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Chionea austriaca in caves and artificial galleries of Slovenia (Diptera, Limoniidae)

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***Chionea austriaca* in caves and artificial galleries of Slovenia (Diptera, Limoniidae). -** We sampled 54 caves and galleries in north and east Slovenia methodically for ecological data and the invertebrate fauna. The snow fly *Chionea austriaca*, recorded in 37% of the cavities, proved indifferent with regard to most of the abiotic factors, but occurred in significantly higher individual numbers in caves on north and east slopes. The subterranean sojourn of *Ch. austriaca* appears merely weather-mediated. No indications of larval development in the caves were found.

Keywords: abiotic factors - speleobiology - distribution - snow fly.

INTRODUCTION

As their scientific and trivial names imply, snow flies – species of the genus *Chionea* – are usually met on the snow surface where they can easily be noticed. Nevertheless, these wing-reduced and somewhat spiderlike limoniids spend most of their adult lifetime in leaf litter, under logs and stones, in subnivean habitats or in mammal burrows. The larvae are soil-dwelling. Low catchability makes snow flies appear so rare that Byers (1983), for instance, referred to a catch of 29 specimens as a rich yield.

Snow flies have been reported from altitudes up to 2700 m (3500 m in North America: Byers, 1983). *Chionea* (*Sphaeconophilus*) *belgica* (Becker, 1912), and *Ch.* (*S.*) *lutescens* Lundström, 1907, occur also in the colline zone and in lowlands (Grootaert, 1984; Reusch, 1988, 1997; Weber & Weidemann, 1993), whereas the bulk of the *Chionea* species prefer forest sites, or open habitats from the submontane zone upwards (Focarile, 1975).

Chionea austriaca (Christian, 1980), originally described from a Lower Austrian cave, is distributed over western Hungary (Christian, unpubl.) and parts of

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Slovenia and Austria. At the northwestern and western limits of distribution *Ch. austriaca* touches the areas of two closely related species, namely *Ch. belgica* and the widespread *Ch. lutescens* (Christian, in press).

Ecological notes on European *Chionea* species focus on aboveground habitats (e.g. Heim de Balsac, 1934; Nadig, 1943, 1949; Bitsch, 1955; Sömme & Östbye, 1969; Hågvar, 1971; Mendl *et al.*, 1977; Itämies & Lindgren, 1985; Heijerman, 1987). Several authors have casually mentioned the sojourn of snow flies in caves (Strobl, 1900; Peyerimhoff, 1906; Bezzi, 1911; Czerny, 1930; Español Coll, 1955, Strinati & Aellen, 1967; Turquin, 1973; Bourne, 1977, 1979; Christian, 1980; Byers, 1983; Novak & Kuštor, 1983; Novak, 2005). Information about environmental conditions in cavities inhabited by snow flies, however, is anecdotal at the best.

The present paper addresses the abiotic conditions at sampling sites of *Ch. austriaca* in caves and artificial galleries in Slovenia. We want to test our hypothesis that this species is only loosely aligned to macrocaverns.

MATERIALS AND METHODS

During the period 1977-2001, 54 caves and artificial galleries (in the following: caves) in central and northern Slovenia (mapped in Novak, 2005) were ecologically investigated in January, April, July and October according to a standardized scheme. All accessible surfaces of the cave passages like walls, ceiling, speleothems, microhabitats below stones and wood, and water surfaces, were carefully inspected for terrestrial animals. Pitfall traps were set, on average, every 3 m starting at the entrance, and exposed for 47±1 hours. Each trap was baited with 3 g of decomposing meat attached on a wire above the trapping liquid (2 cm of fruit juice with cherry and maraschino essences, and a lacing of detergent). Substrate from the close vicinity of the trap sites was sampled for Tullgren extraction.

