii.2011; Sihlwald [47°16'N, 8°33'E, 550m a.s.l.], 1 ♂, 16.viii.1997.

Distribution. Europe: Czech Republic, Germany, Hungary, Poland (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Poa* spp.

Cerodontha (Dizygomyza) hirtae Nowakowski, 1967

Material examined. LU: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006.

Distribution. North America: United States; Europe: Austria, Belgium, Czech Republic, Germany, Greece, Hungary, Netherlands, Poland, Slovakia (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Carex* spp.

Cerodontha (Dizygomyza) silvatica (Groschke & Hering, 1957)

Material examined. GR: Dischmatal [46°45'N, 9°54'E, 1600m a.s.l.], 1 ♂, 1.–20.viii.1991, P. Brodmann leg. **VS**: Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 2 ♂♂, 31.vii.–8.viii.1976.

Distribution. Europe: Czech Republic, Germany, Great Britain, Hungary, Poland (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant *Luzula sylvatica*.

Cerodontha (Icteromyza) rozkosnyi Černý, 2007

Material examined. TI: Bolle di Magadino, [46°09'N, 8°52'E, 200m a.s.l.], 1 ♂, 9.viii.1997.

Distribution. Europe: Czech Republic, Greece, Hungary, Romania; Africa: Morocco; Asia: Israel, Turkey (Dursun *et al.* 2015, Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (Phytagromyza) flavocingulata (Strobl, 1909)

Material examined. GR: Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂, 23.vi.2017. **VS**: Mund, Finnen [1400m a.s.l.], 1 ♂, 21.vi.2014.

Distribution. North America: Canada; Europe: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Hungary, Latvia, Lithuania, Netherland, Norway, Poland, Romania, Slovakia, Sweden, former Yugoslavia; Asia: Asian Russia –Yakutia (Nartshuk and Bagachanova 2010, Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Agropyron*, *Agrostis*, *Alopecurus*, *Arrhenatherum*, *Bromus*, *Calamagrostis*, *Dactylis*, *Festuca*, *Holcus*, *Poa*, *Phleum*.

Cerodontha (Poemyza) morula (Hendel, 1920)

Material examined. ZH: Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait], 1 ♂, 3.–10.viii.1984; Hönggerberg [47°25'N, 8°30'E, 520m a.s.l.], 1 ♂, 19.vii.2008; Marthalen [47°38'N, 8°39'E, 390m a.s.l.], 1 ♂, 8.vi.2008.

Distribution. Europe: Austria, Czech Republic, Hungary (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Cerodontha (Poemyza) pygmella (Hendel, 1931)

Material examined. GR: Sur, 1600m a.s.l., [46°31'N, 9°38'E], 1 ♂, 3.vi.2000; Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 1 ♂, 27.vi.2015. **TI**: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–24.vi.2001; Fusio [46°26'N, 8°39'E, 1300m a.s.l.], 1 ♂, 26.vii.1997; Robiei [46°27'N, 8°31'E, 1900m a.s.l.], 1 ♂, 4.–5.vii.2008. **VS**: Grône, Poutafontana, 500m a.s.l., [46°15'N, 7°27'E],1 ♂, 1.vii.2001. **ZH**: Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait], 1 ♂, 3.–7.vii.1998; Flaach [47°35'N, 8°37'E, 350m a.s.l.], 1 ♂, 22.vii.1996.

Distribution. Europe: Czech Republic, Estonia, Denmark, Finland, Germany, Great Britain, Hungary, Lithuania, Norway, Poland, Slovakia, Spain incl. Canary Islands, Sweden; Asia: Iran, Asian Russia – Kamchatka, Kuril Islands (Papp and Černý 2016, Ranji *et al.* 2015). First record from Switzerland.

Biology. Host plants *Calamagrostis*, *Festuca*.

Cerodontha (Poemyza) thunebergi Nowakowski, 1967

Material examined. TG: Weinigen, Ochsenfurt [47°35'N, 8°37'E, 450m a.s.l.], 1 ♂, 29.v.1999. **VS**: Leuk [46°19'N, 7°38'E, 700m a.s.l., banan bait], 1 ♂, 27.–29.vii.1993; Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 2.vi.1999, 580m a.s.l., 1 ♂, 30.vi.–4.vii.2001 [banana bait]. **ZH**: Flaach [47°35'N, 8°37'E, 350m a.s.l.], 1 ♂, 22.vii.1996; Hönggerberg [47°25'N, 8°30'E, 520m a.s.l., banana bait], 1 ♂, 13.–17.vii.1996.

Distribution. Europe: Belarus, Czech Republic, Finland, France, Germany, Hungary, Lithuania, Slovakia; Asia: Japan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia beigerae Griffiths, 1980

Material examined. VS: Oberwald [46°31'N, 8°20'E, 1820m a.s.l., banana bait], 2 ♂♂, 13.–15.viii.1975; Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 2 ♂♂, 31.vii.–8.viii.1976.

Distribution. Europe: Germany, Italy, Poland, Slovakia (Černý 2005a, 2013). First record from Switzerland.

Biology. Host plant *Luzula sylvatica.*

Chromatomyia glacialis (Griffiths, 1964)

Material examined. TI: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–24.vi.2001. **VS**: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E],1 ♂, 3.vii.2001.

Distribution. Europe: Czech Republic, Great Britain, Poland, Sweden. First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia norwegica (Rydén, 1957)

Material examined. AG: Wohlen [47°21'N, 8°18'E, 450m a.s.l.], 1 ♂, 21.v.2011. **GR**: Alp Flix [46°32'N, 9°38'E, 1830m a.s.l., banana bait], 2 ♂♂, 4.–8.viii.1975; Zuoz-Nüd [46°36'N, 9°58'E, 1700m a.s.l.], 1 ♂, 7.viii.1996, B. Merz & G. Bächli leg. **VS**: Oberwald [46°31'N, 8°20'E, 1820m a.s.l., banana bait], 2 ♂♂, 13.–15.viii.1975; Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 25 ♂♂, 31.vii.–8.viii.1976.

Distribution. North America: Canada, United States; Europe: Czech Republic, Finland, Germany, Latvia (Karpa 2008), Lithuania, Norway, Poland, Slovakia, Sweden. First record from Switzerland.

Biology. Host plants *Arctagrostis*, *Brachypodium*, *Calamagrostis*, *Cinna*, *Deschampsia*, *Melica*.

Chromatomyia ochracea (Hendel, 1920)

Material examined. TI: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–24.vi.2001. **VS**: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 1 ♂, 3.vii.2001.

Distribution. Europe: Austria, Czech Republic (Černý *et al.* 2013), Finland, Germany, Poland, Russia, Sweden. First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia primulae (Robineau-Desvoidy, 1851)

Material examined. GR: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2005, P. Duelli leg.

Distribution. Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Ireland, Italy, Lithuania, Montenegro, Netherlands, Norway, Poland, Spain incl. Canary Islands, Sweden; Asia: Japan. First record from Switzerland.

Biology. Host plants *Primula* spp.

Chromatomyia rhaetica Griffiths, 1980

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l., banana bait], 5 ♂♂, 6.–11.vi.1973. **VS**: Oberwald [46°31'N, 8°20'E, 1820m a.s.l., banana bait], 1 ♂, 13.–15.viii.1975.

Distribution. Europe: Austria, Czech Republic, Slovakia. First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia spenceriana Griffiths, 1980

Material examined. VS: Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 1 ♂, 31.vii.–8.viii.1976.

Distribution. Europe: Czech Republic, Sweden. First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia styriaca Griffiths, 1980

Material examined. AG: Wettingen [47°27'N, 8°21'E, 420m a.s.l.], 2 ♂♂, 18.vii.1996; Würenlingen [47°32'N, 8°16'E, 420m a.s.l.], 1 ♂, 20.vii.1996, 2 ♂♂, 31.viii.1999; 1 ♂, 27.vii.2001. **LU**: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 2 ♂♂, 10.vi.2006. **ZH**: Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait], 2 ♂♂, 8.–16.vi.1984; Embrach, Haumühle [47°31'N, 8°36'E, 400m a.s.l.], 3 ♂♂, 9.v.1998; Marthalen [47°38'N, 8°39'E, 390m a.s.l.], 3 ♂♂, 8.vi.2008; Zürichberg [47°24'N, 8°33'E, 600m a.s.l., canopy trap], 1 ♂, 2.–3.vii.1983.

Distribution. Europe: Austria, Czech Republic, Germany, Finland, Latvia, Lithuania, Poland, Slovakia, Sweden. First record from Switzerland.

Biology. Host plant unknown.

Chromatomyia succisae (Hering, 1922)

Material examined. AG: Rottenschwil [47°19'N, 8°22'E, 390m a.s.l.], 1 ♂, 14.vi.2008. **VD**: Changins [46°24'N, 6°14'E, 430m a.s.l.], 1 ♂, 2000, P. Duelli leg. **VS**: Pfynwald [46°38'N, 7°37'E, 600m a.s.l., canopy trap], 1 ♂, 2.–6.viii.1999.

Distribution. Europe: Andorra, Denmark, France, Germany, Great Britain, Ireland, Italy, Lithuania, Netherlands, Poland, Sweden; Asia: Cyprus, Israel, Turkey, Uzbekistan (Černý 2007b, 2009, Černý and Merz 2006, Zlobin 2005). First record from Switzerland.

Biology. Host plants *Dipsacus*, *Knautia*, *Succisa.*

Chromatomyia tschirnhausi Griffiths, 1980

Material examined. GL: Klönthal [47°01'N, 8°57'E, 850m a.s.l., banana bait], 1 ♂, 11.–14.ix.1974. **GR**: Dischmatal [46°45'N, 9°54'E, 1600m a.s.l.], Net, 2 ♂♂, 16.–30.vi.1990, 1 ♂, 16.–31.vii.1991, 1 ♂, 1.–20.viii.1991, all P. Brodmann leg. **UR**: Furkapass, ALPFOR area, [46°35'N, 8°25'E, 2500m a.s.l.], 3 ♂♂, 25.vii.2012.

Distribution. Europe: Austria, Czech Republic, Poland, Norway, Slovakia (Černý *et al.* 2009, Černý and Farkač 2004). First record from Switzerland.

Biology. Host plant unknown.

Liriomyza aculeolata Zlobin, 2003

Material examined. GR: Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂, 23.vi.2017. **VS**: Jeizinen [46°20'N, 7°44'E, 1250m a.s.l.], 1 ♂, 26.vi.1999.

Distribution. Europe: Hungary, Russia, Spain, Sweden, Ukraine (Papp and Černý 2017, Zlobin 2005). First record from Switzerland.

Biology. Host plant unknown.

Liriomyza amoena (Meigen, 1830)

Material examined. SO: Messen [47°06'N, 7°27'E, 510m a.s.l.], 1 ♂, 15.iii.2004, B. Wermelinger leg.

Distribution. Europe: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Latvia, Lithuania, Madeira Islands, Moldavia, Netherlands, Poland, Romania, Slovakia, Spain, Sweden; Asia: Turkey, Japan, India (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Sambucus* spp.

Liriomyza buhri Hering, 1937

Material examined. GR: Dischmatal [46°45'N, 9°54'E, 1600m a.s.l.], 1 ♂, 22.v.1991, 1 ♂, 16.–31.vii.1991, P.

Brodmann leg. **TI**: Cardada, Gimetta, 1700m a.s.l., [46°12'N, 8°48'E], 1 ♂, 24.viii.2013; Robiei [46°27'N, 8°31'E, 1900m a.s.l.], 2 ♂♂, 4.–5.vii.2008; Val Bavona [46°24'N, 8°34'E, 600m a.s.l.], 1 ♂, 27.vii.1997. **UR**: Furkapass, ALPFOR Area, [46°35'N, 8°25'E, 2500m a.s.l.], 1 ♂, 25.vii.2012. **VS**: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 1 ♂, 3.vii.2001; Morgins, Porte de Culet [46°13'N, 6°52'E, 1700m a.s.l.], 3 ♂♂, 28.vii.2004; Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 15.v.1996, B. Merz & G. Bächli leg. **ZH**: Marthalen [47°38'N, 8°39'E, 390m a.s.l.], 2 ♂♂, 8.vi.2008.

Distribution. Europe: Czech Republic, Denmark, Estonia, Finland, France, Germany, Lithuania, Montenegro, Norway, Poland, Slovakia, Sweden; Asia: Asian Russia – Yakutia, Turkey (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Campanula*, *Jasione*, *Phyteuma*.

Liriomyza centaureae Hering, 1927

Material examined. SH: Merishausen [47°46'N, 8°37'E, 540m a.s.l.], 1 ♂, 9.viii.1999. **SZ**: Biberbrugg [47°09'N, 8°43'E, 860m a.s.l.], 1 ♂, 25.vi.2011.

Distribution. Europe: Croatia, Czech Republic, Denmark, Estonia, France, Germany, Great Britain, Hungary, Italy, Latvia, Lithuania, Poland, Slovakia, Spain, Sweden; Asia: Asian Russia – Yakutia, Turkey (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Centaurea* spp.

Liriomyza dendranthemae Nowakowski, 1975

Material examined. GR: Davos [46°48'N, 9°50'E, 2550m a.s.l.], 1 ♂, 2000, 1 ♂, 2001, 1 ♂, 2004, 2 ♂♂, 2006, all P. Duelli leg. **VS**: Zeneggen [46°16'N, 7°52'E, 1400m a.s.l.], 1 ♂, 22.v.2014.

Distribution. Europe: Poland. First record from Switzerland.

Biology. Host plant unknown.

Liriomyza europaea Zlobin, 2003

Material examined. VS: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 1 ♂, 3.vii.2001.

Distribution. Europe: Czech Republic, Great Britain, Greece, Sweden (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown, the species belongs to the *L. flaveola* group, known as grass miners.

Liriomyza graminivora Hering, 1949

Material examined. VS: Grône, Poutafontana, 500m a.s.l., [46°15'N, 7°27'E], 3 ♂♂, 18.v.1996, B. Merz & G. Bächli leg., 3 ♂♂, 1.vii.2001, 3 ♂♂, 1.vii.2001, B. Merz & G. Bächli leg.; Leuk [46°19'N, 7°38'E, 600m a.s.l., banana bait], 1 ♂, 23.viii.–2.ix.1977. **ZH**: Flaach [47°35'N, 8°37'E, 350m a.s.l.], 22 ♂♂, 30.vi.2000; Marthalen [47°38'N, 8°39'E, 390m a.s.l.], 3 ♂♂, 8.vi.2008.

Distribution. Europe: Czech Republic, Germany, Hungary, Lithuania, Romania, Russia, Slovakia, Spain; Asia: Uzbekistan (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Arrhenatherum*, *Festuca*, *Hordeum*, *Poa*.

Liriomyza hampsteadensis Spencer, 1971

Material examined. AG: Habsburg [47°28'N, 8°11'E, 490m a.s.l.], 1 ♂, 9.viii.2004; 1 ♂, 16.viii.2004, 1 ♂, 23.viii.2004; Sarmenstorf [47°19'N, 8°15'E, 580m a.s.l.], 1 ♂, 9.viii.2004, 1 ♂, 6.ix.2004, all B. Wermelinger leg. **GR**: Lenzerheide [46°43'N, 9°33'E, 1550m a.s.l.], 1 ♂, 8.viii.1998; Lüsai, 1800 m a.s.l., [46°37'N, 10°22'E], 1 ♂, 24.vi.2017. **GR:** Rothenbrunnen [46°46'N, 9°26'E, 630m a.s.l.], 1 ♂, 8.viii.1996, B. Merz & G. Bächli leg. **SO**: Messen [47°06'N, 7°27'E, 510m a.s.l.], 1 ♂, 9.viii.2004; 1 ♂, 14.ix.2004, all B. Wermelinger leg. **ZH**: Embrach, Haumühle [47°31'N, 8°36'E, 400m a.s.l.], 1 ♂, 9.v.1998. **ZH:** Uitikon [47°22'N, 8°27'E, 540m a.s.l.], 1 ♂, 2001, 1 ♂, 2004; Rafz [47°19'N, 8°35'E, 410m a.s.l.], 1 ♂, 2004, all P. Duelli leg.

Distribution. Europe: Belgium, Czech Republic, Germany, Great Britain, Greece, Hungary, Italy, Lithuania; Africa: Egypt (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant *Achillea millefolium*.

Liriomyza hieracivora Spencer, 1971

Material examined. TI: Bolle, Magagadino [46°09'N, 8°52'E, 200m a.s.l.], 1 ♂, 2005, P. Duelli leg. **ZH**: Zürich [47°23'N, 8°33'E, 430m a.s.l.], 1 ♂, 24.vi.–5.viii.2006, Th. Sattler leg.

Distribution. Europe: Czech Republic, Denmark, Germany, Hungary, Lithuania, Poland, Sweden; Asia: Asian Russia – Yakutia, Turkey (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Hieracium* spp.

Liriomyza infuscata Hering, 1926

Material examined. GR: Alp Flix, 1950m a.s.l., [46°32'N, 9°38'E], 1 ♂, 2.vi.2000, G. Bächli leg.; Marmorera, 1600m a.s.l., [46°31'N, 9°38'E, 1 ♂, 2.vi.2000; Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2005, P. Duelli leg.; Sur, 1600m a.s.l., [46°31'N, 9°38'E], 3 ♂♂, 3.vi.2000; Tinizong, 1350m a.s.l., [46°35'N, 9°37'E], 1 ♂, 2.vi.2000. **VD**: Changins [46°24'N, 6°14'E, 430m a.s.l.], 1 ♂, 2004, P. Duelli leg. **VS**: Leuk [46°19'N, 7°38'E, 700m a.s.l., banana bait], 2 ♂♂, 23.viii.–2.ix.1977.

Distribution. Europe: Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Latvia, Lithuania, Norway, Poland, Portugal (Černý et al. 2018), Russia, Slovakia, Spain, Sweden, Ukraine; Asia: Asian Russia – West and East Siberia, Mongolia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown, but this species is surely a grass miner.