Environmental parameters were determined chiefly according to Stewart *et al.* (1974) and Rowell (1997). The distance from a trap to entrance and surface, respectively, and the cross-section of the passage at the trap site were taken from cave maps (Novak, 2005). Illumination was measured using a Lunasix luxmeter. Substrate pH was determined with a combined electrode (91–02 Orion, USA; Orion Ionalyser 407 A) in elutriated fresh samples after 2-4 hrs stirring in an equal volume of distilled water. Substrate carbonate and organic matter contents were established for the dried and pulverized <2 mm fraction; carbonate was quantified by Scheibler calcimetry, ignition loss after heating at 700ºC for 1 h. Ground and air temperatures were measured with decimal thermometers (Intos, Croatia). Air humidity was determined with a psychrometer according to August, ground moisture by drying at 105ºC to constant weight. Airflow was detected with a hand-held anemometer (Munro IM159) or, when below $0.3\ m \cdot s^{-1}$, derived from the velocity of fog or magnesium smoke (cf. Andrieux, 1970).

Cold hardiness of one male, collected on a south-facing meadow slope at Studence (46º18’53” N, 15º09’51” E, 330 m) on snow, 31.01.2006, was determined in a thermostat chamber THK/V1-2020 (Elelstro, Slovenia). The specimen was enclosed in a glass tube with a scrap of wet paper and cooled down to lethal temperature in 12 hour treats in steps of 1°C/day, with intermediate 12 hour breaks at acclimatization temperature of +8°C.

Voucher specimens of *Ch. austriaca* are deposited in the Slovenian Museum of Natural History (Ljubljana), in the Muséum d'histoire naturelle de la Ville de Genève, and in the Natural History Museum, Vienna.

RESULTS

Three of 14 European *Chionea* species (Oosterbroek, 2005) have been recorded in Slovenia (Oosterbroek & Simova-Tošić, 2003, and own data; Fig. 1). *Ch.* (*Chionea*) *araneoides* Dalman, 1816 was found in the Krma valley (UTM: VM13); *Ch.* (*Sphaeconophilus*) *alpina* Bezzi, 1908 is known from Mt. Grmada (VM61, 640 m),

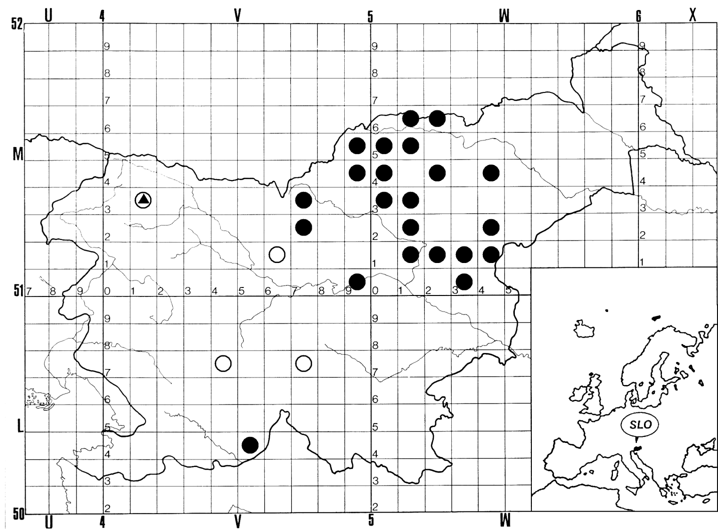

FIG. 1

Records of snow flies in Slovenia: ▲ *Chionea araneoides*, O *Ch. alpina* and ● *Ch. austriaca*.

Zdenska jama cave (VL77, 460 m), Dobrepolje (VL77, 450 m), Mačkovica cave (VL47, 480 m) (Simova-Tošić & Sivec, 1977), and the alpine ice cave Ivačičeva jama in Mt. Kredarica at 2435 m a.s.l. (Novak & Kuštor, 1983); the third species, *Ch.* (*S.*) *austriaca* was encountered in numerous caves in central and eastern Slovenia (Table 1). Here we add three snow-surface records of *Ch. austriaca*: Mt. Jesenik (WM13, 688 m), Studence (WM13, 330 m) and Mt. Snežnik (VL54, 1690 m, currently the southernmost locality), and a further cave record: Brezno pod Durcami in Mt. Raduha (VM84, 1840 m, currently the highest record in Slovenia), which was not included in the systematic investigations.