Liriomyza lituanica Pakalniškis, 1992

Material examined. GE: Jussy, Prés de Villette, 475m a.s.l., [46°14'N, 6°16'E], 1 ♂, 8.viii.2000; Russin, Biolay, 360m a.s.l., [46°11'N, 6°01'E], 1 ♂, 9.viii.2000, all B. Merz & G. Bächli leg. **VD**: Cudrefin [46°57'N, 7°01'E, 430m a.s.l.], 1 ♂, 2001, P. Duelli leg.

Distribution. Europe: Czech Republic, Hungary, Italy, Latvia, Lithuania; Asia: North Korea (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Peucedanum*, *Selinum*.

Liriomyza muranica Černý, 2012

Material examined. VS: Mund, Finnen [46°19'N, 7°54'E, 1400m a.s.l.], 6 ♂♂, 21.vi.2014; Visperterminen [46°15'N, 7°54'E, 1550m a.s.l.], 1 ♂, 21.vii.2004; Zeneggen [46°16'N, 7°52'E, 1400m a.s.l.], 9 ♂♂, 22.vi.2014.

Distribution. Europe: Slovakia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown.

Liriomyza occipitalis Hendel, 1931

Material examined. GR: Lüsai, 1800m a.s.l., [46°37'N, 10°22'E], 1 ♂, 24.vi.2017; Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂, 23.vi.2017; Sur, 1550m a.s.l., [46°31'N, 9°38'E, 1 ♂, 3.vi.2000; Tinizong, 1350m a.s.l., [46°35'N, 9°37'E], 1 ♂, 3.vi.2000. **LU**: Luzern [47°01'N, 8°19'E, 440m a.s.l.], 1 ♂, 10.vi.2006.

Distribution. Europe: Czech Republic, Finland, France, Germany, Great Britain, Hungary, Poland, Russia, Slovakia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant *Equisetum arvense*.

Liriomyza oldenbergi Hering, 1933

Material examined. TI: Bolle di Magadino [46°09'N, 8°52'E, 200m a.s.l.], 8 ♂♂, 9.viii.1997. **VS**: Jeizinen [46°20'N, 7°44'E, 1500m a.s.l.], 22 ♂♂, 10.viii.2013; Pfynwald [46°38'N, 7°37'E, 600m a.s.l., banana bait], 2 ♂♂, 26.–28.vii.1993; Visperterminen, 1400m a.s.l., [46°15'N, 7°54'E, 1 ♂, 31.vii.1998, B. Merz & G. Bächli leg.

Distribution. Europe: Germany, Hungary, Lithuania (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Peucedanum* spp.

Liriomyza pascuum (Meigen, 1838)

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l., banana bait], 1 ♂, 6.–11.vi.1973.

Distribution. Europe: Austria, Belgium, Bulgaria, Croatia, Czech Republic, France incl. Corsica, Germany, Great Britain, Latvia, Lithuania, Montenegro, Poland, Romania, Serbia, Spain; Asia: Turkey (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Euphorbia* spp.

Liriomyza phryne Hendel, 1931

Material examined. AG: Würenlingen, Bärengraben [47°31'N, 8°15'E, 420m a.s.l.], 2 ♂♂, 13.v.1998, B. Merz & G. Bächli leg., 2 ♂♂, 27.vii.2001. **BE**: Ligerz [47°06'N, 7°08'E, 600m a.s.l.], 2 ♂♂, 29.v.2010. **BL**: Bubendorf [47°27'N, 7°44'E, 500m a.s.l.], 623.25/253.75, 1 ♂, 6.–13.vii.2000, M. Wolf leg. **GE**: Bernex, Chante-Merle, 420m a.s.l., [46°11'N, 6°03'E], 1 ♂, 7.viii.2000, B. Merz & G. Bächli leg. **LU**: Dierikon [47°06'N, 8°22'E, 550m a.s.l.], 1 ♂, 2000, 1 ♂, 2001, 1 ♂, 2003; Ruswil [47°05'N, 8°08'E, 820m a.s.l.], 1 ♂, 2000, 1 ♂, 2004, 1 ♂, 2005, all P. Duelli leg. **UR**: Seelisberg [47°16'N, 8°33'E, 810m a.s.l.], 1 ♂, 4.–7.viii.1973. **ZG**: Steinhausen [47°12'N, 8°29'E, 500m a.s.l.], 1 ♂, 2005, 2 ♂♂, 2006, all P. Duelli leg. **ZH**: Hönggerberg [47°25'N, 8°30'E, 520m a.s.l., banana bait], 1 ♂, 29.vi.–3.vii.1999; Marthalen [47°38'N, 8°39'E, 390m a.s.l.], 2 ♂♂, 8.vi.2008.

Distribution. Europe: Andorra, Austria, Belarus, Belgium, Czech Republic, Estonia, Latvia, Lithuania, France, Germany, Great Britain, Greece, Italy, Poland, Norway, Russia, Slovakia, Spain, Sweden (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Agropyron*, *Arrhenatarum*, *Dactylis*, *Holcus*, *Lolium*.

Liriomyza pisivora Hering, 1954

Material examined. VS: Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 1 ♂, 19.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, France incl. Corsica, Germany, Great Britain, Hungary, Lithuania, Poland, Russia; Asia: Asian Russia – Yakutia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Lathyrus*, *Pisum*, *Vicia*.

Liriomyza pseudopygmina (Hering, 1933)

Material examined. VS: Pfynwald [46°38'N, 7°37'E, 600m a.s.l.], 4 ♂♂, 19.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Lithuania, Spain; Asia: Japan (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Raphanus*, *Sinapis*, *Sisymbrium*.

Liriomyza solivaga Spencer, 1971

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l.], 1 ♀, 31.viii.1999. **GR**: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 4 ♂♂, 2004, 10 ♂♂, 2005, all P. Duelli leg. **UR**: Furkapass, ALPFOR Area, [46°35'N, 8°25'E, 2500m a.s.l.], 1 ♂, 24.vii.2012. **VS**: Jeizinen, 1500–2000m a.s.l., [46°20'N, 7°44'E], 2 ♂♂, 3.vii.2001.

Distribution. Europe: France, Great Britain, Spain (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown.

Liriomyza sonchi Hendel, 1931

Material examined. BL: Pratteln [47°31'N, 7°42'E, 285m a.s.l.], 4 ♂♂, 2004, P. Duelli leg. **VD**: Changins [46°24'N, 6°14'E, 430m a.s.l.], 1 ♂, 2000, 2 ♂♂, 2005, all P. Duelli leg.

Distribution. Europe: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Italy, Lithuania, Netherlands, Norway, Poland, Russia, Slovakia, Spain, Sweden; Africa: Morocco; Asia: China, India, Iran, Japan (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Arnoseris*, *Cichorium*, *Conyza*, *Euphorbia*, *Erigeron*, *Eryngium*, *Lactuca*, *Lapsana*, *Lepidium*, *Mycelis*, *Picris*, *Prenanthes*, *Reichardia*, *Sonchus*.

Liriomyza soror Hendel, 1931

Material examined. AG: Habsburg [47°28'N, 8°11'E, 490m a.s.l.], 1 ♂, 30.viii.2004, B. Wermelinger leg. **BL**: Pratteln [47°31'N, 7°42'E, 285m a.s.l.], 2 ♂♂, 2000, 7 ♂♂, 2004, P. Duelli leg. **GE**: Lullier [46°14'N, 6°15'E 480m a.s.l., light trap], 1 ♂, viii.1992, H. Hächler leg. **VS**: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 1 ♂, 3.vii.2001, 1 ♂, 26.vi.2004.

Distribution. Europe: Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Great Britain, Greece, Hungary, Lithuania, Poland, Russia, Slovakia, Sweden (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Carduus*, *Cirsium*.

Liriomyza taurica Zlobin, 2003

Material examined. UR: Seelisberg [46°58'N, 8°35'E, 810m a.s.l., banana bait], 3 ♂♂, 4.–7.viii.1973. **VS**: Jeizinen [46°20'N, 7°44'E, 1500m a.s.l.], 1 ♂, 26.vi.1999. **ZH**: Dietikon [47°24'N, 8°24'E, 390m a.s.l., banana bait], 1 ♂, 8.–16.vi.1984.

Distribution. Europe: Andorra, Czech Republic, Germany, Greece, Ukraine (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown, the species belongs to the *L. flaveola* group, known as grass miners.

Liriomyza valerianae Hendel, 1932

Material examined. VD: La Dôle, 1500m a.s.l., [46°26'N, 6°06'E], 1 ♂, 26.vii.2004.

Distribution. Europe: Denmark, Estonia, Finland, France, Germany, Great Britain, Lithuania, Netherlands, Norway, Poland, Sweden. (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Centranhus*, *Eupatorium*, *Valeriana*, *Valerianella*.

Liriomyza wachtlii Hendel, 1920

Material examined. GR: Celerina [46°31'N, 9°52'E, 1890m a.s.l.], 1 ♂, 2005, P. Duelli leg.

Distribution. North America: Canada; Europe: Austria, Czech Republic, Finland, Germany, Montenegro, Russia, Sweden; Asia: Asian Russia – Yakutia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plants *Veratrum album*, *V. lobelianum*, *V. nigrum*.

Metopomyza xanthaspioides (Frey, 1946)

Material examined. GR: Marmorera, 1600m a.s.l., [46°31'N, 9°38'E], 2 ♂♂, 2.vi.2000.

Distribution. Europe: Czech Republic, Estonia, Finland, France, Germany, Hungary, Lithuania, Norway, Poland, Russia, Slovakia, Sweden; Asia: Asian Russia – East Siberia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown.

Napomyza inquilina (Kock, 1966)

Material examined. VS, Leuk-Rotafen, [46°19'N, 7°41'E, 850m a.s.l.], 1 ♂, 16.v.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Germany; Asia: Asian Russia – East Siberia (as *N. hirtella* Zlobin, 1994). First record from Switzerland.

Biology. Host plant *Linaria vulgaris*.

Nemorimyza posticata (Meigen, 1830)

Material examined. GE: Jussy, Prés de Villette, 475m a.s.l., [46°14'N, 6°16'E, 1 ♂, 8.viii.2000, B. Merz & G. Bächli leg. **GL:** Richisau [47°01'N, 8°54'E, 1100m a.s.l.], 1 ♂, 7.–11.viii.1995.

Distribution. North America: Canada, United Stares; Central America: Costa Rica; Europe: Austria, Belarus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Hungary, Ireland, Italy, Lithuania, Poland, Netherlands, Norway, Spain, Sweden; Asia: China, Japan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Aster*, *Baccharis*, *Buphthalmum*, *Erechtites, Solidago*.

Phytobia cambii (Hendel, 1931)

Material examined. VS: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 17.vi.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Latvia, Lithuania, Netherlands, Poland, Portugal (Černý et al. 2018), Romania, Russia, Slovakia, Sweden; Asia: Asian Russia – East Siberia, Japan (Papp and Černý 2016). First record from Switzerland.

Biology. Host plants *Alnus*, *Betula*, *Populus*, *Salix*.

Phytomyza abdominalis Zetterstedt, 1848

Material examined. NE: Rochefort [46°59'N, 6°49'E, 800m a.s.l., banana bait], 1 ♂, 5.–8.vii.1982. **TI**: San Giorgio [45°54'N, 8°57'E, 1100m a.s.l.], 1 ♂, 18.vi.1995, B. Merz & G. Bächli leg. **VS**: Bürchen [46°17'N, 7°49'E, 1600m a.s.l., banana bait], 1 ♂, 17.–19.viii.1993, 1500–1650m a.s.l., 1 ♂, 2.vii.2001; Leuk [46°19'N, 7°38'E, 600m a.s.l., banana bait], 3 ♂♂, 23.viii.–2.ix.1977.

Distribution. Europe: Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Lithuania, Norway, Poland, Sweden. First record from Switzerland.

Biology. Host plant *Hepatica nobilis*.

Phytomyza angelicastri Hering, 1932

Material examined. GR: Landquart [46°58'N, 9°36'E, 580m a.s.l., banana bait], 1 ♂, 9.–12.viii.1974; Santa Maria, Müstair, 1850m a.s.l., [46°36'N, 10°25'E], 1 ♂ 1 ♀, 23.vi.2017. **UR**: Furkapass, ALPFOR area, [46°35'N, 8°25'E, 2500m a.s.l.], 1 ♂, 23.vii.2012.

Distribution. Europe: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Lithuania, Norway, Poland, Slovakia, Sweden (Černý 2011). First record from Switzerland.

Biology. Host plants *Angelica*, *Aegopodium*.

Phytomyza angelicivora Hering, 1924

Material examined. VS: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 1 ♂, 2.vii.2001; Visperterminen, 1300–2300m a.s.l., [46°15'N, 7°54'E], 4 ♂♂, 30.vii.1998, B. Merz & G. Bächli leg.

Distribution. Europe: Czech Republic, Germany, Russia (Černý and Vlk 2005). First record from Switzerland.

Biology. Host plant *Angelica palustris*.

Phytomyza arnicicola Lundquist, 1949

Material examined. GR: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2005, P. Duelli leg.

Distribution. North America: United States incl. Alaska; Europe: Czech Republic, Sweden; Asia: Asian Russia – Yakutia (Nartshuk and Bagachanova 2010). First record from Switzerland.

Biology. Host plant *Arnica alpina*.

Phytomyza bellidina Hendel, 1934

Material examined. GR: Sur, 1600m a.s.l., [46°31'N, 9°38'E], 2 ♂♂, 3.vi.2000; Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 9 ♂♂, 27.vi.2015.

Distribution. Europe: France, Italy, Portugal, Republica of Malta, Spain, former Yugoslavia. First record from Switzerland.

Biology. Host plants *Bellis perennis*, *B. sylvestris*.

Phytomyza carlestolrai Černý, 2007

Material examined. GR: Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 1 ♂, 27.vi.2015.

Distribution. Europe: Andorra, France (Černý 2009). First record from Switzerland.

Biology. Host plant unknown.

Phytomyza cirsii Hendel, 1923

Material examined. TI: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–26.vi.2001; Robiei [46°27'N, 8°31'E, 1900m a.s.l.], 1 ♂, 4.–5.vii.2008. **VS**: Baltschieder [46°18'N, 7°52'E, 650m a.s.l.], 1 ♂, 17.vi.1996, B. Merz & G. Bächli leg.

Distribution. Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Lithuania, Netherlands, Poland, Slovakia, Spain, Sweden; Asia: Turkey (Černý 2009, 2011). First record from Switzerland.

Biology. Host plants *Cirsium*, *Cynara*, *Serratula*, *Scolymus*.

Phytomyza coniopais Hering, 1931

Material examined. GR: Tschlin, 1500m a.s.l., [46°52'N, 10°26'E], 1 ♂, 25.vi.2016.

Distribution. Europe: Austria (Franz 1989), Germany, Poland. First record from Switzerland.

Biology. Host plant *Conium maculatum*.

Phytomyza erigerophila Hering, 1927

Material examined. GR: Ftan Clünas [46°48'N, 10°15'E, 2000m a.s.l.], 1 ♂, 5.viii.1996, B. Merz & G. Bächli leg.

Distribution. North America: Canada and United States; Europe: Bulgaria, Czech Republic, Denmark, Finland, France incl. Corsica, Germany, Great Britain, Lithuania, Netherlands, Norway, Poland; Asia: Japan. First record from Switzerland.

Biology. Host plants *Aster*, *Conyza*, *Erigeron*.

Phytomyza farfarae Hendel, 1935

Material examined. GR: Santa Maria, Müstair, Craistas [46°36'N, 10°25'E, 1850m a.s.l.], 1 ♂, 30.vi.2013; Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 1 ♂, 27.vi.2015.

Distribution. Europe: Austria, Bulgaria, Czech Republic, Germany, Italy, Montenegro, Poland, Romania, Slovakia. First record from Switzerland.

Biology. Host plants *Tussilago*, *Petasites*.

Phytomyza ferina Spencer, 1971

Material examined. GR: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 3 ♂♂, 2000, P. Dueli leg. **UR**: Furkapass, ALPFOR Area, [46°35'N, 8°25'E, 2500m a.s.l.], 1 ♂, 24.vii.2012. **VS**: Morgins, Portes du Soleil [46°12'N, 6°48'E, 1900m a.s.l.], 1 ♂, 27.vii.2004.

Distribution. Europe: Great Britain, Poland. First record from Switzerland.

Biology. Host plant unknown.

Phytomyza flavofemorata Strobl, 1893

Material examined. BS: Basel, Zoologischer Garden, Sektor E, E2, [47°34'N, 7°35'E, 280m a.s.l.], 1 ♂, 1.–15.iv.2005, D. Burckhardt leg. **GR**: Celerina [46°31'N, 9°52'E, 1890m a.s.l.], 4 ♂♂, 2000, 4 ♂♂, 2001, all P. Duelli leg.; Dischmatal [46°45'N, 9°54'E, 1600m a.s.l.], Net., 3 ♂♂, 16.–31.vii.1990, 1 ♂, 16.–31.vii.1991, 2 ♂♂, 1.–20.viii.1991, all P. Brodmann leg.; Lantsch [46°41'N, 9°34'E, 1460m a.s.l.], 1 ♂, 2000, P. Duelli leg.; Tschlin, 1600m a.s.l., [46°52'N, 10°26'E], 1 ♂, 24.vi.2016. **VS**: Jeizinen [46°20'N, 7°44'E, 1500m a.s.l.], 1 ♂, 26.vi.1999, 1500–2000m a.s.l., 2 ♂♂, 3.vii.2001; Leuk [46°19'N, 7°38'E, 700m a.s.l., banana bait], 3 ♂♂, 27.–29.vii.1993; Visp [46°18'N, 7°53'E, 650m a.s.l., banana bait], 1 ♂, 9.–11.viii.1993.