In 20 (37%) of the 54 caves, 38 specimens (11 males, 27 females; sex ratio 29:71) of *Ch. austriaca* were met, at altitudes between 270 and 1515 m (Tab. 1). Tab. 2 compiles values of abiotic factors at effective trapping sites. All specimens were trapped in pitfalls exposed in January. Larvae were neither seen, nor trapped or Tullgren-extracted. Most adults occurred in the entrance zone of the caves during the winter (Fig. 2). Caves opening in northern and eastern slopes were significantly more

TABLE 1: *Chionea austriaca* in caves of Slovenia. No = current number as in Novak, 2005; Cad = cadastral number in the Slovene cave register; Capital letters indicate artificial galleries; UTM code (see Fig. 1); Alt = altitude (m); Bed = bedrock: c = conglomerate, l = limestone, d = dolomite, m = marble, p = pegmatite, s = schists, t = tonalite); Ind, Date = number of individuals and date of collection [ddmmyy].

Cave or gallery	No	Cad	UTM	Co-ordinates (N, E)	Alt	Bed	Ind, Date
Rački pekel	10	465	VM73	46º23'27", 14º43'14"	590	l	1♀, 060179
Zijalka v Dovji Griči	11	376	VM72	46º18'18", 14º40'14"	1515	l	1♂, 4♀, 100179
Jama pri Votli peči	18	3263	VM95	46º32'51", 14º58'33"	400	p	1♀, 120179
Skobirjeva votlica	19	3956	VM94	46º27'45", 14º58'46"	940	d	1♀, 050179
Brdajsova jama	23	3497	VM90	46º07'03", 14º54'02"	651	l	1♂, 3♀, 210179
Objekt pri Žnodru	25	B1	WM05	46º30'34", 15º03'22"	550	l	1♀, 110178
Rdečka jama	26	3488	WM04	46º26'54", 15º03'44"	858	c	1♂, 120178
Lokoviška jama	27	3959	WM03	46º22'03", 15º01'27"	370	l	1♀, 070178
Umetni rov v Bistriškem grabnu	30	U2	WM16	46º38'47", 15º07'56"	480	s	2♀, 150178
Zapečke peči	31	3208	WM15	46º32'49", 15º13'26"	610	l	1♂, 150178
Špegličeva jama	34	3512	WM12	46º17'58", 15º11'55"	400	l	1♀, 090179
Ocvirkova jama v Štadlerjevem gozdu	35	5348	WM11	46º12'29", 15º11'11"	320	l	2♂, 2♀, 090179
Jama pod Herkovimi pečmi	37	1849	WM26	46º37'35", 15º16'04"	545	l	2♀, 190178
Jaklova luknja	38	4636	WM24	46º28'56", 15º16'49"	1100	t	1♂, 110178
Fantovska luknja 2	40	3967	WM21	46º12'14", 15º18'35"	480	l	1♂, 4♀, 180179
Jama v kamnolomu pri Suhem	42	4632	WM31	46º08'40", 15º23'55"	500	l	1♂, 18011978
Glija jama	43	84	WM30	46º06'39", 15º26'32"	515	l	1♀, 18011978
Luknja pri Naceku na Planici	45	2407	WM44	46º28'30", 15º34'13"	730	m	1♂, 200178
Jama v kamnolomu nad Studenicami	46	252	WM42	46º17'51", 15º37'11"	400	l	1♂, 2♀, 170179
Rov	47	U4	WM41	46º09'31", 15º35'43"	270	s	1♀, 170179