Distribution. Europe: Austria, Belarus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Russia, Slovakia, Sweden, former Yugoslavia. First record from Switzerland.

Biology. Host plants *Melampyrum arvense*, *M. pratense*.

Phytomyza hendeli Hering, 1923

Material examined. AG: Würenlingen [47°32'N, 8°16'E, 420m a.s.l., banana bait], 1 ♂, 6.–11.vi.1973, G. Bächli leg. **GR**: Nationalpark [46°40'N, 10°12'E, 2000m a.s.l.], 1 ♂, 2001, 1 ♂, 2005, P. Duelli leg. **VS**: Branson, Follaterre [46°08'N, 7°05'E, 500m a.s.l.], 1 ♂, 29.vii.2004; Visperterminen [46°15'N, 7°54'E, 1550m a.s.l.], 2 ♂♂, 21.vii.2004.

Distribution. Europe: Croatia, Czech Republic, Denmark, Finland, Germany, Great Britain, Greece, Latvia, Lithuania, Netherlands, Norway, Poland, Slovakia, Sweden; Asia: India (Černý 2011, Černý *et al.* 2006, Karpa 2008). First record from Switzerland.

Biology. Host plant *Anemone nemorosa*.

Phytomyza krygeri Hering, 1949

Material examined. BE: Ligerz [47°06'N, 07°08'E, 600m a.s.l.], 3 ♂♂, 29.v.2010.

Distribution. Europe: Czech Republic, Denmark, Finland, Germany, Great Britain, Netherlands, Norway, Poland, Sweden (Zlobin 2005). First record from Switzerland.

Biology. Host plant *Aquilegia vulgaris*.

Phytomyza leucanthemi Hering, 1935

Material examined. JU: Delémont [47°22'N, 07°20'E, 500m a.s.l., banana bait], 1 ♂, 2.–6.viii.1974.

Distribution. Europe: Czech Republic, Denmark, France, Germany, Great Britain, Ireland, Latvia, Lithuania, Norway, Poland, Slovenia, Sweden. First record from Switzerland.

Biology. Host plant *Chrysanthemum leucanthemum*.

Phytomyza melana Hendel, 1920

Material examined. GR: Ftan, Clünas [46°48'N, 10°15'E, 2000m a.s.l.], 1 ♂, 5.viii.1996, B. Merz & G. Bächli leg. **TI**: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–24.vi.2001.

Distribution. Europe: Austria, Germany, Great Britain, Poland, Norway (Andersen 2013). First record from Switzerland.

Biology. Host plants *Pimpinella major*, *P. saxifraga*.

Phytomyza monticola Černý, 2007

Material examined. GR: Dischmatal [46°45'N, 09°54'E, 1600m a.s.l.], 1 ♂, 16.–31.vii.1990, P. Brodmann leg.

Distribution. Europe: Andorra. First record from Switzerland.

Biology. Host plant unknown.

Phytomyza mutellinae Beiger, 1961

Material examined. GR: Marmorera, 1600m a.s.l., [46°31'N, 09°38'E], 1 ♂, 2.vi.2000.

Distribution. Europe: Czech Republic, Poland, Slovakia (Černý 2013). First record from Switzerland.

Biology. Host plant unknown.

Phytomyza mylini Hering, 1954

Material examined. VS: Visp [46°18'N, 07°53'E, 670m a.s.l.], 1 ♂, 2000, P. Duelli leg.

Distribution. Europe: Czech Republic, Finland, France, Germany, Latvia, Lithuania, Poland (Kahanpää 2014, Karpa 2008, Withers 2014). First record from Switzerland.

Biology. Host plants *Carum*, *Cicuta*, *Daucus*, *Ligusticum*, *Selinum*, *Seseli*, *Silaum*.

Phytomyza nigrifemur Hering, 1934

Material examined. TI: Acquacalda [46°33'N, 8°49'E, 1750m a.s.l.], 1 ♂, 22.–24.vi.2001. **VS**: Jeizinen, 2000m a.s.l., [46°20'N, 7°44'E], 2 ♂♂, 3.vii.2001; Leuk [46°19'N, 7°38'E, 700m a.s.l., banana bait], 1 ♂, 27.–29.vii.1993.

Distribution. Europe: Austria, Belarus, Bulgaria, Czech Republic, Estonia, Finland, France, Germany, Great Britain, Latvia, Lithuania, Norway Poland, Russia, Slovakia, Sweden (Andersen 2013, Černý 2013). First record from Switzerland.

Biology. Host plant *Melampyrum nemorosum*.

Phytomyza paraciliata (Godfray, 1985)

Material examined. AG: Rottenschwil [47°19'N, 8°22'E, 390m a.s.l.], 1 ♂, 14.vi.2008. **VS**: Leuk [46°19'N, 7°38'E, 600m a.s.l., banana bait], 3 ♂♂, 23.viii.–2.ix.1977; Oberwald [46°31'N, 8°20'E, 1820m a.s.l., banana bait], 3 ♂♂, 13.–15.viii.1975; Riederalp [46°23'N, 8°02'E, 2050m a.s.l., banana bait], 9 ♂♂, 31.vii.–8.viii.1976.

Distribution. Europe: Great Britain, Spain. First record from Switzerland.

Biology. Host plant *Leucanthemum vulgare*.

Phytomyza picridocecis Hering, 1957

Material examined. VS: Mund, Finnen [46°19'N, 7°54'E, 1400m a.s.l.], 1 ♂, 21.vi.2014.

Distribution. Europe: Germany. First record from Switzerland.

Biology. Host plant unknown.

Phytomyza pimpinellae Hendel, 1924

Material examined. GR: Tschierv, 1700m a.s.l., [46°38'N, 10°20'E], 1 ♂, 27.vi.2015. **SZ**: Biberbrugg [47°09'N, 8°43'E, 860m a.s.l.], 1 ♂, 25.vi.2011.

Distribution. Europe: Austria, Belarus, Bosna and Herzegovina, Czech Republic, Finland Germany, Great Britain, Hungary, Italy Latvia, Lithuania, Netherlands, Norway, Poland, Slovakia, Sweden (Černý 2013, Černý and Vála 2005, Kahanpää 2014). First record from Switzerland.

Biology. Host plants *Pimpinella major*, *P. saxifraga*.

Phytomyza senecionis Kaltenbach, 1869

Material examined. NE: Rochefort [46°59'N, 6°49'E, 800m a.s.l., banana bait], 2 ♂♂, 5.–8.vii.1982.

Distribution. Europe: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Germany, Italy, Netherlands, Poland, Slovakia (Černý 2006). First record from Switzerland.

Biology. Host plants *Senecio* spp.

Phytomyza sitchensis Griffiths, 1973

Material examined. GR: Marmorera, 1600m a.s.l., [46°31'N, 9°38'E], 1 ♂, 2.vi.2000. **SZ**: Alpthal [47°04'N, 8°43'E, 1150m a.s.l.], 1 ♂, 2004, P. Duelli leg. **UR**: Furkapass ALPFOR Area, [46°35'N, 8°25'E, 2500m a.s.l.], 1 ♂, 23.vii.2012, 1 ♂, 25.vii.2012.

Distribution. North America: Alaska; Europe: Denmark, Germany, Great Britain (Petersen and von Tschirnhaus 2001). First record from Switzerland.

Biology. Host plant *Conioselinum* sp.

Pseudonapomyza moraviae Černý, 1992

Material examined. VS: Leuk-Platten [46°19'N, 7°42'E, 600m a.s.l.], 1 ♂, 22.vii.2004.

Distribution. Europe: Czech Republic, Hungary, Lithuania, Poland, Russia, Slovakia (Papp and Černý 2017). First record from Switzerland.

Biology. Host plant unknown.

Discussion

A total of 108 species of the family Agromyzidae are recorded as new for the fauna of Switzerland. These species were collected randomly and extensively at localities in 19 cantons. Five species are new for Central Europe, namely *Liriomyza solivaga*, *Ophiomya vanyushai*, *Phytomyza bellidina*, *P. carlestolrai* and *P. monticola*. Additional species rarely recorded from Central Europe are *Cerodontha* (*Cerodontha*) *alpestris*, *C.* (*C.*) *coxalis*, C. (*Icteromyza*) *rozkosnyi*, *C.* (*Poemyza*) *morula*, *Chromatomyia glacialis*, *Ch. spenceriana*, *Liriomyza aculeolata*, *L. dendranthemae*, *L. europaea*, *L. lituanica*, *L. muranica*, *Melanagromyza arnicarum*, *M. eriolepidis*, *M. nibletti*, *Napomyza inquilina*, *Ophiomyia mohelensis*, *Phytomyza arnicicola*, *P. ferina*, *P. picridocecis* and *P. sitchensis*. Four species recently described from Hungary, are also new for the fauna of Switzerland namely *Agromyza longiphallus*, *A. seticercus*, *Cerodontha* (*Butomomyza*) *falcata*, *Ophiomyia hungarica* and *O. pannonica*. Our records increase the number of Agromyzidae of Switzerland to 395 species. The potencial number of Swiss Agromyzidae species is probably much higher, expected number agromyzid in Switzerland is probably 500 species. Such a conclusion seems to be confirmed by a comparison of species richness in neighbouring countries, 389 species known from Austria (Černý 2013, Černý and Merz 2006, Franz 1989, Griffiths 1980, Lonsdale 2017, Martinez 2013), 481 species from the 567 species from Germany (Barták 1998, Martinez 2013, von Tschirnhaus 1999), 385 species from Francie (Černý 2005b, 2009, 2013, Černý and Merz 2006, 2007, Martinez 2013, Withers 2014), 298 species from Italy (Bella et al. 2007, Černý 2006, 2013, Martinez 2013, Süss 1999, 2001, 2002, 2003, Süss and Moreschi 2005) and hitherto any species recorded from Liechtenstein.

Our investigation of a previously unstudied collection indicates that such collections contain many new records for Switzerland. They also contain many additional localities. Knowledge of the Agromyzidae is thus improved. We are aware of other such collections which are awaiting exploration. We suggest that more specialists investigate agromyzids, not only to improve faunal details, but also to clear up the biological background of the species discovered.

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APPENDIX 1

Updated checklist of the Agromyzidae of Switzerland

Each species is followed by at least one reference about its occurrence in Switzerland. The following abbreviations are used: N = New record from Switzerland presented in this paper; R1 = Černý 2005a; R2 = Černý 2009; R3 = Černý 2013; R4 = Černý and Merz 2005; R5 = Černý and Merz 2006; R6 = Černý and Merz 2007; R7 = Černý and Merz 2012; R8 = Eder and Baur 2003; R9 = Martinez 1998; R10 = Martinez 2013; R11 = Nartshuk and von Tschirnhaus 2017; R12 = Papp 1984; R13 = Spencer 1964; R14 = Spencer 1966; R15 = Spencer 1990; R16 = Spencer 1992.

Agromyzidae Fallén, 1810
Subfamily Agromyzinae

***Agromyza* Fallén, 1810**
– *abiens* Zetterstedt, 1848 – R1, R9, R10
– *albipennis* Meigen, 1830 – R1, R9, R10
– *albitarsis* Meigen, 1830 – N
– *alnibetulae* Hendel, 1931 – R9, R10, R12
– *ambigua* Fallén, 1823 – R9, R10
– *anderssoni* Spencer, 1976 – N
– *anthracina* Meigen, 1830 – R2, R9, R10
– *audcenti* Gibbs, 2004 – R6
– *bicaudata* (Hendel, 1920) – R1
– *bromi* Spencer, 1966 – R1, R9, R10
– *cinerascens* Macquart, 1835 – R1, R4
– *conjuncta* Spencer, 1966 – N
– *drepanura* (Mamonov, 1929) – N
– *erythrocephala* Hendel, 1920 – R3
– *filipendulae* Spencer, 1976 – N
– *flaviceps* Fallén, 1923 – R3
– *frontella* (Rondani, 1875) – R1
– *hendeli* Griffiths, 1963 – R1
– *idaeiana* Hardy, 1853 – R1, R4
– *longiphallus* L. Papp in Papp & Černý 2015 – N
– *lucida* Hendel, 1920 – R1
– *luteitarsis* (Rondani, 1875) – R2
– *lyneborgi* Spencer, 1976 – R11
– *marionae* Griffiths, 1963 – R1
– *mobilis* Meigen, 1830 – R1, R4, R9, R10
– *myosotidis* Kaltenbach, 1864 – R9, R10
– *nana* Meigen, 1830 – R1, R4, R9, R10
– *nigrella* (Rondani, 1875) – R9, R10
– *nigrescens* Hendel, 1920 – R9, R10
– *nigripes* Meigen, 1830 – R1, R4, R9, R10
– *nigrociliata* Hendel, 1931 – R9, R10
– *orobi* Hendel, 1920 – R9, R10
– *polygoni* Hering, 1941 – R1, R4, R9, R10
– *prespana* Spencer, 1957 – R1
– *pseudoreptans* Nowakowski, 1967 – R1
– *pseudorufipes* Nowakowski, 1964 – R1
– *reptans* Fallén, 1823 – R4, R9, R10
– *rondensis* Strobl, 1900 – R1
– *seticercus* L. Papp in Papp & Černý 2015 – N
– *spenceri* Griffiths, 1963 – N
– *sulfuriceps* Strobl, 1898 – R1, R9, R10
– *viciae* Kaltenbach, 1872 – R1 (as *A. quadriseta* Zlobin, 2001), R9, R10
– *vicifoliae* Hering, 1932 – R9, R10
– *woerzi* Groschke & Hering, 1957 – N

***Hexomyza* Enderlein, 1936**
– *cecidogena* (Hering, 1927) – N
– *simplicoides* (Hendel, 1920) – R10, R14

***Melanagromyza* Hendel, 1920**
– *aenea* (Meigen, 1830) – R10, R14
– *aeneoventris* (Fallén, 1823) – R4, R9, R10
– *albocilia* Hendel, 1931 – R2
– *arnicarum* Hering, 1942 – N
– *astragali* Spencer, 1976 – R1
– *cunctans* (Meigen, 1830) – R1, R4, R9, R10
– *eriolepidis* Spencer, 1961 – N
– *eupatorii* Spencer, 1957 – N
– *lappae* (Loew, 1850) – R9, R10
– *nibletti* Spencer, 1957 – N
– *pubescens* Hendel, 1923 – N
– *sativae* Spencer, 1957 – N
– *tripolii* Spencer, 1957 – N
– *zlobini* Pakalniškis, 1996 – N

***Ophiomyia* Braschnikov, 1897**
– *aeneonitens* (Strobl, 1893) – R1
– *alliariae* Hering, 1954 – N
– *beckeri* (Hendel, 1923) – R4
– *campanularum* Starý, 1930 – R1
– *cichorii* Hering, 1949 – R7
– *collini* Spencer, 1971 – R5
– *cunctata* (Hendel, 1920) – R1
– *curvipalpis* (Zetterstedt, 1848) – R1, R9, R10
– *eucodonus* Hering, 1960 – N
– *galii* Hering, 1937 – R1
– *heracleivora* Spencer, 1957 – R2
– *heringi* Starý, 1930 – R6
– *hungarica* Černý in Papp & Černý 2015 – NR
– *inaequabilis* (Hendel, 1931) – R1
– *labiatarum* Hering, 1937 – R2
– *longilingua* (Hendel, 1920) – R9, R10, R14
– *maura* (Meigen, 1838) – N
– *melandryi* de Meijere, 1924 – R6
– *mohelensis* Černý, 1994 – N
– *moravica* Černý, 1994 – R6
– *nasuta* (Melander, 1913) – R1, R4, R9, R10

– *orbiculata* (Hendel, 1931) – R1, R4, R9, R10, R13
– *pannonica* Černý in Papp & Černý 2015 – N
– *pinguis* (Fallén, 1820) – R1, R9, R10
– *pulicaria* (Meigen, 1830) – R4, R9, R10
– *rostrata* (Hendel, 1920) – N
– *submaura* Hering, 1926 – R1
– *vanyushai* Guglya, 2014 – N
– *vimmeri* Černý, 1994 – R1

Subfamily Phytomyzinae

Amauromyza **Hendel, 1931**
subgenus ***Amauromyza*** **Hendel, 1931**
– *leonuri* Spencer, 1971 – R4

subgenus ***Cephalomyza*** **Hendel, 1931**
– *flavifrons* (Meigen, 1830) – R1
– *gyrans* (Fallén, 1823) – R6
– *karli* (Hendel, 1927) – N
– *labiatarum* (Hendel, 1920) – R4
– *luteiceps* (Hendel, 1920) – N
– *mihalyii* Spencer, 1971 – R1
– *monfalconensis* (Strobl, 1909) – R1, R9, R10, R16
– *verbasci* (Bouché, 1847) – R9, R10

Aulagromyza **Enderlein, 1936**
– *anteposita* (Strobl, 1898) – R9, R10, R16
– *buhri* (de Meijere, 1938) – R9, R10
– *discrepans* (van der Wulp, 1871) – R6
– *hendeliana* (Hering, 1926) – R9, R10, R16
– *luteoscutellata* (de Meijere, 1924) – R1
– *orphana* (Hendel, 1920) – R1
– *similis* (Brischke, 1880) – R1
– *trivittata* (Loew, 1873) – R1, R9, R10

Calycomyza **Hendel, 1931**
– *artemisiae* (Kaltenbach, 1856) – R9, R10
– *humeralis* (von Roser, 1840) – R1, R9, R10
– *solidaginis* (Kaltenbach, 1969) – R9, R10

Cerodontha **Rondani, 1861**
subgenus ***Butomomyza*** **Nowakowski, 1967**
– *angulata* (Loew, 1869) – R1
– *caricivora* (Groschke, 1954) – N
– *eucaricis* Nowakowski, 1967 – R9, R10
– *falcata* Černý in Papp & Černý, 2016 – N
– *mellita* Spencer, 1971 – N
– *pseuderrans* (Hendel, 1931) – N
– *rohdendorfi* Nowakowski, 1967 – R1
– *scirpi* (Karl, 1926) – R9, R10
– *staryi* (Starý, 1930) – R6

subgenus ***Cerodontha*** **Rondani, 1861**
– *affinis* (Fallén, 1823) – R1, R4, R9, R10
– *alpestris* Martinez, 1987 – N
– *coxalis* Martinez, 1987 – N
– *denticornis* (Panzer, 1806) – R1, R4, R9, R10
– *flavicornis* (Egger, 1862) – R9, R10, R12
– *fulvipes* (Meigen, 1830) – R1, R4, R9, R10
– *phragmitophila* Hering, 1935 – N
– *unguicornis* Hendel, 1932 – R1, R4

subgenus ***Dizygomyza*** **Hendel, 1920**
– *bimaculata* (Meigen, 1830) – R1, R4
– *brisiaca* Nowakowski, 1973 – N
– *caricicola* (Hering, 1926) – R4
– *chaixiana* (Hering, 1956) – N
– *crassiseta* (Strobl, 1900) – R1
– *fasciata* (Strobl, 1880) – R1
– *griffithsi* Nowakowski, 1967 – R1
– *hirtae* Nowakowski, 1967 – N
– *iraeos* (Robineau-Desvoidy, 1851) – R9, R10
– *luctuosa* (Meigen, 1830) – R1
– *luzulae* (Groschke & Hering, 1957) – R1
– *morosa* (Meigen, 1830) – R1, R9, R10
– *silvatica* (Groschke & Hering, 1957) – N
– *spinata* (Groschke, 1954) – R1
– *suturalis* (Hendel, 1931) – R2

subgenus ***Icteromyza*** **Hendel, 1931**
– *geniculata* (Fallén, 1823) – R4, R9, R10
– *rozkosnyi* Černý, 2007 – N

subgenus ***Phytagromyza*** **Hendel, 1920**
– *flavocingulata* (Strobl, 1909) – N

subgenus ***Poemyza*** **Hendel, 1931**
– *alpina* Nowakowski, 1967 – R1
– *atra* (Meigen, 1830) – R1, R9, R10
– *beigerae* Nowakowski, 1973 – R1
– *calamagrostidis* Nowakowski, 1967 – R1
– *imbuta* (Meigen, 1838) – R9, R10
– *incisa* (Meigen, 1830) – R1
– *lateralis* (Macquart, 1835) – R1
– *lyneborgi* Spencer, 1972 – R1
– *morula* (Hendel, 1920) – N
– *muscina* (Meigen, 1830) – R9
– *phragmitidis* Nowakowski, 1967 – R6
– *pygmaea* (Meigen, 1830) – R1
– *pygmella* (Hendel, 1931) – N
– *spencerae* Zlobin, 1993 – R1
– *superciliosa* (Zetterstedt, 1860) – R9, R10, R12
– *thunebergi* Nowakowski, 1967 – N
– *vladimiri* Černý in Černý & Merz, 2007 – R6

subgenus ***Xenophytomyza*** **Frey, 1946**
– *atronitens* (Hendel, 1920) – R1
– *biseta* (Hendel, 1920) – R1, R9, R10
– *venturii* Nowakowski, 1967 – R9, R10

Chromatomyia **Hardy, 1849**
– *aizoon* (Hering, 1932) – R9, R10
– *alpigenae* (Hendel, 1925) – R9, R10
– *beigerae* Griffiths, 1980 – N
– *ciliata* (Hendel, 1935) – R9, R10, R16
– *fuscula* (Zetterstedt, 1838) – R1

– *gentianae* (Hendel, 1920) – R9, R10
– *gentianella* (Hendel, 1932) – R1, R9, R10, R12
– *glacialis* (Griffiths, 1964) – N
– *hoppiella* Spencer, 1990 – R1, R4, R9, R10, R15
– *horticola* (Goureau, 1851) – R1, R4, R9, R10
– *isicae* (Hering, 1962) – R1
– *milii* (Kaltenbach, 1864) – R1, R4, R9, R10
– *nigra* (Meigen, 1830) – R1, R9, R10
– *norwegica* (Rydén, 1957) – N
– *ochracea* (Hendel, 1920) – N
– *opacella* (Hendel, 1935) – R1
– *periclymeni* (Hendel, 1922) – R4, R9, R10
– *primulae* (Robineau-Desvoidy, 1851) – N
– *pseudomilii* Griffiths, 1980 – R1
– *ramosa* (Hendel, 1923) – R1, R4, R9, R10, R16
– *rhaetica* Griffiths, 1980 – N
– *saxifragae* (Hering, 1924) – R9, R10
– *soldanellae* (Starý, 1950) – R9, R10, R16
– *spenceriana* Griffiths, 1980 – N
– *styriaca* Griffiths, 1980 – N
– *succisae* (Hering, 1922) – N
– *syngenesiae* Hardy, 1849 – R9, R10
– *tschirnhausi* Griffiths, 1980 – N
– *vernalis* (Grischke & Hering, 1957) – R5

***Galiomyza* Spencer, 1981**
– *galiivora* (Spencer, 1969) – R1
– *morio* (Brischke, 1880) – R1, R9, R10
– *violiphaga* (Hendel, 1932) – R9, R10

***Gymnophytomyza* Hendel, 1936**
– *heteroneura* (Hendel, 1920) – R9, R10

***Liriomyza* Mik, 1894**
– *aculeolata* Zlobin, 2003 – N
– *amoena* (Meigen, 1830) – N
– *approximata* (Hendel, 1920) – R1
– *artemisicola* de Meijere, 1924 – R4, R9, R10, R16
– *balcanica* (Strobl, 1898) – R4
– *bryoniae* (Kaltenbach, 1858) – R5
– *buhri* Hering, 1937 – N
– *centaureae* Hering, 1927 – N
– *cicerina* (Rondani, 1875) – R9, R10
– *congesta* (Becker, 1903) – R1, R4, R9, R10
– *demeijerei* Hering, 1930 – R6
– *dendranthemae* Nowakowski, 1975 – N
– *dianthicola* (Venturi, 1949) – R5
– *dracunculi* Hering, 1932 – R4
– *erucifolii* de Meijere, 1944 – R1, R4
– *europaea* Zlobin, 2003 – N
– *flaveola* (Fallén, 1823) – R1, R4, R9, R10
– *globulariae* Hendel, 1931 – R9, R10, R12
– *graminivora* Hering 1949 – N
– *hampsteadensis* Spencer, 1971 – N
– *hieracii* (Kaltenbach, 1862) – R9, R10
– *hieracivora* Spencer, 1971 – N
– *huidobrensis* (Blanchard, 1926) – R9, R10
– *infuscata* Hering, 1926 – N
– *intonsa* Spencer, 1976 – R3
– *lituanica* Pakalniškis, 1992 – N
– *lutea* (Meigen, 1830) – R1
– *muranica* Černý, 2012 – N
– *nietzkei* Spencer, 1973 – R9, R10
– *obliqua* Hendel, 1931 – R1
– *occipitalis* Hendel, 1931 – N
– *oldenbergi* Hering, 1933 – N
– *orbona* (Meigen, 1830) – R4, R9, R10
– *pascuum* (Meigen, 1838) – N
– *pedestris* Hendel, 1931 – R6
– *phryne* Hendel, 1931 – N
– *pisivora* Hering, 1954 – N
– *polygalae* Hering, 1927 – R1, R9, R10, R12
– *pseudopygmina* (Hering, 1933) – N
– *ptarmicae* de Meijere, 1925 – R2
– *puella* (Meigen, 1830) – R6
– *pusilla* (Meigen, 1830) – R4 (as syn. *L. eupatorii* (Kaltenbach, 1873)), R9
– *pusio* (Meigen, 1830) – R7
– *richteri* Hering, 1927 – R9, R10
– *solivaga* Spencer, 1971 – N
– *sonchi* Hendel, 1931 – N
– *soror* Hendel, 1931 – N
– *strigata* (Meigen, 1830) – R4, R9, R10
– *taraxaci* Hering, 1927 – R1
– *taurica* Zlobin, 2003 – N
– *trifolii* (Burgess in Comstock, 1880) – R9, R10
– *urophorina* Mik, 1894 – R9, R10
– *valerianae* Hendel, 1932 – N
– *virgula* Frey, 1946 – R6
– *wachtlii* Hendel, 1920 – N
– *yasumatsui* Sasakawa, 1972 – R4

***Metopomyza* Enderlein, 1936**
– *flavonotata* (Haliday, 1833) – R1
– *nigriorbita* (Hendel, 1931) – R1
– *scutellata* (Fallén, 1823) – R1
– *xanthaspioides* (Frey, 1946) – N
– *xanthaspis* (Loew, 1858) – R1, R9, R10

***Napomyza* Westwood, 1840**
– *achilleanella* von Tschirnhaus, 1992 – R6
– *bellidis* Griffiths, 1967 – R1
– *carotae* Spencer, 1966 –R9, R10
– *cichorii* Spencer, 1966 – R1 R4, R9, R10
– *elegans* (Meigen, 1830) – R1
– *hirticornis* Hendel, 1932 – R9, R10
– *inquilina* (Kock, 1966) – N
– *lateralis* (Fallén, 1823) – R9, R10
– *maritima* von Tschirnhaus, 1981 – R1
– *merita* Zlobin, 1993 – R6
– *nigriceps* van der Wulp, 1871 – R1
– *scrophulariae* Spencer, 1966 – R6
– *tripolii* Spencer, 1966 – R1

***Nemorimyza* Frey, 1946**
– *posticata* (Meigen, 1830) – N

***Phytobia* Lioy, 1864**
– *cambii* (Hendel, 1931) – N
– *mallochi* (Hendel, 1924) – R9, R10, R12

***Phytoliriomyza* Hendel, 1931**
– *arctica* (Lundbeck, 1901) – R1, R9, R10
– *melampyga* (Loew, 1869) – R1, R9, R10
– *perpusilla* (Meigen, 1830) – R1

***Phytomyza* Fallén, 1810**
– *abdita* Hering, 1927 – R9, R10, R12, R15
– *abdominalis* Zetterstedt, 1848 – N
– *adenostylis* Hering, 1926 – R9, R10, R16
– *adjuncta* Hering, 1928 – R9, R10
– *affinis* Fallén, 1823 – R1, R9, R10
– *albipennis* Fallén, 1823 – R1
– *alpestris* Hendel, 1920 – R9, R10, R12
– *alpina* Groschke & Hering, 1957 – R9, R10
– *angelicae* Kaltenbach, 1872 – R1, R9, R10, R16
– *angelicastri* Hering, 1932 – N
– *angelicivora* Hering, 1924 – N
– *aquilegiae* Hardy, 1849 – R9, R10
– *arnicae* Hering, 1925 – R9, R10, R16
– *arnicicola* Lunndquist, 1949 – N
– *artemisivora* Spencer, 1971 – R1, R9, R10, R16
– *aurei* Hering, 1931 – R9, R10
– *bellidina* Hendel, 1934 – N
– *bipunctata* Loew, 1858 – R9, R10
– *brischkei* Hendel, 1922 – R1, R9, R10
– *buhriella* Spencer, 1969 – R6
– *calthivora* Hendel, 1934 – R1
– *calthophila* Hering, 1931 – R1
– *campanulae* Hendel, 1920 – R4
– *carlestolrai* Černý, 2007 – N
– *chaerophylli* Kaltenbach, 1856 – R1, R9, R10
– *chaerophylliana* Hering, 1931 – R6
– *cirsii* Hendel, 1923 – N
– *clematidis* Kaltenbach, 1859 – R9, R10
– *coniopais* Hering, 1931 – N
– *continua* Hendel, 1920 – R9, R10
– *crassiseta* Zetterstedt, 1860 – R1
– *digitalis* Hering, 1925 – R9, R10
– *erigerophila* Hering, 1927 – N
– *eumorpha* Frey, 1946 – R1
– *evanescens* Hendel, 1920 – R1
– *fallaciosa* Brischke, 1880 – R1
– *farfarae* Hendel, 1935 – N
– *ferina* Spencer, 1971 – N
– *flavicornis* Fallén, 1823 – R1, R4
– *flavofemorata* Strobl, 1893 – N
– *glechomae* Kaltenbach, 1862 – R1, R9, R10
– *griffithsi* Spencer, 1963 – R6
– *gymnostoma* Loew, 1858 – R1, R4
– *hendeli* Hering, 1923 – N
– *heracleana* Hering, 1937 – R1
– *hirsuta* Spencer, 1976 – R1
– *homogyneae* Hering, 1927 – R1
– *hoppi* Hering, 1925 – R9, R10, R12
– *ilicis* Curtis, 1846 – R4, R9, R10
– *kaltenbachi* Hendel, 1922 – R9, R10, R12
– *krygeri* Hering, 1949 – N
– *kurilensis* Iwasaki 2000 – R2
– *kyffhusana* Hering, 1928 – R4,
– *latifolii* Groschke & Hering, 1957 – R9, R10
– *leucanthemi* Hering, 1935 – N
– *marginella* Fallén, 1823 – R9, R10, R12
– *medicaginis* Hering, 1925 – R7
– *melana* Hendel, 1920 – N
– *minuscula* Goureau, 1851 – R9, R10
– *monticola* Černý, 2007 – N
– *mutellinae* Beiger, 1961 – N
– *mylini* Hering, 1954 – N
– *narcissiflorae* Hering, 1928 – R9, R10, R12, R15
– *nigrifemur* Hering, 1934 – N
– *nigripennis* Fallén, 1823 – R1, R4, R9, R10
– *nigritula* Zetterstedt, 1838 – R9, R10
– *notata* Meigen, 1830 – R1, R9, R10
– *origani* Hering, 1931 – R1, R4
– *paraciliata* (Godfray, 1985) – N
– *pauliloewii* Hendel, 1920 – R1
– *penicilla* Hendel, 1935 – R9, R10
– *petoei* Hering, 1924 – R9, R10
– *picridocecis* Hering, 1957 – N
– *pimpinellae* Hendel, 1924 – N
– *plantaginis* Robineau-Desvoidy, 1851 – R1, R4, R9, R10
– *platonoffi* Spencer, 1976 – R2
– *platystoma* (Hendel, 1920) – R1
– *pubicornis* Hendel, 1920 – R1
– *pullula* Zetterstedt, 1848 – R1, R4
– *pulsatillae* Hering, 1924 – R12
– *ranunculi* (Schrank, 1803) – R1, R4, R9, R10
– *ranunculicola* Hering, 1949 – R1
– *ranunculivora* Hering, 1932 – R6
– *rapunculi* Hendel, 1927 – R1
– *rectae* Hendel, 1924 – R9, R10
– *rhabdophora* Griffiths, 1964 – R1
– *robustella* Hendel, 1936 – R6
– *rostrata* Hering, 1934 – R1
– *rufipes* Meigen, 1830 – R1, R9, R10
– *salviae* (Hering, 1924) – R6
– *sedi* Kaltenbach, 1869 – R1
– *sedicola* Hering, 1924 – R9, R10
– *senecionis* Kaltenbach, 1869 – N
– *sitchensis* Griffiths, 1973 – N
– *soenderupi* Hering, 1941 – R1
– *solidaginis* Hendel, 1920 – R9, R10
– *spondylii* Robineau-Desvoidy, 1851 – R4, R9, R10
– *tenella* Meigen, 1830 – R1, R4, R9, R10
– *tetrasticha* Hendel, 1927 – R6
– *thalictri* Escher-Kündig in de Rougemont, 1912 – R9, R10, R12, R15
– *thymi* Hering, 1928 – R9, R10, R12, R15
– *trollii* Hering, 1930 – R9, R10, R16
– *trolliivora* Hering, 1935 – R9, R10
– *varipes* Macquart, 1835 – R1

– *veronicicola* Hering, 1925 – R4
– *virgaureae* Hering, 1926 – R9, R10, R12
– *vitalbae* Kaltenbach, 1872 – R1, R4, R9, R10
– *wahlgreni* Rydén, 1944 – R1, R9, R10
– *zarzyckii* Nowakowski, 1975 – R2

***Pseudonapomyza* Hendel, 1920**
– *atra* (Meigen, 1830) – R1
– *balkanensis* Spencer, 1973 – R9, R10
– *errata* Zlobin, 1993 – R1, R4
– *eurasiatica* Zlobin, 2003 – R1, R4
– *europaea* Spencer, 1973 – R1, R9, R10, R12
– *moraviae* Černý, 1992 – N
– *strobliana* Spencer, 1973 – R1
– *vota* Spencer, 1973 – R1, R4

***Selachops* Wahlberg, 1844**
– *flavocinctus* Wahlberg, 1844 – R9, R10

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PENSOFT.

Alpine Entomology

Dual function of *Potentilla* (Rosaceae) in the life history of the rare boreoalpine osmiine bee *Hoplitis* (*Formicapis*) *robusta* (Hymenoptera, Megachilidae)

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Abstract

Hoplitis robusta (Nylander) is a rare and poorly known osmiine bee species occurring in the subalpine zone of the Alps. The discovery of two nests of *H. robusta* in a thin branch of a dead fallen spruce on a sunny clearing of a subalpine spruce forest allowed the investigation of the nest architecture, the analysis of the larval diet and the assessment of the nest building material. X-raying, computed tomography and subsequent dissection of the nest branch revealed that the nests were built in L-shaped pupation tunnels of cerambycid beetles, which were probably cleaned from wood debris by the female bees with the aid of their large and powerful mandibles after nest site selection. The two nests contained five and six linearly arranged brood cells separated from each other by thin partitions built from masticated green leaves ("leaf pulp"). They were sealed at their opening by a thick plug consisting of several successive layers of leaf pulp constructed immediately behind each other. Microscopical analysis of the larval provisions of eight brood cells and of 41 pollen loads of females from museum and private collections showed that *H. robusta* exhibits a strong preference for the pollen of *Potentilla* (Rosaceae). Based on field observations, DNA metabarcoding of one nest plug and stereomicroscopic analysis of the leaf pulp matrix, *Potentilla* was also identified as an important source for the leaf pulp needed for nest construction, rendering *H. robusta* one of the few bee species known to collect floral resources and nest building material from the very same plant.