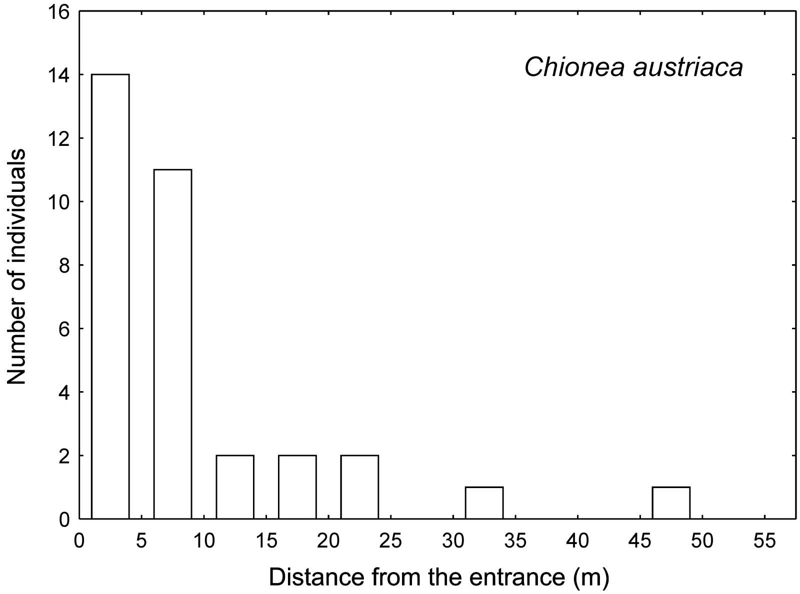

FIG. 2
Yield of *Ch. austriaca* individuals relating to the distance between cave entrance and trap locality.

frequently settled by *Ch. austriaca* as compared to other slopes (χ^2 = 24.54; $P <$ 0.001), and hosted significantly more individuals (χ^2 = 17.05; P = 0.017) (Tab. 3).

Preference for any kind of bedrock was not observed. In two cases (26 and 38 in Tab. 1) entrances were situated in various types of forests.

By comparing the meteorological conditions in caves with vs. those without *Ch. austriaca* we found that in "*Chionea* caves" the air and ground temperatures were significantly lower, and airflow significantly higher. There were no significant differences regarding relative air humidity and substrate moisture (Tab. 4). Males and females did not differ significantly with respect to any abiotic parameter at the trapping sites ($F_{1,37}$ = 0.000-2.614; P = 0.11-0.98).

In the cold hardiness test the single male of *Ch. austriaca* died at -7°C.

DISCUSSION

Adult *Ch. austriaca* were trapped in caves only during the cold season, in agreement with the period of their occurrence on snow. The temperature demands of *Ch. austriaca* are comparable to those of most other European snow flies (Wojtusiak, 1950; Bourne, 1979), and its supercooling ability – admittedly determined for one specimen only – seems to agree with the values reported for *Ch. araneoides* (mean supercooling point -7.5°C, range -10.5 /-4.5°C: Sömme & Östbye, 1969). A vast ecological range of *Ch. austriaca* is indicated by the large altitudinal range, indifference to bedrock, its occurrence in forested as well as in non-forested areas, and inside caves by tolerance

TABLE 2: January values of abiotic factors at effective trapping sites of *Ch. austriaca*, compared to the extreme values in "*Chionea* caves" and to the mean and extreme values of all the 54 caves (based on 605-617 sampling sites).

	Mean ± s.d. (min-max) at effective trapping sites	**Min-Max in "*Chionea* caves"**	**Mean ± s.d. (min-max) in all the 54 caves**
Distance from entrance [m]	8±10 (0-49)	0-121	31±31 (0-121)
Distance from surface [m]	9±8 (1-40)	0-70	18±14 (0-80)
Passage cross-section [m^2]	5±7 (0?36)	0.2-80	13±31 (0.2-460)
Illumination [lx]	258±169 (0-~10,000)	0-~100,000	194±171 (0-~100,000)
pH	7.9±0.8 (4.3-8.6)	4.3-8.7	8.1±0.6 (2.4-8.9)
CO_3^{-2} [%]	21.4±24.0 (0.0-76.0)	0-96.6	31.9±29.8 (0.0-98.7)
Ignition loss [%]	13.2±15.2 (0.3-52.9)	0.3-85.9	10.7±13.2 (0.3-85.9)
Air temperature [^{0}C]	1.2±3.8 (-5.0-8.9)	-5.0-11.5	3.6±4.4 (-6.0-11.5)
Ground temperature [^{0}C]	1.6±3.3 (-3.0-9.0)	-4.6-12.6	4.1±4.2 (-7.2-12.6)
Relative air humidity [%]	91±12 (65-100)	54-100	95±9 (54-100)
Substrate moisture [%]	18.4±12.0 (0.2-46.7)	0.0-73.6	20.8±14.7 (0.0-87.6)
Airflow [m/s]	0.07±0.04 (0.00-2.00)	0.00-10.00	0.11±0.73 (0.00-10.00)
Soil colour / modus (min-max)	10YR 5/4 (5Y 3/2-7.5YR 5/6)	5YR 5/8-5Y 5/2	10YR4/4 (5YR 3/2-2.5Y 6/4)

TABLE 3: Distribution of *Ch. austriaca* with respect to slope orientation of cave entrances.