Zusammenfassung

Hoplitis robusta (Nylander) ist eine seltene und erst unzureichend erforschte Bienenart aus der Verwandtschaft der Mauerbienen (Osmiini). Sie kommt bei uns ausschliesslich in der subalpinen Stufe der Alpen vor. Die zufällige Entdeckung von zwei Nestern, welche sich in einem dünnen Ast einer umgestürzten toten Fichte auf einer sonnigen Lichtung eines subalpinen Fichtenwaldes befanden, ermöglichte die Analyse der Nestarchitektur, der Larvenvorräte und des Nestbaumaterials. Die Untersuchung des besiedelten Astes durch Röntgen, Computertomographie und anschliessende Präparation ergab, dass beide Nester in Hakengängen von Bockkäfern (Cerambycidae) angelegt worden waren, welche die Weibchen mit Hilfe ihrer ausgesprochen kräftigen Mandibeln wahrscheinlich vorgängig gesäubert hatten. Die zwei Nester enthielten fünf bzw. sechs linienförmig hintereinander angelegte Brutzellen, die durch dünne Wände aus zerkauten Laubblättern («Pflanzenmörtel») voneinander getrennt waren. Die Nester wurden an ihrer Öffnung mit einem dicken Propfen verschlossen, der aus mehreren direkt hintereinander liegenden Wänden aus Pflanzenmörtel gebaut wurde. Die lichtmikroskopische Analyse der Larvenvorräte in acht Brutzellen sowie der Pollenladungen von 41 Weibchen aus Museums- und Privatsammlungen ergab, dass *H. robusta* den Pollen hauptsächlich auf Fingerkraut (*Potentilla*) sammelt. Mehrere Beobachtungen von Nestbaumaterial sammelnden Weibchen, die genetische Analyse eines Nestverschlusses und die Untersuchung des Nestbaumaterials unter dem Binokular ergaben, dass *Potentilla* auch eine sehr wichtige Pflanzenmörtelquelle ist. Damit gehört *H. robusta* zu den wenigen bisher bekannten Bienenarten, welche sowohl den Pollen als auch das Nestbaumaterial auf den gleichen Pflanzen sammeln.

Introduction

Bees depend on several types of resources for their reproduction (Westrich 1989). They need suitable nesting sites to hide the brood cells, flowers to collect pollen and nectar and specific materials to build the nests. In some highly specialized Palaearctic osmiine bees (Megachilidae), floral resources and nest building material are harvested from the very same plants. In *Haetosmia vechti* flowers of *Heliotropium* (Boraginaceae) serve as the exclusive pollen source, while masticated green leaves of the same plant are used to construct the brood cells (Gotlieb et al. 2014). Similarly, several pollen specialist *Hoplitis* and *Osmia* species of the subgenera *Anthocopa* and *Tergosmia*, respectively, each build their brood cells from petals of their exclusive pollen host, such as *Centaurea* (Asteraceae) in *Hoplitis saundersi, Convolvulus* (Convolvulaceae) in *H. perezi*, *Linum* (Linaceae) in *H. mocsaryi*, Malvaceae in *H. cristatula* and *H. jakovlevi*, or *Hedysarum* (Fabaceae) in *Osmia avosetta* (Ferton 1890, 1892, 1894, 1897, Westrich 1989, Rozen et al. 2010, Müller 2018a, G. Le Goff personal communication). By exploiting the same plant for different types of resources, these bees likely avoid costs incurred by searching for and exploiting alternative plants. In the present contribution, we report on the dual function of *Potentilla* (Rosaceae) as a source for both pollen and nest building material for *Hoplitis robusta* (Nylander), a rare boreoalpine osmiine bee.

Hoplitis robusta is a holarctic megachilid bee species of 6–9 mm length distributed in the boreal zone across Europe, Asia and North America with outposts in mountainous regions of the western USA and the Alps (Müller and Mauss 2016). In the Alps, *H. robusta* occurs from western Switzerland over northern Italy to eastern Austria, where it mainly inhabits open forests and windfalls between 1200 m a.s.l. and the timber line (Schwarz et al. 1996, Ebmer 1997, 2001, Amiet et al. 2004, Kopf 2008, SwissBeeTeam 2018). Among the osmiine bees, *H. robusta* belongs to the subgenus *Formicapis*, which comprises three additional species all restricted to a comparatively small area that ranges from northern Mongolia and China to southeasternmost Russia and Korea, suggesting an eastern Asian origin of the subgenus (Müller and Mauss 2016).

The biology of *Hoplitis robusta* is only fragmentarily known, which is likely due to the species' rare and scattered occurrence throughout the Alpine arc. Based on observations of individuals flying around dead spruces and wooden fences, *H. robusta* was assumed to nest in insect burrows in dead wood (Frey-Gessner 1880, 1908–1912). This assumption was later supported by the discovery of several nests built in drilled borings of artificial trap nest blocks in the Rocky Mountains/USA (Clement and Rust 1975). Still, however, no nests of *H. robusta* in a natural substrate have ever been found, neither in North America nor in Europe. A similar poor knowledge pertains to the host plant choice of *H. robusta*, which was completely unknown until recently, when *Potentilla* was identified as a seemingly important host based on the microscopic analysis of pollen contained in the metasomal scopa of collected females (Müller and Mauss 2016). However, the low number of pollen samples analysed in the cited study renders it difficult to evaluate the true significance of *Potentilla* pollen in the species' larval diet.

Numerous attempts to find nests of *Hoplitis robusta* in the Swiss Alps during the past decade – including the repeated exposure of bundles of hollow bamboo stems that imitated insect burrows in dead wood – failed. In Summer 2018, however, a female of *H. robusta* was by chance observed sealing her nest in a branch of a dead spruce. X-raying of the branch revealed the existence of a second nest of a different female within the same branch. The discovery of these first truly natural nests of *H. robusta* allowed the investigation of the nest architecture, the assessment of the nest building material and the analysis of the larval diet and prompted the analysis of additional female pollen loads, all aiming at getting a more complete picture of the life history of this rare and enigmatic alpine bee species.

Methods

The nests of *Hoplitis robusta* were discovered in the Calfeisen valley near St. Martin/St Gallen (46°55.455N, 9°21.305E) at an elevation of 1520 m a.s.l. on 27.6.2018. The nest branch was sawed off at its base and brought to the Animal Hospital of the University of Zurich, where it was X-rayed using a Bucky Diagnost CS/TH X-Ray (Philips) combined with a Profect CS Mammo-Reader (Fujifilm). In addition, the two nests were examined by computed tomography (CT) using a 16-slice CT Brilliance scanner (Philips). Following the X-ray and CT-examination, which enabled the exact localization of the nests within the branch, the nests were dissected with the aid of a smoothing plane and a pocket knife to analyse their architecture and the nest contents.

The pollen host spectrum of *Hoplitis robusta* was assessed by microscopic analysis of the scopal pollen contents of 41 females from museum and private collections originating from 27 different localities distributed across the Alps and from three different localities in Finland. The pollen samples from the Alps (n = 15) analysed by Müller and Mauss (2016) were included in the present study and supplemented with numerous new samples (n = 26). In addition, remains of the larval provisions in eight brood cells of two nests were microscopically analysed. The methodology for pollen removal, manufacture of pollen samples, pollen identification and data evaluation follows Müller (2018b). For each brood cell, the proportions of the different pollen types were estimated to the nearest 10%. Pollen of *Fragaria* and *Potentilla* – two closely related genera within the Rosaceae – could not be reliably separated by the method applied in the present study, both being subsumed under the "*Potentilla* type" in palynology (Beug 2004). As *Fragaria vesca* L. – the only *Fragaria* species occurring in the subalpine habitats of *H. robusta* – flowers early in spring when the flight period of *H. robusta* has not yet started, all pollen grains of the *Potentilla* type were invariably assigned to the genus *Potentilla*.

To assess the source of the nest building material, DNA metabarcoding of the two nest plugs consisting of masticated green leaves (= "leaf pulp") was performed by the ISO 9001:2008 certified and ISO 17025:2005 accredited laboratory of Eurofins Medigenomix GmbH (Ebersberg, Germany). DNA of 1g plant material from each nest plug was extracted with the Maxwell 16 FFS nucleic acid extraction kit (Promega) following the manufacturer's manual. From the extracted DNA, barcoding sequences of the nuclear marker ITS2 and the chloroplast marker trnL were PCR amplified using target specific next-generation sequencing primers and analysed by amplicon sequencing on the Illumina MiSeq platform. For unknown reasons, the extraction of amplifiable DNA from the plug of nest 1 failed. The amplified sequences from the plug of nest 2 were sorted into sequence sets according to their similarity, each represented by a master sequence. The master sequences were identified to species or genus level by comparing them with known plant sequences made available by the NCBI database. We refrained from performing metabarcoding of the cell partitions as they were heavily contaminated with pollen of the larval provisions. Instead, the leaf pulp matrix of all cell partitions and the outermost partition of the plug of nest 1, which was still available after the unsuccessful DNA amplification (see above), was stereomicroscopically examined at a magnification of 40× and compared with the leave indument of plant species collected in a radius of 15 m around the nesting site on 16.9.2018.

Data on flower visits and sources of nest building material are based on field observations in the Swiss Alps near Visperterminen/Valais (46°15.00N, 7°55.50E), St. Martin/St Gallen (46°55.50N, 9°21.30E), Curaglia/Grisons (46°40.25N, 8°50.10E), Sedrun/Grisons (46°41.20N, 8°47.50E), Sent/Grisons (46°48.55N, 10°21.10E) and Vals/Grisons (46°36.90N, 9°11.80E) from 2010 to 2018. A "flower visit" is defined as one continuous observation of a single female irrespective of the number of flowers she visited.

Results

Nesting site and nest architecture

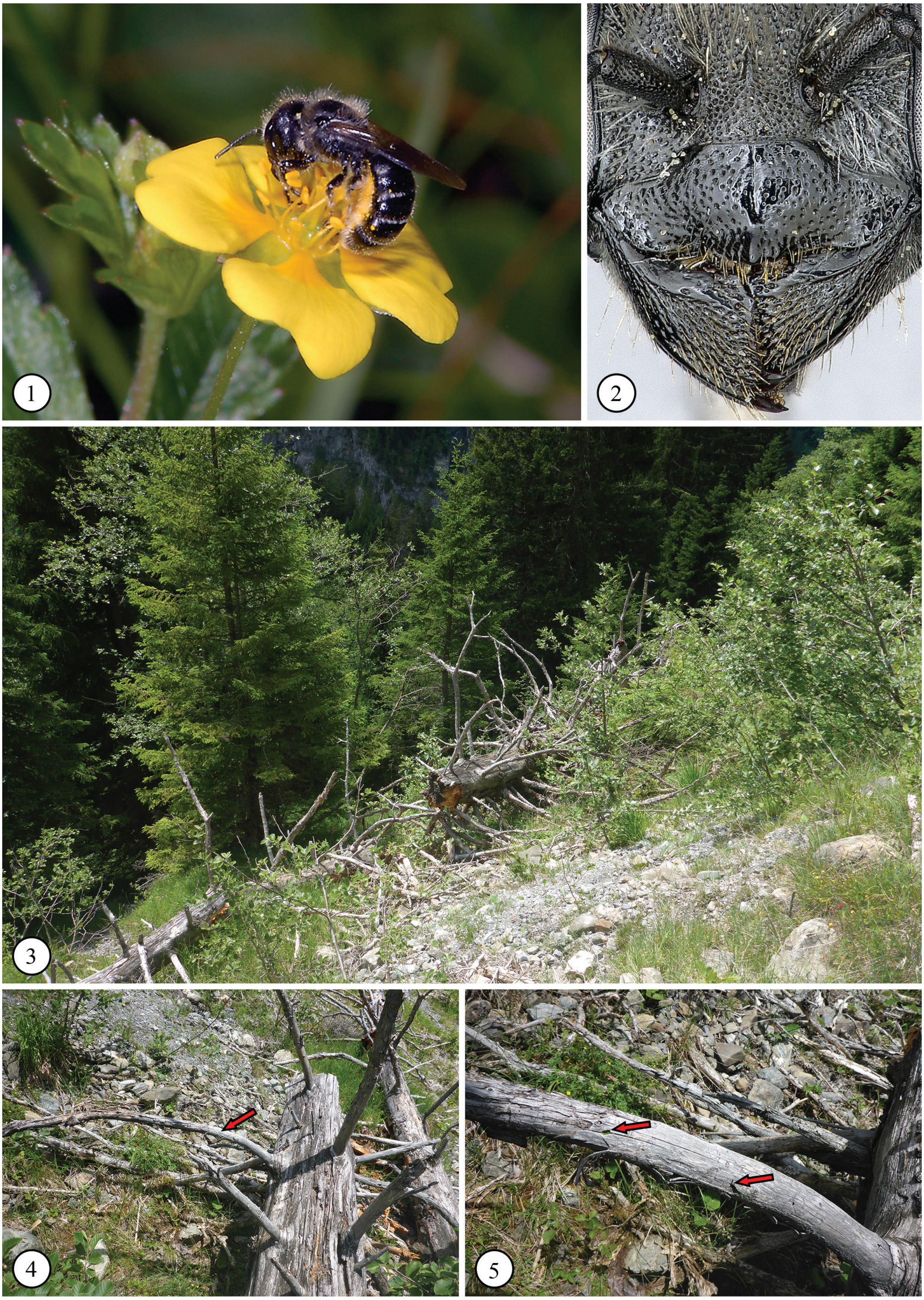
The two nests of *Hoplitis robusta* were found on a sunny clearing of a subalpine spruce forest (Fig. 3). They were situated in a 4 cm thick and 90 cm long branch of a dead fallen spruce (*Picea abies* (L.) H. Karst.) (Figs 4, 5), the nest entrances being in a distance of 31 cm (nest 1) and 20 cm (nest 2) from the branch base. Both nests were built in L-shaped pupation tunnels of an unknown cerambycid beetle species (Figs 6, 9, 10 and Suppl. materials 1, 2). The two L-shaped tunnels had a length of 6.5 cm and 5.7 cm and were oval in shape with a mean diameter of about 6 × 3 mm and 5.5 × 3 mm. Upon discovery of the nests, the female of nest 1 was finalizing the nest seal, whereas nest 2 was already finished. As the oldest bee larva in the innermost brood cell of nest 1 was in a slightly more advanced stage than the youngest larva in the outermost brood cell of nest 2 (Figs 9, 10), the two nests must have been built by two different females.

The two nests contained six and five linearly arranged brood cells all situated in the straight horizontal part of the L-shaped tunnel (Figs 6, 9, 10 and Suppl. materials 1, 2). The brood cells, whose length ranged from 5.5–7.5 mm, were separated from each other by 0.3–0.5 mm thin partitions constructed from leaf pulp without addition of any supplementary material (Fig. 11). Neither nest was sealed by a wall of leaf pulp against its rear end, the larval provision of the innermost brood cell directly contacted the wood at the bottom of the tunnel. In both nests, the outermost brood cell was not closed at its anterior end by a cell partition (Figs 9, 10), the distance between its base and the bottom of the nest plug measured 14 mm and 17 mm.

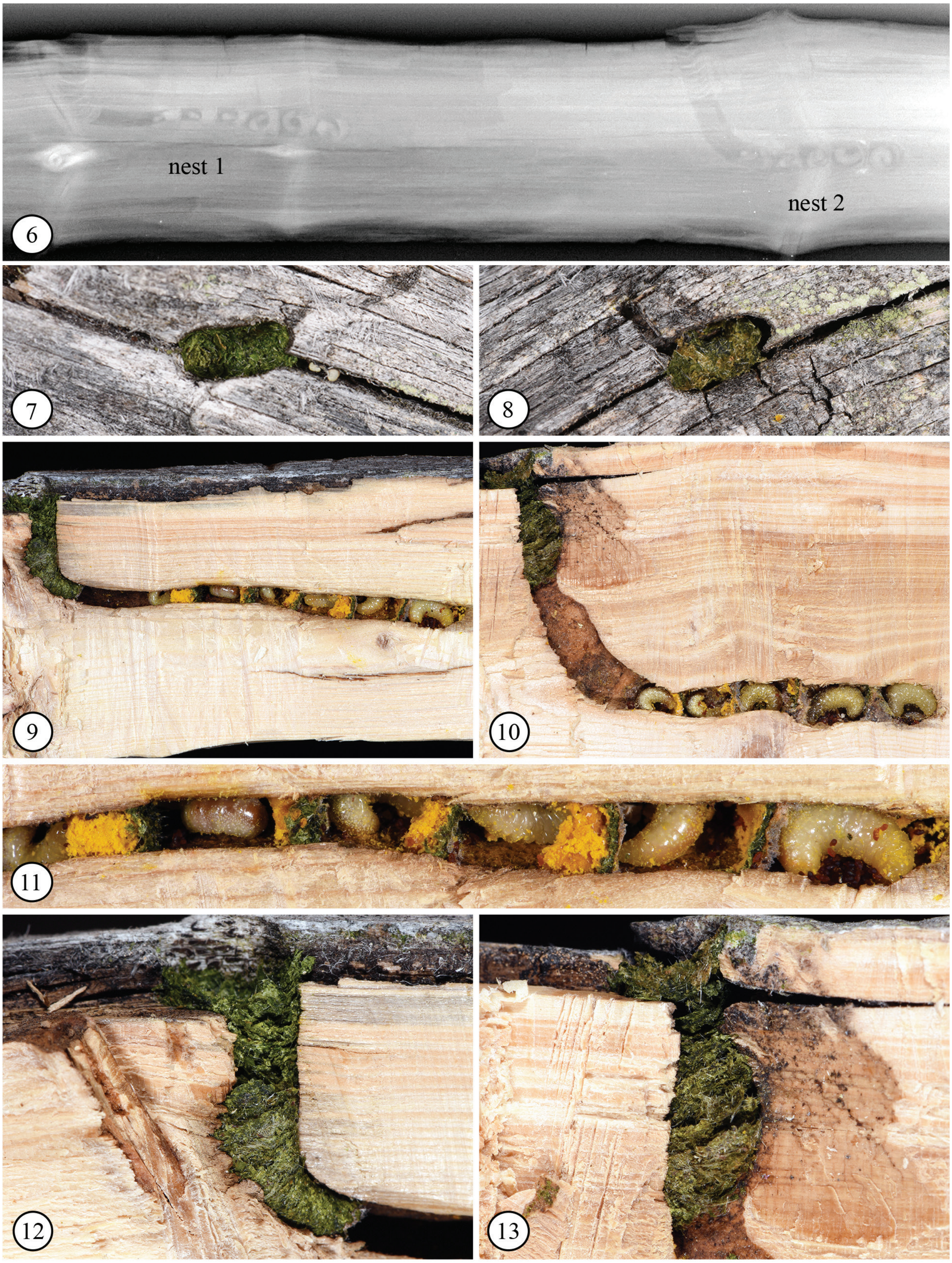
Both nests were sealed by a thick nest plug exclusively constructed from leaf pulp (Figs 12, 13). The two nest plugs had a length of 12 mm and 11 mm and consisted of ten and eight 1–2 mm thick partitions, which were built immediately behind each other (Fig. 6 and Suppl. materials 1, 2) The outermost plug partition consisted of more finely masticated leaves than the inner partitions; its exterior side was smoothed and about 2–3 mm behind the burrow entrance (Figs 7, 8).

Pollen hosts

Hoplitis robusta harvested the pollen of five plant families (Tab. 1). However, it exhibited a strong preference for *Potentilla* (Rosaceae) (Fig. 1), as revealed by the composition of both the female scopal loads and the brood cell provisions (Tab. 1, 2). In the scopal loads, pollen of *Potentilla* constituted 77.1% of the total pollen grain volume and it was recorded in 37 out of 41 loads, 26 of which



Figures 1–5. *Hoplitis robusta*. **1)** Female collecting pollen and nectar on *Potentilla erecta*. **2)** Head of female. **3)** Nesting habitat in the Calfeisen valley near St. Martin (St Gallen). **4)** Dead fallen spruce (*Picea abies*) with nesting branch marked with red arrow. **5)** Nesting branch with nest entrances marked with red arrows.



Figures 6–13. *Hoplitis robusta*. **6)** X-ray of nest branch with nest 1 (left) and nest 2 (right). **7, 8)** Nest seal of nest 1 (left) and nest 2 (right) consisting of leaf pulp. **9, 10)** Dissected nest 1 with six brood cells (left) and nest 2 with five brood cells (right) in L-shaped pupation tunnels of cerambycid beetles. **11)** Close-up view of brood cells in nest 1. **12, 13)** Nest plug of nest 1 (left) and nest 2 (right), each consisting of several successive partitions of leaf pulp.

Table 1. Pollen composition of female pollen loads of *Hoplitis robusta*. n = total number of pollen loads, N = number of pollen loads from different localities. Countries: A = Austria, CH = Switzerland, FIN = Finland. Plant families: AST = Asteraceae, CIS = Cistaceae, FAB = Fabaceae, RAN = Ranunculaceae, ROS = Rosaceae. Definition of bee host range after Müller and Kuhlmann (2008).

n	N	Origin (and number) of pollen loads	% pollen grain volume (number of loads)	Preferred host	% pollen grain volume of preferred host	% pure loads of preferred host	% loads with preferred host	Host range
41	30	A (2), CH (35), FIN (4)	ROS (*Potentilla*) 77.1% (37), ROS (*Rubus*) 1.4% (1), CIS (*Helianthemum*) 13.6% (9), FAB (*Medicago*) 3.2% (1), FAB (*Lotus*) 0.3% (1), AST (Cichorioideae) 1.8% (3), RAN (*Ranunculus*) 1.6% (4), unknown 1% (3)	*Potentilla*	77.1%	63.4%	90.2%	polylectic (5 plant families) with strong preference for *Potentilla* (Rosaceae)

were pure loads. In the cell provisions, pollen of *Potentilla* was the exclusive constituent in six out of eight provisions, while two provisions additionally contained moderate amounts of pollen of *Helianthemum* (Cistaceae). Pollen collection by females of *H. robusta* at six different localites in the Swiss Alps (see Methods) was invariably observed on flowers of *Potentilla erecta* (L.) Raeusch. (n = 27 flower visits), except for two females that visited the flowers of *Potentilla aurea* L. and *Ranunculus lanuginosus* L., respectively.

Pollen collecting females worked the *Potentilla* flowers in a rapid and efficient way (Fig. 1): they embraced the anthers below their body and – while turning slowly around the flower centre – picked up the pollen directly into the scopa by rapidly seesawing the underside of the metasoma against the anthers (Fig. 1); simultaneously, they sucked nectar from the base of the androecium.

Nest building material

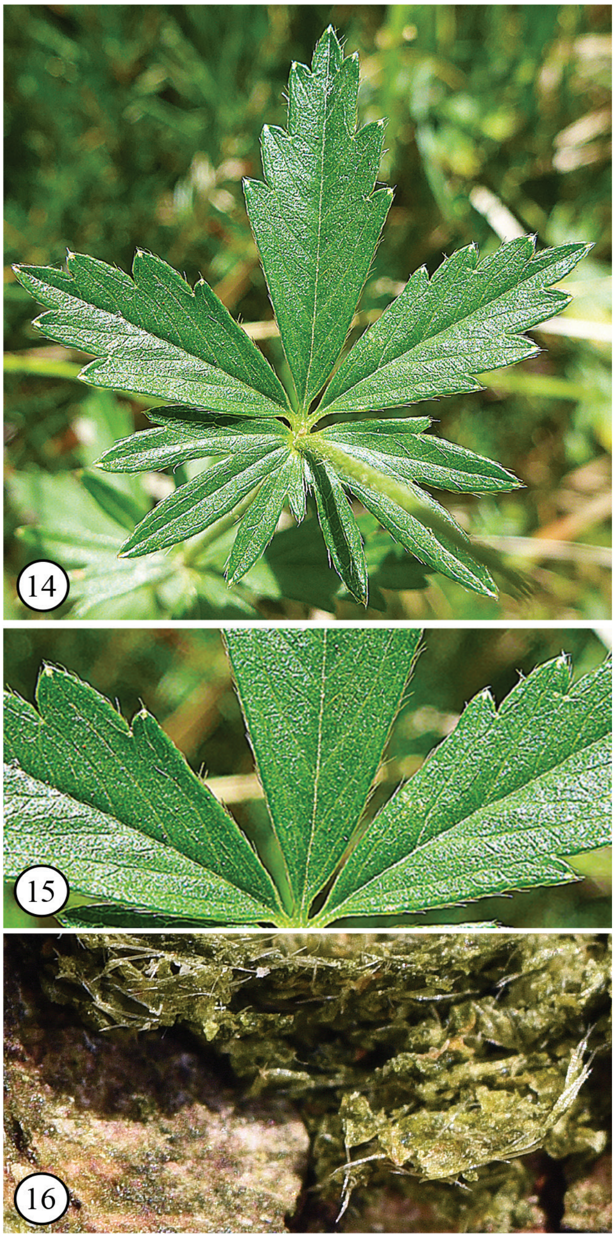
Four females of *Hoplitis robusta* were observed in the Grisons near Sedrun on 1.8.2013, near Sent on 5.7.2016 and near Curaglia on 29.6.2018 harvesting material for nest construction from green leaves of *Potentilla erecta*. DNA metabarcoding revealed that the plug of nest 2 was constructed from masticated leaves of three rosaceous herb species including *Potentilla erecta* (Tab. 3).

Table 2. Pollen composition of larval provisions in eight brood cells of *Hoplitis robusta* from two nests owned by different females; in brood cells 1–3 of nest 2, the larvae had already devoured all provisions.

		Potentilla	*Helianthemum*
nest 1	brood cell 1	90%	10%
	brood cell 2	100%	
	brood cell 3	100%	
	brood cell 4	90%	10%
	brood cell 5	100%	
	brood cell 6	100%	
nest 2	brood cell 4	100%	
	brood cell 5	100%	
total		97.5%	2.5%

Table 3. Origin of the masticated green leaves used by *Hoplitis robusta* to build the plug of nest 2 based on DNA metabarcoding.

Plant taxon	% sequence reads
Fragaria vesca (Rosaceae)	50.9
Potentilla erecta (Rosaceae)	43.6
Alchemilla spec. (Rosaceae)	5.5



Figures 14–16. 14) Leaf of *Potentilla erecta*. **15)** Close-up view of leaf of *Potentilla erecta* with indumental hairs along the leaf margins and on the leaf surface. **16)** Leaf pulp matrix of uppermost partition of the plug of nest 1 with numerous indumental hairs possibly originating from *Potentilla* and/or *Fragaria*.

Figure 17. L-shaped pupation tunnel of *Tetropium castaneum* (Cerambycidae) after emergence of the adult beetle with densely packed wood chips and fibers in the straight horizontal part of the tunnel (photo B. Wermelinger).

Although the percentage of sequence reads obtained by next-generation sequencing is only a rough indication for the relative amount of a plant taxon in the extracted DNA, the majority of the leaf material of the nest plug likely originated from *Potentilla erecta* and *Fragaria vesca*. The stereomicroscopic examination of all cell partitions and the uppermost partition of the plug of nest 1 showed that the leaf pulp matrix invariaby contained numerous white, straight and only slightly tapering hairs of about 0.5–0.8 mm length and 0.03 mm maximal width (Fig. 16). Hairs of identical shape and dimensions were found both along the margins and on the upper and lower surface of the leaves of *Potentilla erecta* and *Fragaria vesca* (Figs 14, 15). However, among the 54 plant species collected within a radius of 15 m around the nesting site, the leaves of four additional species also had such hairs, i.e. *Helianthemum* spec. (Cistaceae), *Ranunculus* spec. (Ranunculaceae), *Thymus* spec. (Lamiaceae) and *Trifolium* spec. (Fabaceae), rendering it impossible to unambiguously assign the leaf pulp hairs to a single plant taxon. Nevertheless, the presence of such hairs within the leaf pulp matrix does neither contradict the field observations described above nor the results obtained by DNA metabarcoding and suggests that the cell partitions and the plug of nest 1 might actually have been (partly) built from masticated leaves of *Potentilla* and/or *Fragaria*.

Discussion

Nesting site and nest architecture

The nest architecture of the two nests of *Hoplitis robusta* from the Swiss Alps corresponds well with that of nests found in drilled borings of artificial trap nest blocks in the Rocky Mountains/USA (Clement and Rust 1975). The six North American nests were built in borings with a diameter of 4–5 mm and contained 3–14 linearly arranged and 5.5–11 mm long brood cells; the 0.3–1 mm thin cell partitions were constructed from masticated leaves and the 10–14 mm long nest plugs consisted of 8–13 successive layers of leaf pulp. However, in contrast to the findings of the present study, three North American nests contained 3–18 mm long vestibule cells following the last brood cell and some cell partitions had small pieces of wood embedded in the leaf pulp matrix. Whether the construction of vestibule cells and the combination of leaf pulp with additional material also occurs in European populations of *H. robusta* is unknown. Interestingly, nests of *Hoplitis maritima* (Romankova) – an eastern Asian representative of the subgenus *Formicapis* – were discovered in cerambycid beetle burrows in 4–5 cm thick branches of dead fallen conifers (Romankova 1985), exactly corresponding to the nesting sites of the two females of *H. robusta* in the Swiss Alps; these nests contained 2–6 linearly arranged brood cells and leaf pulp served as material for the construction of both cell partitions and nest plug. The identical nesting biologies of *H. robusta* and *H. maritima* suggest that the use of beetle burrows in dead wood as nesting site and of masticated leaves as nest building material are subgeneric traits of the subgenus *Formicapis*.

Females of *Hoplitis robusta* possess unusually large and powerful mandibles (Fig. 2). As such mandibles do not appear to be adaptive in collecting floral resources nor in harvesting and masticating green leaves, their function remains enigmatic. We hypothesize that these powerful mandibles have evolved as a tool to clean L-shaped pupation tunnels of cerambycid beetles immediately following nest site selection. After emergence, adults of cerambycid beetle species, which gnaw L-shaped tunnels in the last larval instar for pupation, use to leave behind substantial amounts of densely packed wood chips and fibres in the straight horizontal part of the tunnel (Fig. 17). The strong female mandibles might provide the needed strength to remove the wood debris out of the tunnel. A similar cleaning function has been hypothesized for the huge female mandibles of *H. maritima* (Romankova 1985, Müller and Mauss 2016).

Pollen hosts

The composition of the female scopal loads, the pollen content of the brood cells, field observations of flower visiting females and the highly efficient pollen collecting behaviour all suggest that *Hoplitis robusta* is strongly dependent on *Potentilla* (Rosaceae) for its reproduction. Since the pollen of *Potentilla* could not reliably be distinguished from that of *Fragaria* by the method used in the present study (see Methods), it cannot be excluded that *H. robusta* occasionally also exploits flowers of *Fragaria vesca*. However, as the flowering period of *F. vesca* and the flight period of *H. robusta* at most marginally overlap, *Fragaria* is not expected to be a regular pollen host of *H. robusta* in the Alps. A preference for the pollen of herbaceous Rosaceae has also been recorded for eastern Asian *Hoplitis* species of the subgenus *Formicapis*: *H.*

maritima is oligolectic on *Fragaria* and *Potentilla* (Romankova 1985, Proshchalykin in Quest 2009), and several pollen loads of *H. excisa* (Morawitz) were composed of Rosaceae pollen, mainly of the *Potentilla* type (Müller and Mauss 2016). This suggests that the preferential or exclusive use of herbaceous Rosaceae as pollen hosts is a subgeneric trait of *Formicapis*.

The larval provision of a single brood cell of *Hoplitis robusta* from the Rocky Mountains/USA contained pollen possibly from a legume, such as *Astragalus* or *Trifolium* (Clement and Rust 1975). However, given the uncertainty in pollen identification admitted by the authors and the negligible amount of Fabaceae pollen in the larval diet of *H. robusta* in the Alps (see Tab. 1), the larval provision might possibly have consisted of pollen of the *Potentilla* type, which – albeit distinctly smaller – has a similar morphology and shape as pollen grains of *Astragalus* and *Trifolium*. This assumption is in line with flower records of *H. robusta* from North America, which originate mainly from herbaceous Rosaceae, primarily *Potentilla* (Ascher and Pickering 2018).

Nest building material

The use of green leaves of *Potentilla erecta* as nest building material by *Hoplitis robusta* is documented both by field observations and DNA metabarcoding and is also suggested by the stereomicroscopic analysis of the leaf pulp matrix, clearly indicating that *Potentilla* leaves play an important role for the construction of cell partitions and nest plugs in *H. robusta.* However, *Potentilla* was not the exclusive source, two other rosaceous herbs were also confirmed as suppliers of nest building material, i.e. *Fragaria vesca* and possibly to a lesser and only marginal degree *Alchemilla* spec. The fact that these three taxa all belong to the Rosaceae is surprising and suggests that the selection of leaves for manufacturing leaf pulp is far from accidental and that the leaves of Rosaceae species might possess particularly favourable properties as nest building material. In fact, eight Central European osmiine bee species belonging to two genera and six subgenera were recorded to harvest leaf material for nest construction from rosaceous genera, such as *Fragaria, Potentilla, Rosa* and/or *Sanguisorba*, i.e. *Hoplitis* (*Alcidamea*) *claviventris* (Thomson), *Osmia* (*Erythrosmia*) *andrenoides* Spinola, *O.* (*Helicosmia*) *aurulenta* (Panzer), *O.* (*Helicosmia*) *leaiana* (Kirby), *O.* (*Hoplosmia*) *spinulosa* (Kirby), *O.* (*Melanosmia*) *parietina* Curtis, *O.* (*Melanosmia*) *pilicornis* Smith and *O.* (*Neosmia*) *bicolor* (Schrank) (Müller 1994, 2018a and references therein, Prosi et al. 2016). Although the very poor knowledge on the plant spectra exploited by leaf masticating megachilid bees for nest construction renders any conclusions premature, it is well conceivable that some species including *H. robusta* might be specialized with respect to the plants they use for manufacturing leaf pulp. Interestingly, experiments with the North American *Osmia bruneri* Cockerell in flight cages recently revealed that leaves of *Malva neglecta* and *Sphaeralcea ambigua* (both Malvaceae) as well as of *Oenothera elata* (Onagraceae) were readily accepted by the females as leaf pulp sources, whereas those of *Callirhoe involucrata* and *Hibiscus syriacus* (Malvaceae) as well as of *Cercis canadensis* (Fabaceae) were ignored, suggesting strong preferences for the plants exploited for leaf pulp (Cane submitted).

Conclusions

Among the Central European megachild bees, *Hoplitis robusta* is an exception in that it harvests floral resources and nest building material from the very same plant taxon, i.e. *Potentilla*. Though the dependence on *Potentilla* is not complete, neither for collecting floral resources nor for harvesting nest building material, *Potentilla* plays a key role in the life history of *H. robusta*. The findings of the present study suggest that large stands of *Potentilla erecta* in close neighbourhood to sun-exposed dead wood fulfill all requirements for population survival of *H. robusta* in the subalpine zone of the Alps. Pollen of *Potentilla* is also crucial for the reproduction of other alpine bee species. *Andrena tarsata* Nylander and *Panurginus herzi* Morawitz are strictly specialized on *Potentilla*, while in several polylectic species, such as *Andrena amieti* Praz, Müller & Genoud, *Andrena coitana* (Kirby) or *Panurginus montanus* Giraud, pollen of *Potentilla* often represents a considerable proportion of the collected pollen (Westrich 1989, Müller 2018b, Praz et al. submitted). Thus, species of *Potentilla* and particularly *P. erecta* play a significant role in sustaining populations of numerous bee species in alpine habitats.