Slope orientation	***Ch. austriaca* individuals N (%)**	**Caves with *Ch. austriaca* N (%)**	**All caves N (%)**
N	12 (31.6)	4 (20.0)	10 (18.5)
NE	2 (5.3)	2 (10.0)	3 (5.6)
E	12 (31.6)	6 (30.0)	14 (25.9)
SE	5 (13.2)	3 (15.0)	4 (7.4)
S	4 (10.5)	4 (20.0)	7 (13.0)
SW	0 (0.0)	0 (0.0)	4 (7.4)
W	0 (0.0)	0 (0.0)	10 (18.5)
NW	3 (7.9)	1 (5.0)	2 (3.7)
total	**38 (100)**	**20 (100)**	**54 (100)**

TABLE 4: Selected meteorological parameters of caves with *Ch. austriaca* present vs. absent. January values from all trap sites along the first 10 m (i.e., those without *Chionea* yield included). Significant differences asterisked *.

	***Ch. austriaca* present (N = 103)**	**absent (N = 159)**	**$F_{1, 260}$**	***P***
Air temperature	4.8±2.4 (0.6-9.5)	6.2±2.0 (0.3-11.4)	24.59	<0.001*
Ground temperature	4.7±2.5 (-0.3-11.3)	5.7±2.0 (0.5-11.0)	12.78	<0.001*
Air humidity	94±8 (69-100)	92±22 (43-100)	2.52	0.113
Substrate moisture	23.3±16.1 0.0-65.4	24.8±17.0 (1.1-79.2)	0.52	0.473
Airflow	0.08±0.05 (0.0-10.00)	0.06±0.04 (0.0-5.00)	4.97	0.026*

of wide ranges of illumination, substrate pH, carbonate contents and ignition loss. The conspicuous prevalence of individuals in caves on north and east facing slopes contrasts with the impression that snow flies in open-air habitats do not display any slope orientation preference. Their surface activity, however, is strongly weatherdependent inasmuch heavy frost and wind drive them into more moderate hideaways. So the disproportionately high individual numbers of *Ch. austriaca* in caves opening out on north and east slopes is not a consequence of psychrophily, but rather the result of more frequent chill avoidance migrations there. The highest trapping yield of snow flies in the entrance zone of the caves and in passages of small cross-section supports this conclusion. Lower ground temperature and higher airflow in "*Chionea* caves" may be merely the consequence of the harsh climate conditions on north and east slopes.

Wing reduction of snow flies has been explained as a result of regressive evolution due to temporary exposure to cold and windy weather (Hackman, 1964; Byers, 1961, 1983). This morphological character could lead to consider snow flies as being pre-disposed to life in subterranean habitats (cf. Vandel, 1964; Ginet & Decou, 1982). However, *Ch. austriaca* – like several other European congeners – inhabits macrocaverns facultatively and only temporaryly during its epigean ecophase in the cold season. The fact that maximum density in caves is observed in January, when virtually all females are ready for egg-laying (Christian unpubl.), does not necessarily indicate subterranean oviposition. On the one hand there is no report on larval development of *Chionea* in caves, and on the other hand an extremely long oviposition period (from November to March) was shown for *Ch. araneoides* (Hågvar, 1976), so that females of *Ch. austriaca* – let's assume an adult life span of two months (cf. Byers, 1983) – may lay eggs after they have quitted the cave shelter. Thus, in terms of the classical biospeleological classification (Vandel, 1964), *Ch. austriaca* is best included in the trogloxenes.

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