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Supplementary material 1

Computed tomography (CT) movie of nest 1 of *Hoplitis robusta*

Authors: Andreas Müller, Henning Richter

Data type: species data

Explanation note: Computed tomography (CT) movie of nest 1 of *Hoplitis robusta*; note the vertical nest plug consisting of several successive layers of leaf pulp and the six brood cells in the horizontal part of the L-shaped cerambycid tunnel.

Link: https://doi.org/10.3897/alpento.2.30158.suppl1

Supplementary material 2

Computed tomography (CT) movie of nest 2 of *Hoplitis robusta*

Authors: Andreas Müller, Henning Richter

Data type: species data

Explanation note: Computed tomography (CT) movie of nest 2 of *Hoplitis robusta*; note the vertical plug consisting of several successive layers of leaf pulp and the five brood cells in the horizontal part of the L-shaped cerambycid tunnel.

Link: https://doi.org/10.3897/alpento.2.30158.suppl2

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Rheinheimer J, Hassler M (2018) Die Blattkäfer Baden-Württembergs

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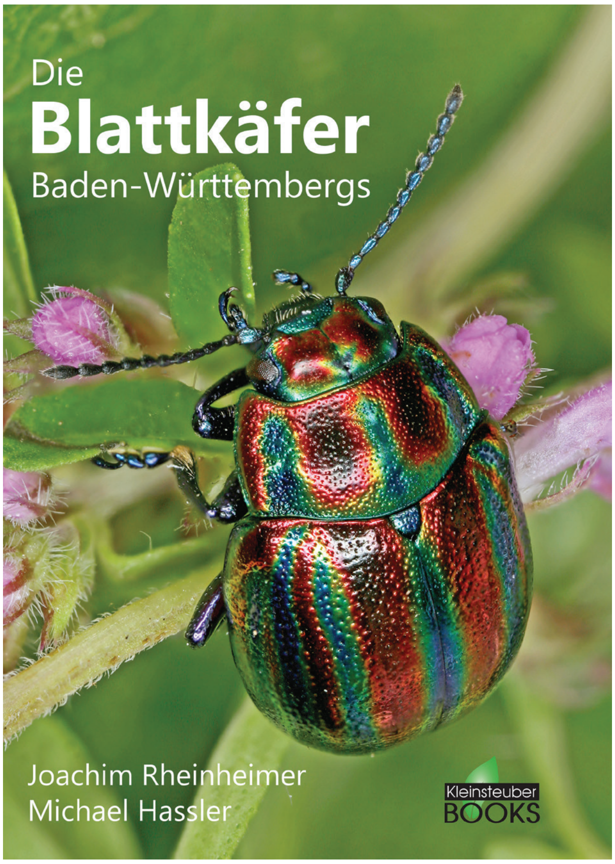
Schillernde Juwelen auf Pflanzen. Manchmal eine einzelne prächtig glänzende *Chrysolina* oder *Oreina* am Wegrand, dann wieder riesige Mengen an kleinsten springenden Blattflohkäfern (Alticinae) auf einem Kreuzblütler. Die Blattkäfer im weiteren Sinn (Chrysomelidae, Orsodacnidae und Megalopodidae) fallen auf, gefallen und faszinieren. Auf der Suche nach Käfern in der Natur draussen führt kein Weg an diesen Familien vorbei. Zahlreich sind die Kolleg/innen, welche dadurch immer wieder «fremdsammeln» und überraschend eine Ansammlung an Blattkäfern hervor zaubern. Meist jedoch ohne Artdiagnose und mit der leisen Hoffnung die Tiere irgendwann einmal bestimmt zu bekommen. Umso erfreulicher, dass nun erstmals ein wirklich bild- und wissensgewaltiges Buch von 2.25 kg über diese lebenden Juwelen verfügbar ist. Viel wurde geschrieben über die Blattkäfer im deutschsprachigen Raum, so viel, dass die verwendete Literatur im neuen Werk von Joachim Rheinheimer und Michael Hassler auf die tatsächlich relevante gekürzt werden musste. Trotzdem sind die Referenzen sehr vollständig. Wie auch die Artenportraits, welche gleich die Blattkäfer-Fauna ganz Deutschlands abdecken. Hier greift sogar der Buchtitel etwas zu kurz! Von der Aufmachung her erinnert der Blattkäfer-Band stark an denjenigen der Rüsselkäfer, er wurde jedoch noch ergänzt: Auf stolzen 928 Seiten werden 543 Arten besprochen. Die grosszügige Einleitung auf über 150 Seiten beleuchtet alle wichtigen Bereiche, von der Lebensraumvielfalt bis zu möglicherweise symbiotisch lebenden Wolbachia-Bakterien. Eine detaillierte faunistische Liste für Baden-Württemberg mit Angaben zur Gefährdung schliesst sich an. Starke 610 Seiten umfasst der eigentliche Kernbereich des Buches: die ausführlichen Artenportraits mit Einblick in Biologie und Mikrohabitate. Wiederum sind – grün hinterlegt – übersichtliche Bestimmungstabellen für



die fortgeschrittenen Anwender/innen beigelegt. Die 82 Bildtafeln mit perfekt wirkenden Habitusbildern stammen von Lech Borowiec und wurden für den vorliegenden Band lizenziert. Zudem wurden Bilder sämtlicher bestimmungsrelevanter Genital-Strukturen angefügt, eine äusserst hilfreiche und für eine korrekte Diagnose unverzichtbare Ergänzung. Besonders bei heimlichen Arten der Alticinae mit hohen Biotopansprüchen besteht faunistisch und biologisch (Larvalstadien!) weiterer Forschungsbedarf, auch darauf wird verwiesen, so dass Nachwuchsforscher/innen zukünftig diese «weissen Flecken» gezielt angehen können und sollen. Schlichtweg atemberaubend sind die Portrait-Fotos lebender Alticinae, welche bei geringster Störung gewaltige Sprünge weit aus dem Fangradius des Interessierten ausführen, wie jede/r feldkundige Koleopterologe/in weiss.

Allen Naturbeobachtenden sei das Werk wärmstens empfohlen. Ganz egal was über Blattkäfer herausgefunden werden möchte, die «Die Blattkäfer Baden-Württembergs» helfen weiter, dies selbst im grössten Teil der gebirgigen Schweiz, «fehlen» hier doch nur rund 40 alpin bis mediterran verbreitete, zusätzlich vorkommende Arten. Auch für professionelle Anwender/innen ist die weit gestreute Information zu diesen Käferfamilien aus derart vielen Quellen noch nie in solch einem übersichtlichen und ansprechenden Format zusammengestellt worden.

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PENSOFT.

Alpine
Entomology

Charles Lienhard at 70

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Charles Lienhard was born in Zurich on 15 January 1949. The spelling of his first name was chosen in honour of his paternal grandfather Karl Lienhard, who emigrated from Zurich to France at the beginning of the 20th century. After a traditional high-school education, including the study of Latin and Ancient Greek, he turned to the natural sciences in 1967, enrolling in the biology course at the Swiss Federal Institute of Technology (Eidgenössische Technische Hochschule, ETH Zurich). Fascinated by the world of insects, and greatly encouraged by Willi Sauter, professor of systematic entomology, he completed his Master's degree with a faunistic study of the Psocoptera (psocids, or barklice and booklice) of the Zurich region in 1972. He joined the Swiss Entomological Society in the same year. After accepting Sauter's suggestion of psocids as a subject, he was surprised to discover that even professional entomologists barely knew this group of fragile but charming insects, which are omnipresent in Swiss forests although their common name in German (Staubläuse) might lead one to expect them only in kitchen cupboards. Lienhard then began a doctorate at the ETH Institute of Entomology, investigating the Psocoptera fauna of the Swiss National Park in Engadin under the supervision of professors Georg Benz and Willi Sauter, a study which was awarded the ETH silver medal in 1977.

From 1976 to 1979 Lienhard was part of a team of biologists studying an alpine grassland ecosystem in the Swiss National Park. He was responsible for the Collembola, which are an extremely diverse group in this habitat (from which psocids are almost entirely absent). In parallel with this study of the community ecology of the soil fauna, Lienhard continued to collect psocids during many trips to the Mediterranean region, accompanied from 1977 by his wife Heidi. She soon came to share his enthusiasm for these small and delicate insects, a group often overlooked despite being easy to collect using simple classical methods (Lienhard et al. 1987), and it was Heidi who sewed the linings of the early modified-umbrella beating trays that he always used in the field. He became an accomplished field entomologist, whose calm and adaptable approach to fieldwork made him a highly valued travelling companion. Lienhard is in many ways a traditional naturalist, interested in the biology and ecology of the species he studies, and was successful in rearing many psocid species, including some for which adults of one sex were previously unknown.

In the course of his Collembola research, Lienhard came into contact with Bernd Hauser, then curator of the Department of Arthropods at the Natural History Museum of Geneva (Lienhard et al. 2016) and responsible for the largest collection of Collembola in Switzerland. Following a fruitful collaboration Lienhard was recruited by Hauser as a research officer in the Department of Arthropods in 1981. When Hauser retired, Lienhard acted as interim curator for a year before resuming his role as research officer under the new curator, Peter Schwendinger in 1999. His role at the museum also involved collaboration with the curator for public outreach, exhibition and educational activities, as well as management of the scientific collections. He participated in many excursions and expeditions organised by Hauser, mainly in the West Palaearctic but including South East Asia, Madagascar and North America. These add up to almost a year of travelling together, and provide Bernd Hauser with some fond memories, not only of the pleasures of the chase but of the opportunity to spend time with a cultured and thoughtful man. It was with Hauser, a noted biospeleologist, that Lienhard first studied the fauna of caves, which later became such a fruitful aspect of his research.

Among Lienhard's most interesting discoveries are the first Old World representatives of the families Troctopsocidae and Protroctopsocidae (six new genera, three from Europe and three from South East Asia), and his contributions to our knowledge of the family Prionoglaridae (five new genera, one from South East Asia, two from southern Africa and two from South America).

Alongside his research, he was editor of the *Revue suisse de Zoologie*, published by the Museum and the Swiss Zoological Society from 1998 to 2005, and of the series *Nationalpark-Forschung in der Schweiz* published by the Scientific Commission of the Swiss National Park from 1989 to 1999. He organised the Second International Workshop on Psocoptera in Geneva in 1996, bringing together experts from five continents; many were already, or would become, friends. Thanks to Lienhard, the Psocoptera collection of the Geneva Museum – a collection created by his own fieldwork and by his worldwide network of contacts depositing specimens – is now of world importance. At the age of 60 Lienhard took early retirement in order to spend more time with his wife, who has multiple sclerosis.

Although Charles Lienhard has described many new taxa, his trademark attention to detail and encyclopaedic knowledge of the Psocoptera gave him a unique opportunity to make a more universal contribution by drawing together all the available information concerning a whole order of insects. His revision of the West Palaearctic species of *Liposcelis* included the first identification key that allows identification of all of the economically important species of this genus worldwide (Lienhard 1990). His book on the Psocoptera of the West Palaearctic, which appeared in the *Faune de France* series (Lienhard 1998), remains the standard work for identifying the psocids of this region and was awarded the A. Constant Prize by the French Entomological Society in 1998. The book is dedicated to André Badonnel, the eminent French Psocoptera specialist who acted as mentor from the beginning of Lienhard's study of the group and left his private collection of Psocoptera to the Geneva Museum on his death in 1991. Conscious that the huge number of genera and species that had been described in the second half of the 20th century made an overview of the order difficult even for specialists, Lienhard suggested to his Australian colleague Courtney Smithers that they should produce an update to the world catalogue that he had published in 1967. The result of this successful collaboration (Lienhard and Smithers 2002) is a compilation of all information concerning the Psocoptera published up to the end of the 20th century. Unlike most such catalogues, this work is not restricted to the taxonomic literature but includes all published works mentioning Psocoptera, and indicates for each species the bibliographic references concerning their geographic distribution, biology, ecology and, where relevant, economic importance. Since 2003 Lienhard has produced annual supplements to the catalogue and bibliography, which are published online in *Psocid News*. Checklists based on the catalogue for all countries, and a thematic bibliography of the Psocoptera literature published between 1688 and 2015 are available online at the *Psocid News* website. Many colleagues working on other groups have expressed envy and astonishment that the world's entire knowledge of the Psocoptera should be so easily accessible, and kept up to date. The *Psocodea Species File Online* database, managed by the Illinois Natural History Survey, was created from the catalogue and its updates. The dedication of the catalogue to his wife Heidi bears witness to the importance of her contribution to Lienhard's scientific work.

On his retirement in 2009, Lienhard was named honorary curator by the Geneva Museum, and he installed a small laboratory in his apartment where he continues his research on Psocoptera. Charles Lienhard is both modest and generous, a combination that has resulted in most of his scientific contacts developing into long-term collaborations during a harmonious career. His relationships with the Museum and with colleagues around the world have led to some particularly interesting projects in the years after his retirement.

The result he finds the most intriguing of his career is the discovery in a Brazilian cave of two specimens of *Psyllipsocus yucatan* with both surfaces of their wings covered by a thin, completely uniform layer of black microcrystals (Lienhard et al. 2012); an enigma for physics and biology! This study is one of Lienhard's numerous contributions to our knowledge of cave Psocoptera resulting from his many contacts amongst biospeleologists (including Bernd Hauser, Pierre Strinati, Villy Aellen, Philip Ashmole, Rodrigo Ferreira, Eugene Marais and Guiseppe Grafitti). He described the first blind (anophthalmus) psocid from a cave on the island of St Helena (Lienhard and Ashmole 1999, 2011). In the cave-dwelling genera *Sensitibilla* and *Afrotrogla* from southern Africa he discovered trichobothria not only on the tibia, for the first time in psocids, but also on the tarsi, something previously unknown in insects (Lienhard 2000, 2007). His study of the psocids of Brazilian caves collected by Rodrigo Ferreira led to the description of 15 new species of *Psyllipsocus* and the discovery of a new secondary genital organ found in the males of some species (Lienhard and Ferreira 2013, 2014, 2015). His discovery of the gynosome (the first female penis found in the animal kingdom) in the new cave-dwelling genus *Neotrogla* from Brazil (Lienhard *et al*. 2010) spawned a research team whose publication in *Current Biology* (Yoshizawa et al. 2014) was awarded the 2017 Ig Nobel Prize for biology. Despite the discovery making the headlines, Lienhard admits that the general interest it aroused, both in the scientific sphere and the wider world, surprised him. It is of particular satisfaction to him that a simple traditional study of morphological taxonomy revealed a phenomenon that currently exercises such fascination for evolutionary biologists.

Lienhard's collaboration with the brilliant young entomologist Kazunori Yoshizawa extends to many fields in addition to that which won the Ig Nobel, and includes the description of a remarkable fossil of a member of the family Archipsyllidae preserved in Cretaceous amber from Myanmar, which allowed them to define the new superorder Paracondylognatha within the Paraneoptera (Yoshizawa and Lienhard 2016). The only other palaeontological contribution Lienhard has made is a revision of the classification of the Psocoptera known from Cretaceous amber (Mockford et al. 2013), a study led by Edward Mockford, doyen of Psocopterists and considered by Lienhard as a shining example throughout his career.

Charles Lienhard with images of *Reticulopsocus besucheti* (male left, female right), beetle-like protroctopsocid collected in Turkey by the Swiss coleopterist Claude Besuchet. (Photo: H. Lienhard, 2017).

Over the last few years Lienhard's two small grandchildren have revived his interest in watercolours and drawing, two pleasures long neglected in favour of scientific illustration. Asked which future projects are particularly dear to him, he replied provocatively, 'Inventing stories for children, and illustrating them with drawings and paintings, is less tedious and gives as much satisfaction as writing a scientific paper!' We hope nonetheless that Charles Lienhard will continue to dedicate part of his time to his beloved psocids.

Acknowledgements

We are grateful to Bernd Hauser for inspiring this article and numerous anecdotes. He and Anita Hollier commented on earlier versions the text.

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Supplementary material 1

Liste des publications de Charles Lienhard

Authors: Nico Schneider, John Hollier

Data type: bibliography

Link: https://doi.org/10.3897/alpento.2.30088.suppl1

Alpine Entomology 2 2018, 155–159 | DOI 10.3897/alpento.2.31585

Protokoll der Jahresversammlung der Schweizerischen Entomologischen Gesellschaft vom 2. und 3. März 2018 am Naturhistorischen Museum der Burgergemeinde Bern

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Die Jahresversammlung der SEG wurde auf Einladung des Naturhistorischen Museums der Burgergemeinde Bern am 2. und 3. März 2018 in Bern durchgeführt.

Der Freitagnachmittag war - neben dem Vorstellen einer neuen invasiven Insektenart und dem Einblick in die Biologie und Verbreitung eines auf Fledermausfliegen parasitisch lebenden Schlauchpilzes - vor allem Themen der angewandten Entomologie in der Forst- und Landwirtschaft gewidmet.

Dr. Jean-Yves Humbert (Universität Bern) eröffnete die Tagung mit einem interessanten Hauptvortrag zum Einfluss von Mäh-Methoden und Mäh-Zeitpunkten von Grasland im Mittelland auf dessen Biodiversität. Ein um wenige Wochen verzögertes Mähen oder das Stehenlassen des Grases auf 10–20% der Fläche hat einen positiven Einfluss auf die Biodiversität von herbivoren Insekten mit Entwicklungsstadien auf der Vegetation. Die Pflanzenzusammensetzung und Artenzahl, sowie die Diversität der Insektenarten, deren Larven nicht direkt von der Vegetation abhängig sind, wurden durch die verschiedenen Mäh-Methoden und Mäh-Zeitpunkte nicht beeinflusst. Mit dieser Erkenntnis können Bewirtschaftungsmassnahmen auf einfachste Weise angepasst werden und dadurch zu einem erhöhten Artenreichtum von Insekten auf solchen Nutzflächen führen.

Folgende acht Vorträge wurden am Freitagnachmittag gehalten:

- Larval and phenological traits predict invertebrate community response to manipulation of mowing regime in extensively managed grasslands
  Jean-Yves Humbert, University of Bern

- Auswirkungen von Blühstreifen auf die Artendiversität von Nützlingen im Gemüseanbau
  Henryk Luka, Research Institute of Organic Agriculture FiBL, Frick

- Borkenkäfer und Klimawandel
  Beat Wermelinger, Eidg. Forschungsanstalt WSL, Birmensdorf

- *Drosophila suzukii*: état des lieux et lutte
  Patrik Kehrli, Agroscope, Nyon

- *Vrestovia fidenas*, ein potentieller Gegenspieler der invasiven
  Kirschessigfliege in der Schweiz
  Sarah Wolf, Agroscope, Zürich

- Laboulbeniales (Fungi: Ascomycota) infection of bat flies (Diptera: Nycteribiidae) from *Miniopterus schreibersii* across Europe
  Tamara Szentivanyi, Museum of Zoology, Lausanne

- Zickzack-Ulmenblattwespe – eine neue invasive Art in der Schweiz
  Doris Hölling, Eidg. Forschungsanstalt WSL, Birmensdorf

- Hivernage des Méligèthes du colza (*Meligethes aeneus* Fab.) et de leurs ennemis naturels dans les champs de colza oléagineux et les habitats semi-naturels
  Philippe Jeanneret, Agroscope, Zürich
  Folgende zwei Poster wurden am Freitag und Samstag präsentiert:

- The effect of lamp proximity to aquatic habitats on the attraction of adult aquatic insects
  Claudia Blumenstein, Deborah Carannante, James David Hale, Raphaël
  Arlettaz – Institute for Ecology and Evolution, University of Bern, Switzerland

- Festival der Schmetterling
  Marc de Roche – Swiss Butterfly Breeders, Bern, Schweiz

Der Samstag war freien Themen aus der Faunistik, Taxonomie, Systematik, sowie des Artenschutzes gewidmet. Zudem wurde auch ein digitales Werkzeug vorgestellt, um wissenschaftliche Abbildungen besser auffindbar, frei zugänglich und wiederverwendbar zu machen.

Hans-Peter Wymann eröffnete diesen zweiten Tag mit einem spannenden und reich bebilderten Vortrag über die Tagfalter des Berner Oberlandes. Dass bis 1990 nur gerade zwei Publikationen über die Schmetterlinge der Nördlichen Westalpen existierten, veranlasste den Referenten, die Tagfalter des Berner Oberlandes etwas genauer zu untersuchen. Während seiner knapp drei Jahrzehnte dauernden Studien konnte er 20 Neumeldungen, 6 Wiederfunde und total 150 Tagfalter für das Berner Oberland nachweisen. Die gewonnenen Kenntnisse über die Schmetterlinge dieser Region konnten auch für den Schutz zahlreicher Habitate und damit für einen erfolgreichen Artenschutz vieler Tagfalter verwendet werden. Ergänzend zu der aktuellen Situation stellte Hans-Peter Wymann diverse mögliche Szenarien für die nacheiszeitliche Wiederbesiedlung des Berner Oberlandes durch die Tagfalter vor.

Folgende neun Vorträge wurden am Samstag gehalten:

- Die Tagfalter des Berner Oberlandes: eine Zwischenbilanz nach 26 Jahren Feldarbeit
  Hans-Peter Wymann, Naturhistorisches Museum Bern

- Artenschutzprojekt *Leucorrhinia pectoralis* (Odonata) – Interaktion zwischen Forschung und Naturschutzpraxis
  Hansruedi Wildermuth, Rüti (ZH)

- Die Höhlenüberwinterer
  Rudolf Bryner, Biel

- Blastobasidae: wenig beachtete Kleinschmetterlings-Familie mit einer
  Neumeldung für die Schweiz
  Andreas Kopp, St. Margarethen

- New population of *Podismopsis* Zubovski, 1900 (Orthoptera, Acrididae, Gomphocerinae) discovered in the Swiss Alps
  Stève Breitenmoser, Givrins

- Préférences écologiques des Coléoptères saproxyliques emblématiques de
  Suisse

- Ein neuer Faltenwespen-Atlas entsteht
  Rainer Neumeyer, Zürich

- Biodiversity Literature Repository: A visual access to taxonomic knowledge
  Donat Agosti, Plazi

- Honigbiene – Teil unserer Biodiversität! André Wermelinger, Montévraz

Die Vortragsreihe am Samstag wurde mit „Winterbergs Überstunde“, einer humoristischen und wissenschaftlich gehaltvollen Vorlesung von Christian Kropf und Uwe Schönbeck, abgerundet.

An der Generalversammlung vom Samstagmorgen nahmen 21 Mitglieder teil.

Dem Naturhistorischen Museum der Burgergemeinde Bern, im Speziellen Hannes Baur, sei für die hervorragende Organisation der Jahresversammlung und für das Offerieren der Pausenverpflegungen herzlich gedankt.

Generalversammlung

Begrüssung

Der Präsident Hannes Baur eröffnet die Generalversammlung um 10:00 und begrüsst die 21 anwesenden Mitglieder und 7 Gäste. Die Anwesenden werden nicht nur zur Jahresversammlung 2018 begrüsst, sondern auch zum 160 jährigen Jubiläum der SEG und des Entomologischen Vereins Bern (EVB). Am 9./10. Oktober 1858 wurde die SEG, und gerademal zwei Wochen später der EVB gegründet. Der Berner Entomologe Rudolf Meyer-Dür (1812–1885), Seifenfabrikant aus Burgdorf, wirkte bei beiden Gründungen als treibende Kraft.

Protokoll der Generalversammlung 2017 in Bern

Das Protokoll wird kommentarlos genehmigt.

Bericht des Präsidenten (Hannes Baur)

Administratives

Im administrativen Bereich wurden wir 2017 wiederum durch das Centre Suisse de Cartographie de la Faune

(CSCF) in Neuchâtel unterstützt. Die SEG ist Mitglied der Plattform Biologie der Akademie der Naturwissenschaften Schweiz (SCNAT) in Bern und wird dort von der Geschäftsleiterin Pia Stieger betreut.

Finanzielle Unterstützung

Die Gesuche des Präsidenten um finanzielle Unterstützung wurden von den angefragten Institutionen in vollem Umfang bewilligt. Es handelt sich dabei um folgende Beträge: Akademie der Naturwissenschaften Schweiz (SCNAT) in Bern: CHF 12’500.–, Biedermann-Mantel-Stiftung in Zürich: CHF 6’000.– und Syngenta AG in Basel: CHF 6’000.–. Wir danken allen drei Geldgebern für ihre wichtigen Beiträge.

Jahresversammlung, Generalversammlung und Vorstandssitzungen

Die entomo.ch, die traditionell zweitägige Jahresversammlung der SEG, wurde am Freitag, 3. und Samstag, 4. März 2017 am Agroscope Changins in Nyon durchgeführt. Unserem lokalen Gastgeber, Stève Breitenmoser, danken wir für die Organisation des Anlasses ganz herzlich. Die Generalversammlung fand am Samstag, 4. März 2017 von 9:45 bis 10:45 am gleichen Ort statt. Die beiden regulären halbjährlichen Vorstandssitzungen fanden am Freitag, 3. März 2017 am Agroscope Changins und am Mittwoch, 1. November 2017 am Naturhistorischen Museum in Bern statt.

Webseite

Die Website unserer Gesellschaft, u.a. mit Information zur Jahrestagung entomo.ch, war auch dieses Jahr wieder im Portal Naturwissenschaften Schweiz der Akademie der Naturwissen-schaften Schweiz (SCNAT) abrufbar. Für die Einführung in das System und die Betreuung danke ich Pascal Blanc (Chefredaktor) sowie Stefan Schmidlin und Mariella Hobi (Support).

Alpine Entomology – die „neuen“ Mitteilungen nehmen Fahrt auf!

An der letzten Generalversammlung in Nyon wurde auf Vorschlag des Vorstandes einstimmig beschlossen, unsere traditionsreichen *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* (kurz die *Mitteilungen)* in ein neues Format zu überführen. Auch die dazu notwendigen Statutenänderung wurde einstimmig angenommen. Die Zeitschrift heisst seit 2017 also neu *Alpine Entomology* und wird vom Pensoft Verlag auf einer eigenen Webplattform publiziert. Die eingereichten Artikel sind nach der redaktionellen Bearbeitung sofort online in verschiedenen elektronischen Formaten (XML, HTML, PDF) zugänglich, was den gesamten Publikationsprozess stark beschleunigt. Unsere Mitglieder erhalten Ende des Jahres aber weiterhin alle Artikel in einem gedruckten Band. Nach dem Rücktritt des langjährigen Chefredakteurs, Dr. Gerhard Bächli, hat Prof. Dr. Thibault Lachat von der HAFL in Zollikofen im Mai 2017 das Amt eines Editors-in-chief übernommen. Er leitet die Redaktion zusammen mit 18 Subject editors. Bei den Redakteuren und allen beteiligten Personen beim Pensoft Verlag möchte ich mich ganz herzlich für die geleistete Arbeit beim Aufbau der neuen Zeitschrift bedanken.

Digitalisierung

Die Publikation der *Mitteilungen* auf der Plattform e-periodica (www.e-periodica.ch) der ETH-Bibliothek konnte mit dem Hinzufügen von Band 89 im letzten Jahr abgeschlossen werden. Damit sind nun sämtlich Bände der *Mitteilungen* von 1862–2016 im PDF-Format öffentlich zugänglich. Die Textinhalte werden auch durch Suchmaschinen wie Google oder Bing indiziert, d.h. bei Suchabfragen gelangt man an die entsprechende Stelle im PDF. Ansprechpartnerin war für die SEG Regina Wanger, Leiterin des DigiCenters der ETH-Bibliothek in Zürich.

Auch die Bände der neuen Zeitschrift *Alpine Entomology* sollen über e-periodica verfügbar gemacht werden. Die Publikation auf einer Schweizer Plattform bietet eine zusätzliche Sicherheit für die Archivierung unserer Zeitschrift.

Dreiländertagung

Vom 13. bis 16. März 2017 fand in Freising-Weihenstephan die entomologische Dreiländertagung der DGaaE, ÖEG und der SEG statt. Der Schwerpunkt lag bei Insekten auf Gehölzen bzw. der Forstentomologie. Weiterhin fand im Rahmen der Tagung das 25. Internationale Symposium zur Entomofaunistik in Mitteleuropa statt. Der Präsident war als Vertreter des SEG anwesend. Gemeinsam mit den Präsidenten der DgaaE und der ÖEG wurden Möglichkeiten zur Durchführung der nächsten Dreiländertagung erörtert.

Insekt des Jahres

In Zusammenarbeit mit Entomologen aus Deutschland und Österreich wurde für das Jahr 2018 die Gemeine Skorpionsfliege *(Panorpa communis)* zum Insekt des Jahres bestimmt. Dazu wurde ein Flyer erarbeitet.

Im Namen des Vorstandes und der Mitglieder der Schweizerischen Entomologischen Gesellschaft danke ich allen genannten Institutionen, Gremien und Personen nochmals ausdrücklich für ihre Unterstützung und ihren Einsatz!

Bericht des Bibliothekars und der Redaktoren (Alpine Entomology und Fauna Helvetica)

Bericht des Bibliothekars (Dr. P. Jeanneret)

En 2017, quelques questions administratives sur le parcours des exemplaires 2016 du Bulletin ont pu être résolues et leur envoi à la bibliothèque de l’ETH a pu être réalisé.

Bericht des Redaktors der Fauna Helvetica (PD Dr. D. Burckhardt)

Im Berichtsjahr wurde kein Band publiziert, die Neubearbeitung der Apidae 1 ging aber in den Druck. Weitere Bände sind in Bearbeitung. Weit fortgeschritten sind die Bände über Amphipoda, Cicadidae und Vespidae.

Wie immer klappte die Zusammenarbeit mit dem CSCF ausgezeichnet. Dafür möchte ich dem Leiter Dr. Y. Gonseth und seinen Mitarbeiterinnen und Mitarbeitern ganz herzlich danken.

Bericht des Chefredaktors von Alpine Entomology (Dr. T. Lachat)

In 2016, the first issue of Alpine Entomology was published by Pensoft. The paper version arrived in time for Christmas 2017. All articles published in the journal are open access and are consequently freely available to everyone. This allows for tremendous visibility of published papers. On average, the articles published last year were viewed by more than 300 unique users.

This first issue includes 15 articles on 128 pages: eight research articles, two book reviews, two short news articles, one checklist, one editorial and one meeting report of the Swiss Entomological Society. Most articles were written in German (8), followed by English (6) and French (1).

Regarding the review processes in 2017, three manuscripts were rejected without invitation to resubmit and six were rejected with resubmission encouraged. The editorial board is now composed of nineteen specialists. We hope to add new members to the editorial team in 2018 in order to alleviate the workload of those editors who were very active during the last year.

After the first year, we can say that Alpine Entomology has passed a key milestone. The excellent support and responsiveness of the publishing company Pensoft plays a major role in this success. Some initial problems must still be resolved but I am confident that Alpine Entomology will gain in quality and reputation in the years to come.

Bericht der Quästorin und der Rechnungsrevisoren

Bericht der Quästorin (E. Leonetti)

Frau Emanuela Leonetti legt den Anwesenden die Jahresrechnung 2017 vor. Daraus sind folgende Zahlen entnommen:

Positionene / Objets	Ausgaben / Dépenses	Einnahmen / Revenus
Publikationskosten / Charges de publications		
Publications MSEG – impression, rédaction	5745.10	
Pensoft: Website, Open access	13564.82	
Publication „Fauna Helvetica“	0	
Verwaltung / Administration	6279.41	
Beitrag sc|nat / Cotisation sc|nat	1’701.00	
Arbeitsgruppenförderung / Soutien groupes de travail	2’000.00	
Charges extraordinaires (bourses de soutien recherche entomologique)	0	
Verkauf Mitteilungen / Ventes bulletins		2’405.00
Mitgliederbeiträge / Cotisations		15’000.09
Ventes Fauna Helvetica		4289.75
Beiträge / Subventions		
sc|nat		14’500.00
Syngenta		6’000.00
Biedermann-Mantel-Stiftung		6’000.00
Spenden und sonstige Einnahmen / Dons et autres produits		320.00
Zinsen / Intérêts:		
SEG-Konten / Comptes SEG	82.40	
Fauna Helvetica-Konto / Compte Fauna Helvetica	60.00	
Augmentation de réserve (résultat Fauna Helvetica)	4’229.75	
Totale / Totaux	**33‘662.48**	**48‘514.84**
Jahresgewinn / Bénéfice annuel 2013		**14‘852.36**

Die Erfolgsrechnung für das Jahr 2017 schloss mit einem Gewinn von CHF 14‘852.36 (Vermögen CHF 95‘540.53).

Erratum: Im Protokoll der Generalversammlung 2016 in Neuchâtel ist das Vermögen 2016 mit CHF 51‘419.31, anstatt mit CHF 80‘688.17 angegeben.

Bericht der Rechnungsrevisoren (C. Monnerat und Dr. M. Sartori)

En tant qu’organe de contrôle de la société Entomologique Suisse, nous avons vérifié les comptes de l’exercice 2017. Nous avons pu constater que:

- le bilan d’ouverture, le bilan de clôture et le compte d’exploitation correspondent à la comptabilité
- les justificatifs sont conformes, exacts et correspondent à l’activité habituelle de la SES
- la fortune de la société correspond aux compte à l’actif du bilan (liquidité + transitoires).

Pour sa part, la caissière assure que la tenue de la comptabilité a été faite, dans les limites de ses compétences, avec exactitude et selon les principes formulés dans le Code des Obligations (CO 959 t 662a/2).

C’est pourquoi nous prions l’assemblée d’accepter les comptes de l’exercice 2017 et de donner décharge à la caissière.

Der Quästorin wird einstimmig Decharge erteilt.

Budget und Mitgliederbeitrag

Budget 2018

Der Präsident stellt das Budget für 2018 vor, das einen Gewinn von CHF 4‘120.- vorsieht.

Mitgliederbeitrag 2018

Die Beiträge bleiben gleich: Mitglieder in der Schweiz CHF 60.-, Studierende oder sich anderweitig in Ausbildung befindende Mitglieder zahlen während drei Jahren nur die Hälfte (CHF 30.-) des ordentlichen Beitrages. Mitgliedern im Ausland, die die gedruckte Version von Alpine Entomology wünschen, werden zusätzlich CHF 15.- Versandkosten verrechnet.

Das Budget und der Mitgliederbeitrag werden einstimmig und ohne Enthaltung genehmigt.

Personelles

Todesfälle

Den beiden SEG-Mitgliedern Peter Sonderegger, Brügg bei Biel (1942–2017) und Egon Knapp-Stiefel, Neuhausen am Rheinfall (1932–2018) wird mit einer Schweigeminute gedacht.

Jahresversammlung 2019

Die nächste Jahresversammlung, entomo.ch 2019, findet am 1. und 2. März 2019 am Naturmuseum in St. Gallen statt.

Ende der Generalversammlung um 10:52

Basel, im Oktober 2018, der Sekretär Matthias Borer